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Schematic and Exploded Views

Schematic

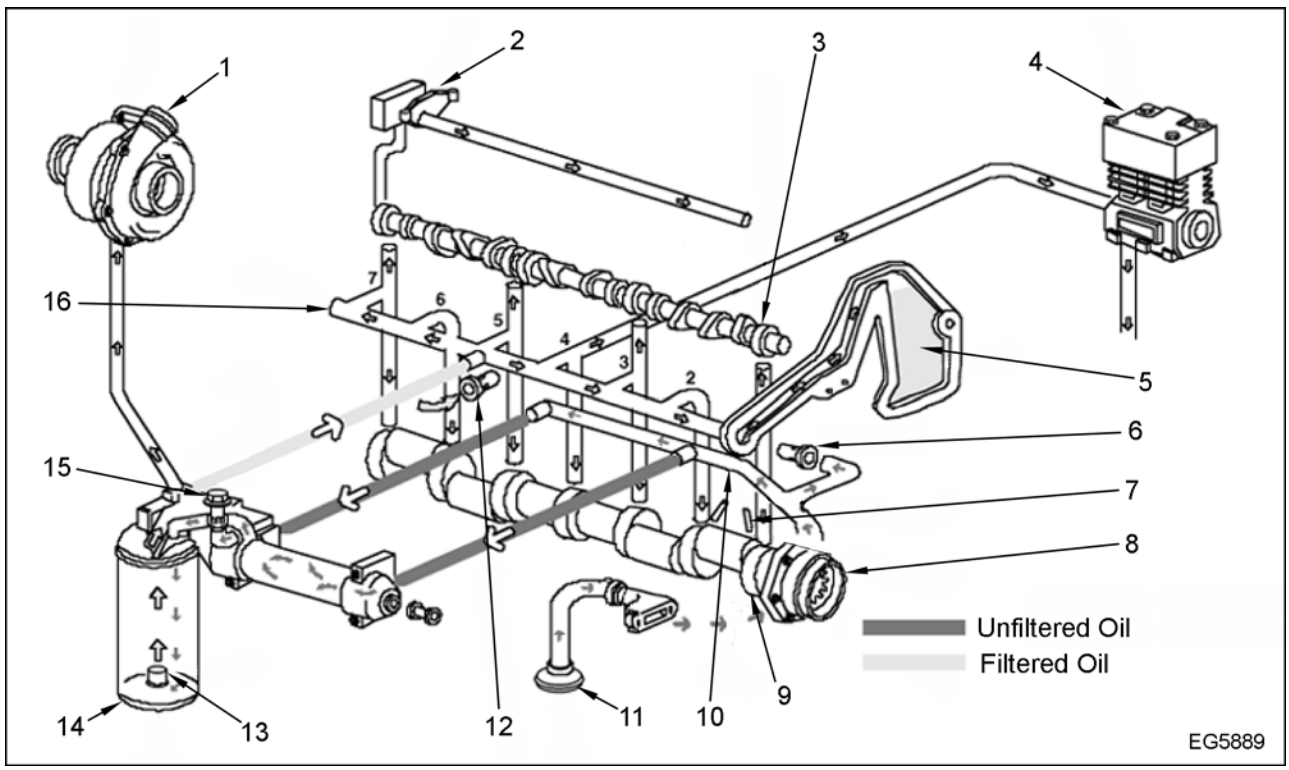

Figure 402 Lubrication System

1. Turbocharger
2. Valve lever assembly
3. Cam bushing journal
4. Air compressor
5. Reservoir
6. Pressure relief valve
7. Piston cooling jets
8. Oil pump
9. Main bearing journal
10. Bypass gallery
11. Pick-up tube
12. Pressure regulator
13. Bypass valve
14. Filter
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16. Main oil gallery

Exploded Views

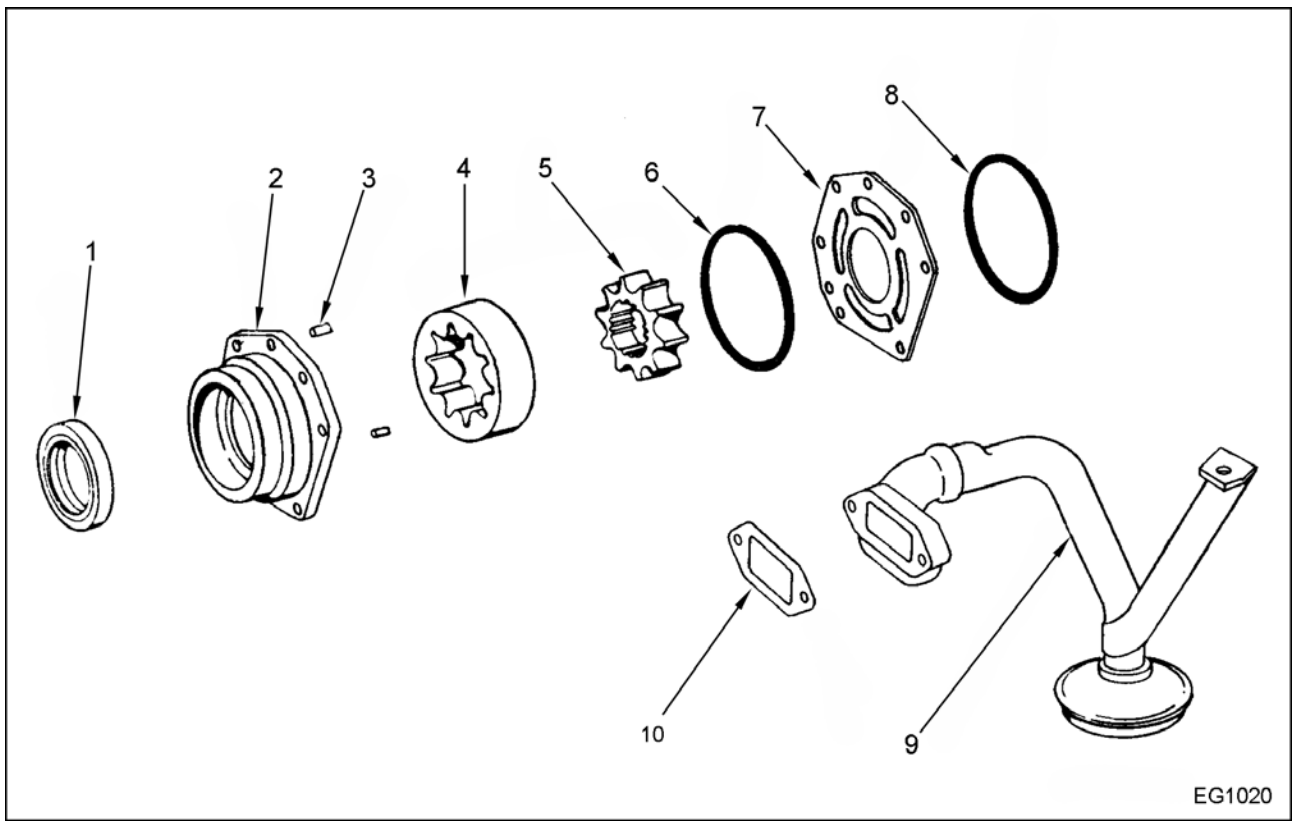

Figure 403 Lubricating Oil Pump and Pickup Tube

1. Oil seal
2. Oil pump housing
3. Dowel pins
4. Rotor assembly (outer)
5. Rotor assembly (inner)
6. O-ring
7. Housing plate
8. O-ring
9. Oil pump inlet pickup tube
10. Gasket

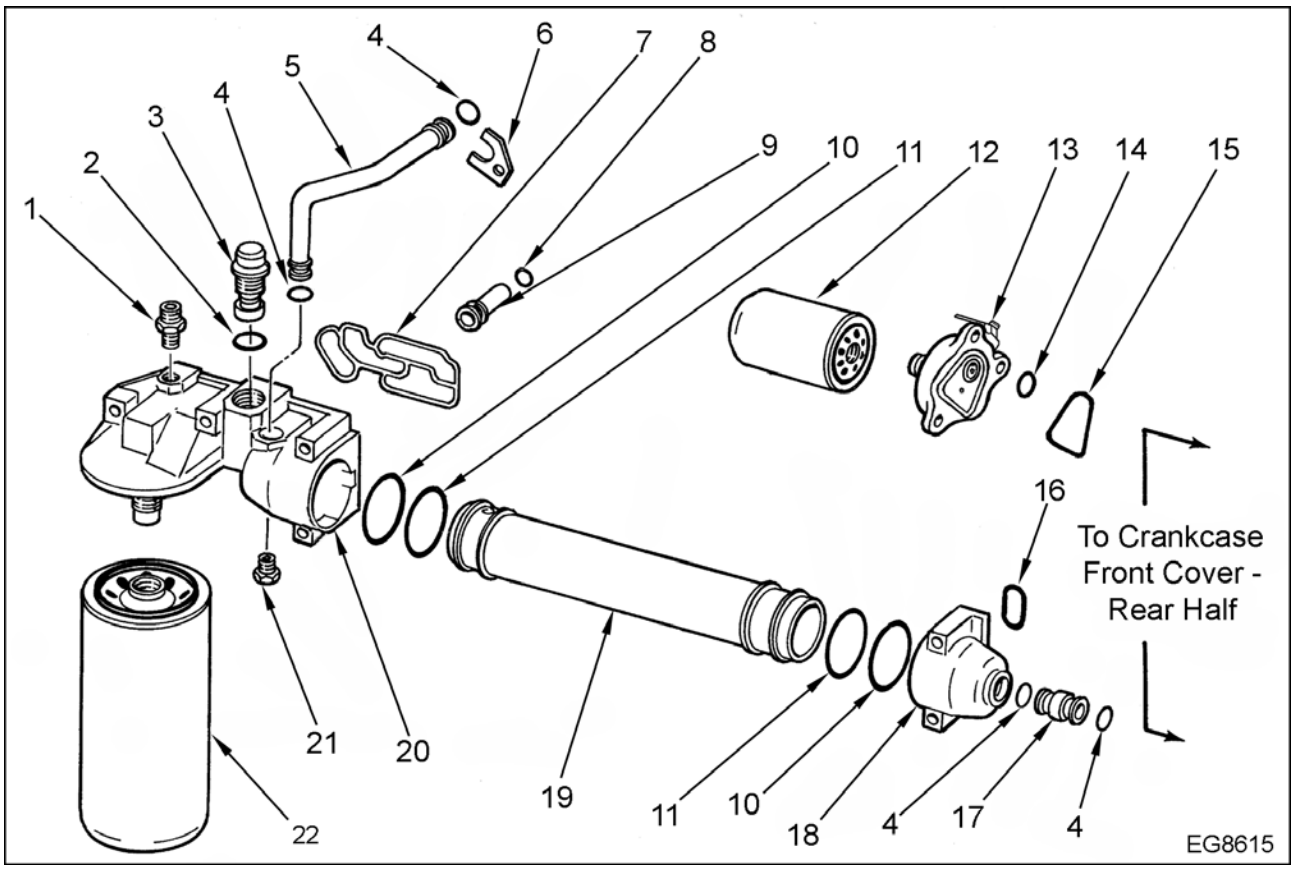

Figure 404 Oil Cooler, Oil Filter, and Coolant Filter

1. Connector
2. O-ring
3. Oil temperature control valve
4. O-ring (4)
5. Oil cooler water inlet tube
6. Water inlet tube bracket
7. Gasket
8. O-ring
9. Pressure regulator valve
10. O-ring
11. O-ring
12. Coolant filter
13. Coolant filter header
14. O-ring
15. Seal
16. Seal
17. Tube
18. Front oil cooler header
19. Oil cooler assembly
20. Oil cooler and filter header
21. Coolant drain plug
22. Oil filter

Remove

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, read all safety instructions in the "Safety Information" section of this manual.

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, make sure the transmission is in neutral or park, parking brake is set, and wheels are blocked before doing diagnostic or service procedures on engine or vehicle.

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

NOTE: Oil filter cartridge and oil header must be removed prior to mounting engine on a stand.

Remove Lubricating Oil Pump

1. Remove vibration damper, see "Vibration Damper Assembly (page 184)" in the "Vibration Damper, Crankshaft, Main Bearings, Flywheel, and Crankcase" section of this manual.
2. Remove and discard front oil seal. Protect nose of crankshaft if a prying device is used.
3. Loosen and remove six oil pump housing cap screws.

NOTE: Two short cap screws are located at the 2 o'clock and 3 o'clock positions.

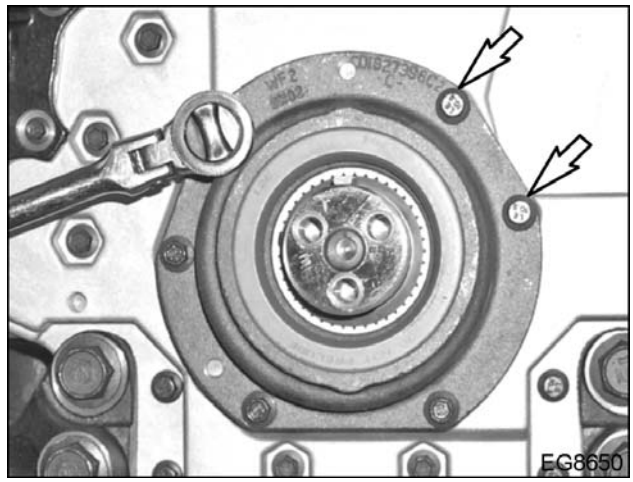

Figure 405 Remove oil pump housing cap screws

4. Remove oil pump housing and O-ring from front cover. Discard O-ring.
5. Remove outer rotor from oil pump housing.

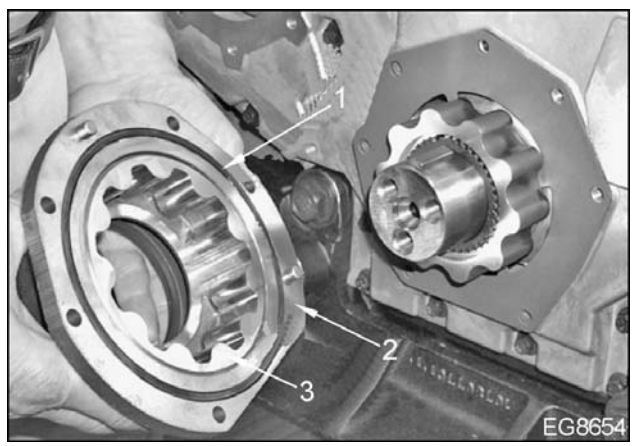

Figure 406 Oil pump housing

1. O-ring
2. Oil pump housing
3. Outer rotor

WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using metal tools.

6. Remove woodruff key from crankshaft. Use hammer and chisel or punch.

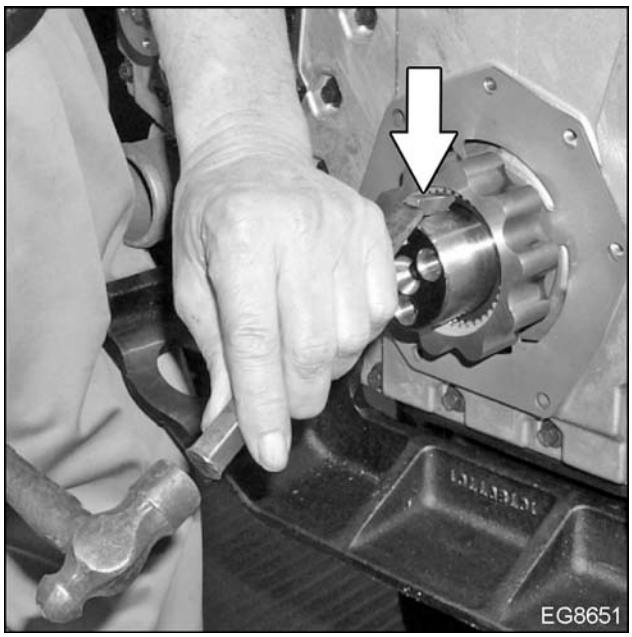

Figure 407 Remove woodruff key

7. Remove inner rotor, washer, and seal from oil pump drive spline.

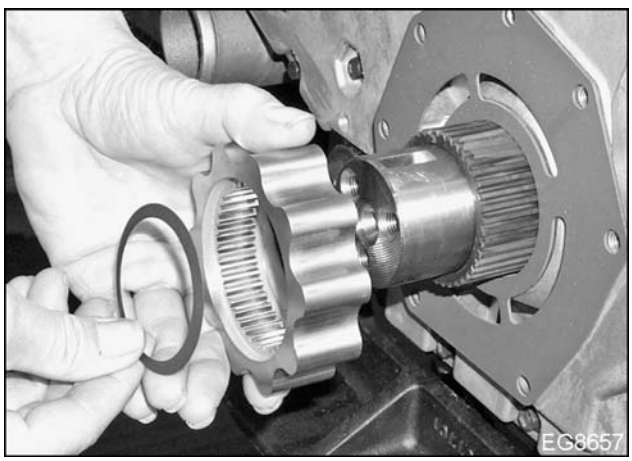

Figure 408 Remove inner rotor, washer, and seal

8. Remove oil pump housing plate. Remove and discard O-ring from front cover.

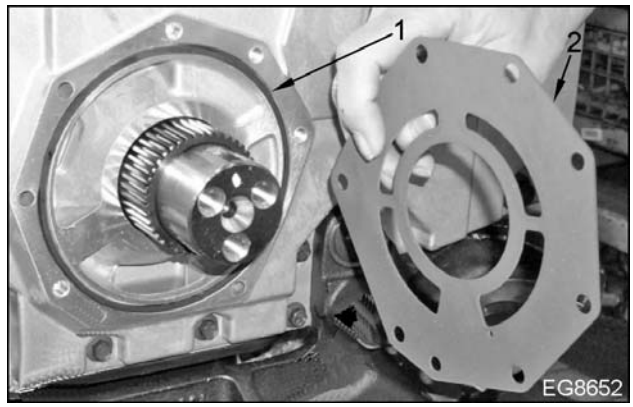

Figure 409 Remove oil pump housing plate

1. O-ring
2. Oil pump plate

Remove Oil Filter and Header

Oil filter cartridge and oil header must be removed prior to mounting engine on a stand.

NOTE: Drain coolant from engine, if removing oil filter and cooler header.

1. Loosen and remove oil feed supply tube nut on top of oil filter header. Remove and discard tube nut O-ring. Cap fitting on header for protection.

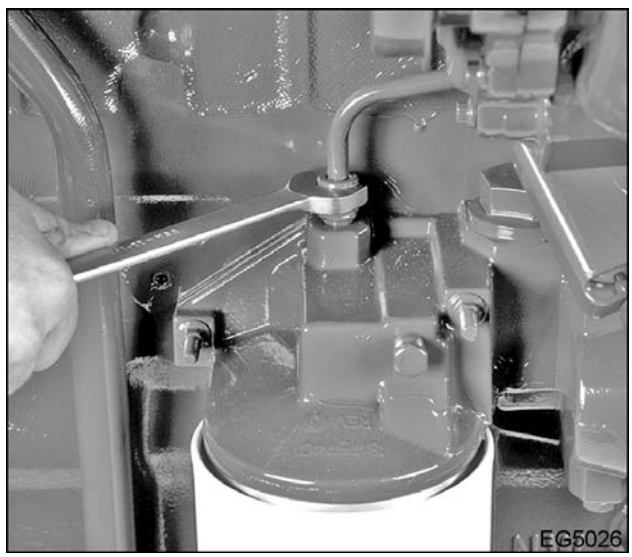

Figure 410 Remove oil supply tube

2. Loosen and remove oil filter cartridge. Discard oil filter cartridge according to local regulations.

NOTE: Some severe service units have a short oil filter with an adapter installed inside the oil filter housing. Do not remove this adapter.

Figure 411 Remove oil filter

3. Remove one water coolant supply tube bolt and retainer plate from crankcase.
4. Remove oil cooler assembly mounting hardware from crankcase.

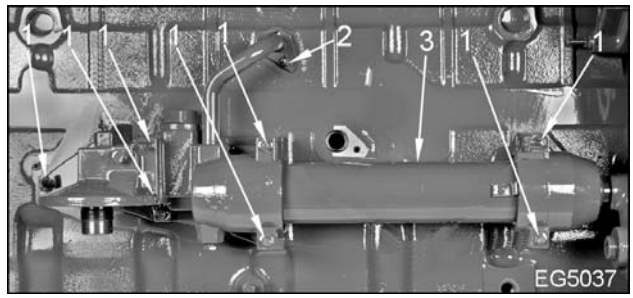

Figure 412 Remove oil cooler mounting bolts

1. Mounting bolts
2. Retainer plate
3. Oil cooler

5. Remove oil cooler and water coolant supply tube as an assembly from crankcase. Discard O-rings, gaskets, and seals.

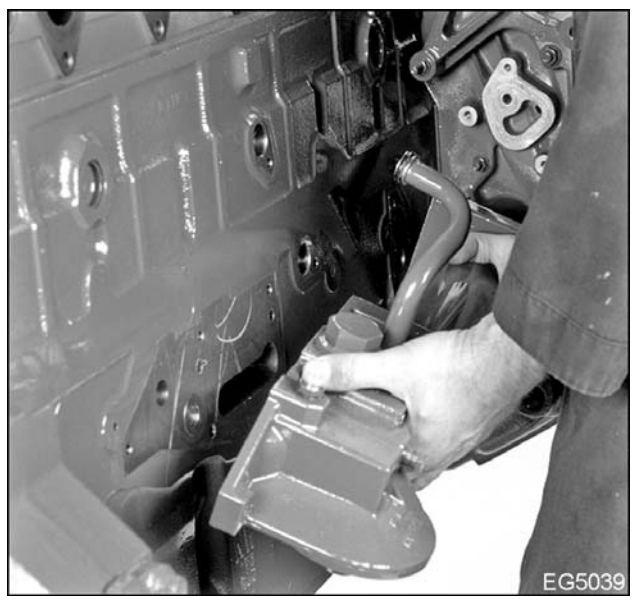

Figure 413 Remove oil cooler

Disassemble

Disassemble Oil Filter and Header

1. Gently tap on front of oil filter header, with non-metallic hammer, to loosen O-rings. Twist headers and separate from cooler bundle.
2. Remove and inspect oil temperature control thermostat in oil filter and cooler header. Reinstall thermostat with new O-ring.

3. Depress regulator valve plunger. Insert length of copper wire through regulator valve. Release plunger to trap copper wire in regulator valve.
4. Pull copper wire removing regulator valve.

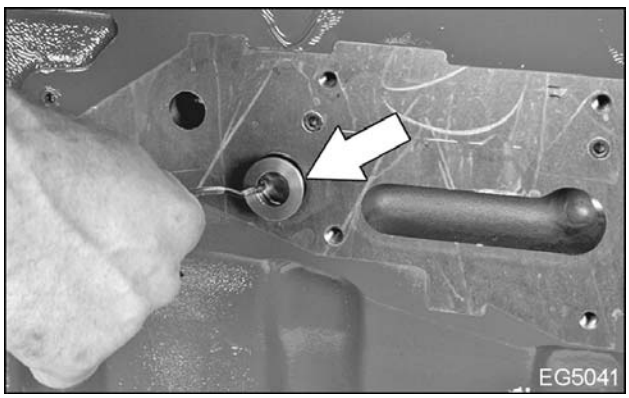

Figure 414 Oil pressure regulator valve

CAUTION: To avoid possible damage to the engine, in case of bearing failure, oil cooler bundle must be replaced. Failed bearing debris cannot be removed from cooler bundle.

5. Disassemble rear and front oil cooler headers from oil cooler bundle.

Clean, Inspect, and Test

WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit the air pressure to 207 kPa (30 psi).

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

Lubricating Oil Pump

Clean Lubricating Oil Pump

1. Wash all parts thoroughly in approved solvent.
2. Dry parts with filtered compressed air.

Inspect and Measure Lubricating Oil Pump

1. Inspect rotors, housing, and plate for nicks, burrs, or scoring. Replace any damaged components.

NOTE: Inner and outer rotors are a matched set and cannot be replaced separately.

2. Measure diametrical clearance between outer rotor and pump housing. Use Feeler Gauge (page 258). If diametrical clearance exceeds “Specifications (page 257),” replace pump assembly.

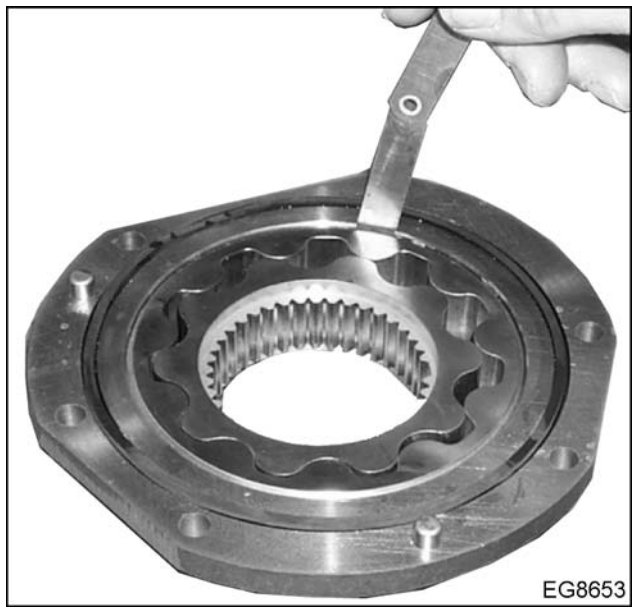

Figure 415 Measure rotors

3. If diametrical clearance is within “Specifications (page 257),” measure housing-to-rotor end clearance, O-ring must be removed. Place Bevelled Edge Straightedge (page 258) across housing. Insert appropriate Feeler Gauge under straightedge at housing and both inner and outer rotors individually.

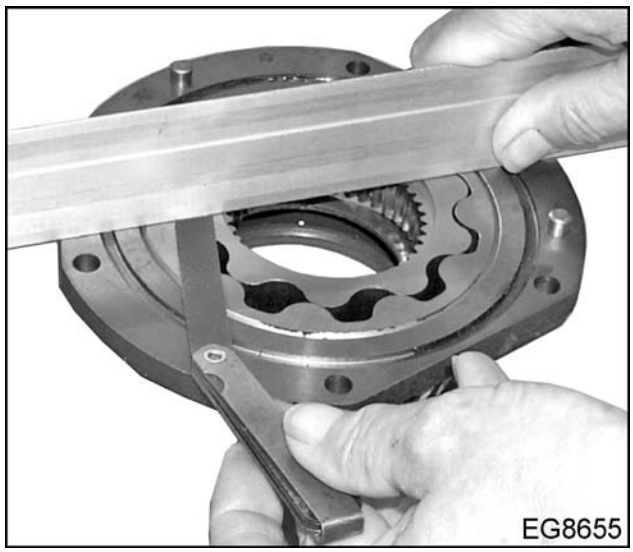

Figure 416 Measure housing and rotor clearance

4. If end clearance is not within "Specifications (page 257)," replace oil pump assembly.

Oil Filter and Header

Clean Oil Filter and Header

1. Immerse oil cooler, front, and filter header in suitable solvent. Flush and drain oil cooler to remove any residue.
2. Dry all components thoroughly with filtered compressed air.

Inspect Oil Filter and Header

1. Inspect oil cooler for blocked tubes and corrosion where tubes are assembled to bundle. Replace oil cooler tube bundle, if required.
2. Inspect header for blocked orifices or damaged threads at oil filter threaded insert.
3. Remove any debris that may be blocking oil flow passages.

Leak Test Oil Filter and Header

1. Fasten Oil Cooler Test Plate to oil cooler header with new oil cooler gaskets.
2. Install oil filter.
3. Install air pressure gauge to oil cooler filter header at turbocharger supply fitting.
4. Immerse assembly in container of clean tap water.
5. Apply 690 kPa (100 psi) of air pressure while assembly is immersed.
6. Inspect header castings, O-ring seals, and 1/4NPTF water side opening for leakage. Replace any leaking component as required and retest.

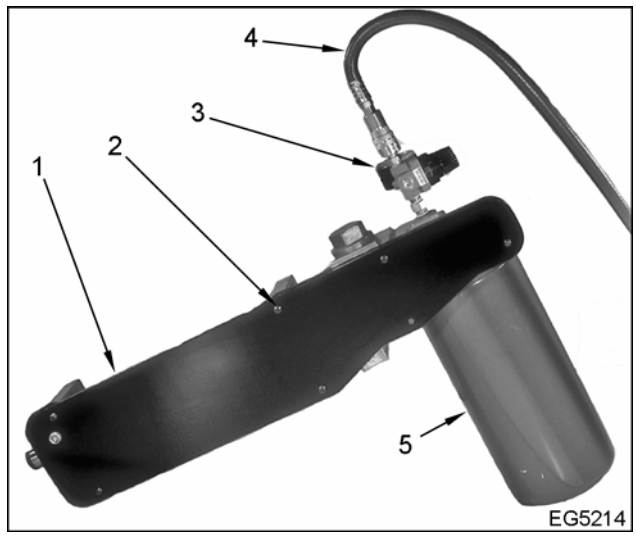

Figure 417 Leak test oil filter and header

1. Oil Cooler Test Plate
2. Oil Cooler Test Plate mounting bolts
3. Air pressure regulator
4. Air hose
5. Oil filter

Assemble

Assemble Oil Cooler and Header

CAUTION: To avoid engine damage, use new O-rings when assembling oil cooler. Do not nick, cut, or distort O-rings during assembly.

1. Install new O-rings on oil cooler bundle. Do not nick, cut, or distort O-rings during installation.
2. Use Lubriplate™ to lubricate oil cooler bundle, headers, and O-rings on cooler bundle.
3. Carefully press assembly together. Make sure locating clip of oil cooler headers (front and rear) align in slots of oil cooler bundle and header is not

cocked. This procedure can be accomplished by using body weight to press assembly together.

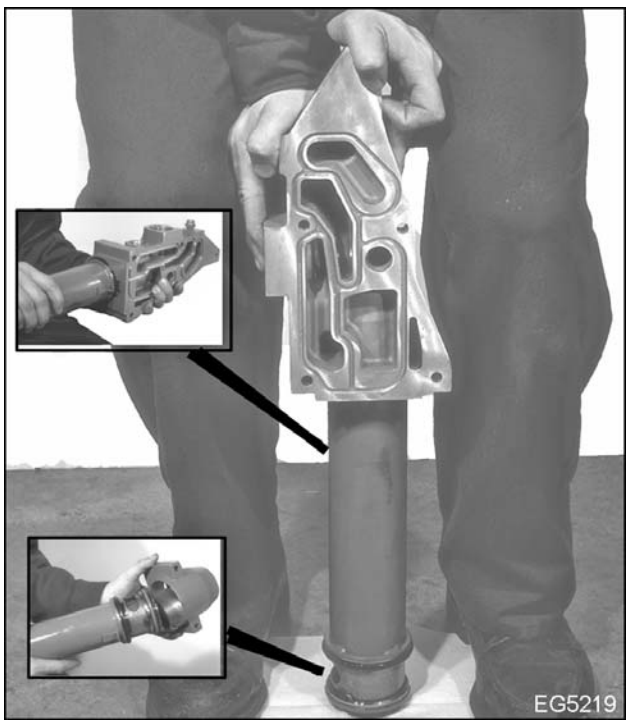

Figure 418 Assemble oil cooler and headers

Install

Install Oil Filter and Header

Oil filter cartridge and oil header can only be installed if engine is off stand.

1. Install water outlet tube in front cover.
2. Install oil cooler assembly with new square cut O-ring at front header and new O-ring gasket at rear header.
3. Install oil pressure relief valve in crankcase.
4. Install filter header and oil cooler assembly on crankcase. Install appropriate bolts and nuts. Tighten nuts on bolts to “Special Torque (page 258).”

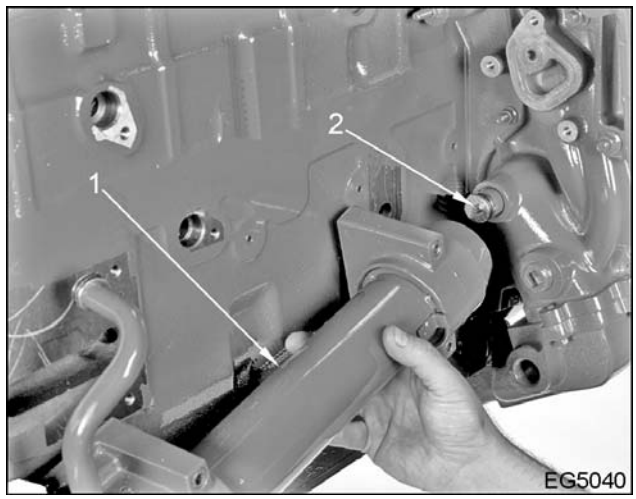

Figure 419 Install water outlet tube

1. Oil cooler
2. Water outlet tube

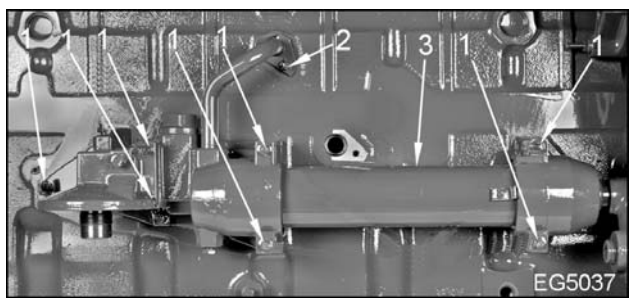

Figure 420 Install oil cooler

1. Mounting bolts
2. Retainer plate
3. Oil cooler

5. Install water inlet tube in crankcase. Install retainer plate for water coolant supply tube and tighten bolt.

CAUTION: To avoid engine damage, do not overtighten filter. A damaged filter may fracture or leak.

CAUTION: To avoid possible engine damage, do not remove adapter and place a long oil filter in place of a short oil filter on severe service applications.

NOTE: On some severe service applications a short oil filter and filter adapter have been installed.

6. (For short oil filter applications) Insure filter adapter is in place and sealed.

7. Lubricate filter gasket on new oil filter with clean engine oil. Install new oil filter on filter header.
8. Tighten filter one full turn after gasket contacts filter header.

Figure 421 Install oil filter

9. Prime the lubricating system. See “Prime Lubricating System” in this section.

Install Lubricating Oil Pump

1. Apply hydraulic sealant sparingly to outside diameter of oil seal.
2. Install new oil seal on lubricating oil pump housing.
3. Press seal in oil pump housing so front of seal is flush with front of oil pump housing. Wipe any excess sealant from housing and seal.

CAUTION: To avoid damage to oil pump housing and engine, do not use a press fixture that stops against front of oil pump housing. This will distort oil pump housing.

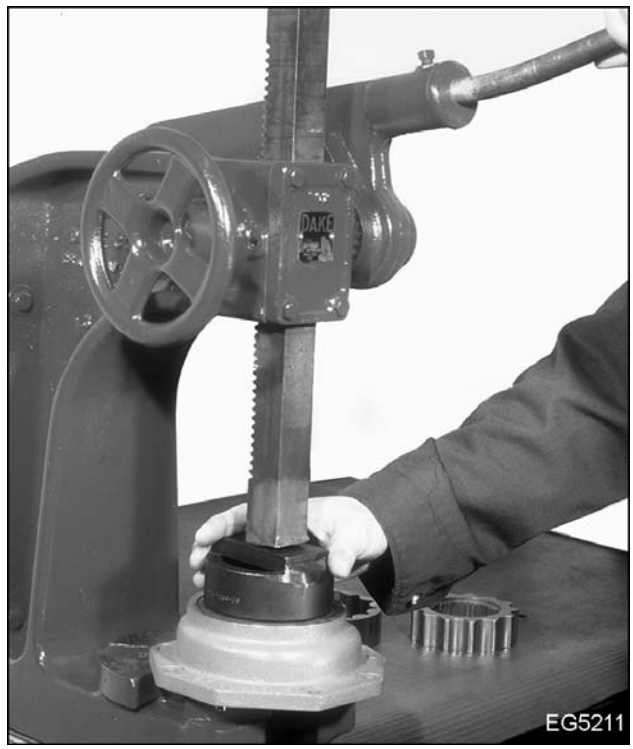

Figure 422 Install oil seal

4. Install new O-ring on front cover. Install housing plate.

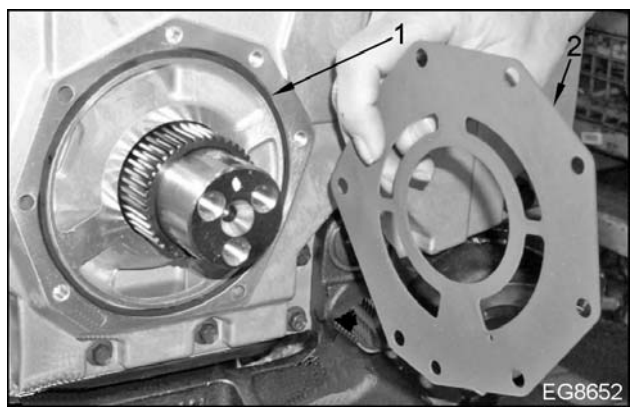

Figure 423 Install O-ring and housing plate

1. O-ring
2. Oil pump housing plate

5. Lubricate inner rotor with clean engine oil. Install inner rotor, washer, and seal on crankshaft gear spline.

NOTE: The washer and seal can be installed in either direction.

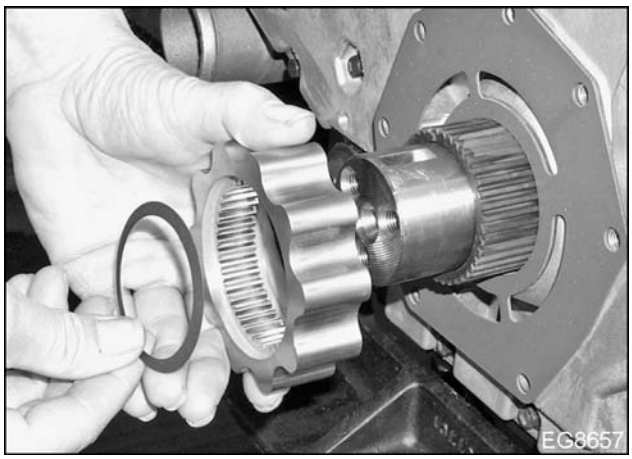

Figure 424 Install inner rotor, washer, and seal

6. Install woodruff key in groove. Lightly tap woodruff key in place.

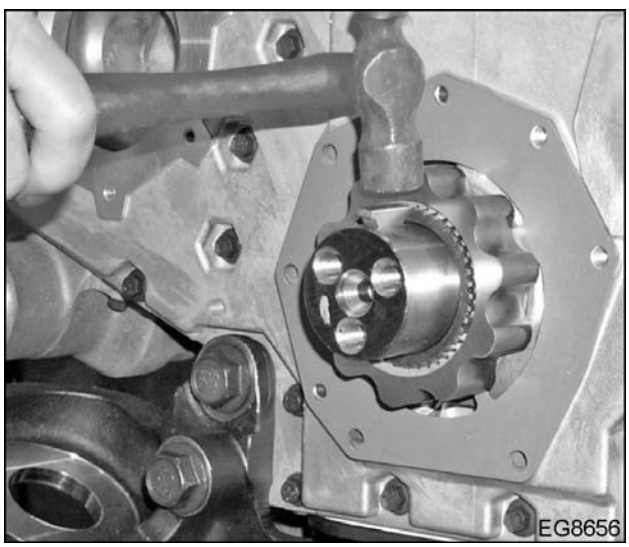

Figure 425 Install woodruff key

7. Lubricate outer rotor with clean engine oil. Install outer rotor on oil pump housing.
8. Install new O-ring in housing groove. Align housing dowel pins with mounting locations.
9. (For DT 466E engines only) Before installation, lubricate seal with clean engine oil.

   CAUTION: To avoid damage to engine, do not lubricate seal used on DT 530E engines, lubricating seal may affect seal life and performance.

   CAUTION: To avoid engine damage, seals are not interchangeable between DT 466E and DT 530E, due to seal thickness and seal material.

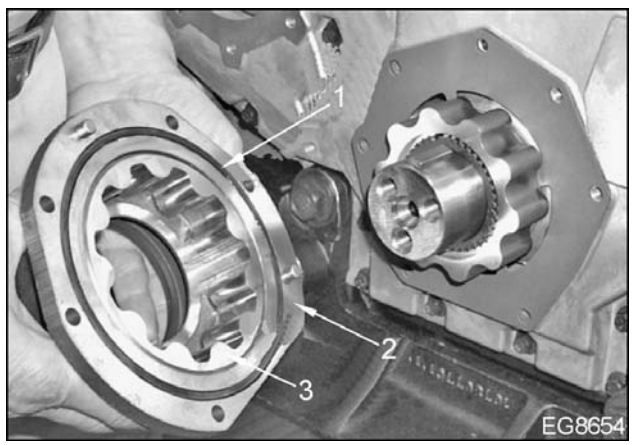

Figure 426 Oil pump housing

1. O-ring
2. Oil pump housing
3. Outer rotor

10. Install six oil pump housing cap screws (two short cap screws are located at two and three o'clock) in front cover. Tighten cap screws to "Standard Torque (page 343)."

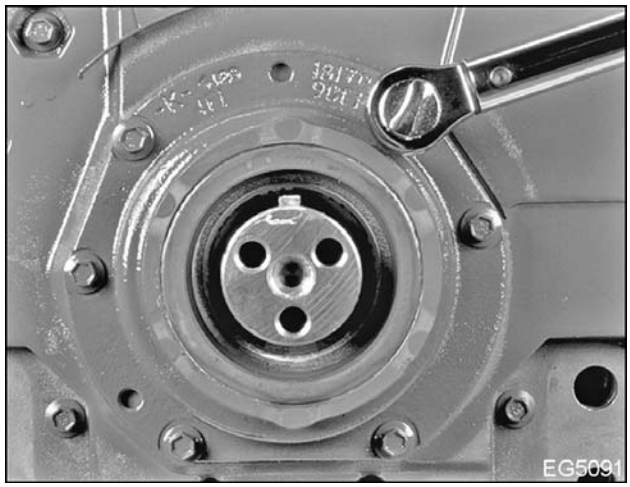

Figure 427 Install oil pump housing

11. Install vibration damper, see “Vibration Damper Assembly (page 184)” in the “Vibration Damper, Crankshaft, Main Bearing, Flywheel, and Crankcase” section of this manual.

Prime Lubricating System

Pressure Priming (Preferred Method)

WARNING: To avoid serious personal injury, possible death, and damage to vehicle or engine, do not rotate any diesel engine when priming with oil. This may cause engine to accidentally start.

CAUTION: To avoid possible engine damage, after engine has been fully assembled, lubricate engine with oil before startup to prevent any damage to internal parts.

NOTE: Make sure there is a new lube oil filter installed before oil is added.

1. Inject sufficient oil in engine to fill oil filters and charge entire system.
2. After priming, check oil level before engine is put back in service.

Crankcase Refill Capacities

Description	Crankcase Refill Capacity
DT 466 with filter change	28.3 Liters (30 quarts)
DT 466 without filter change	24.6 Liters (26 quarts)
DT 466 w/short oil filter with filter change	26.4 Liters (28 quarts)
DT 466 w/short oil filter without filter change	22.7 Liters (24 quarts)
DT 530 and HT 530 with filter change	28.3 Liters (30 quarts)
DT 530 and HT 530 without filter change	24.6 Liters (26 quarts)
DT 530 and HT 530 w/short oil filter with filter change	25.6 Liters (27 quarts)
DT 530 and HT 530 w/short oil filter without filter change	21.8 Liters (23 quarts)

NOTE: Engines equipped with bypass filtering system require additional oil.

Alternate Method

CAUTION: To avoid possible engine damage, engine must be well-oiled when using alternate method of system priming.

1. Crank, but do not start, engine until oil pressure appears on oil pressure gauge.
2. When oil pressure appears, engine may be started.

Engine Run-In Procedure

After installing new pistons or new rings, engine must be “run-in.”

1. Operate engine at low idle with no load for five minutes.
2. Check for leaks in oil, fuel, water, and air induction systems.
3. Observe turbocharger for any of the following. Investigate and correct any of these conditions

immediately to avoid possible turbocharger or engine failure.

Unusual noise

Oil leaks

Loose mounting to engine

Excessive vibration

Excessive exhaust smoke

Air leaks in air cleaner-to-turbocharger or turbocharger-to-intake manifold ducts

4. Tighten all cap screws, hold-down nuts and air connections to and from turbocharger after initial warm-up.
5. Operate engine at 3/4 rated speed and 1/2 - 3/4 throttle for ten minutes.
6. Operate engine at rated speed and full throttle for 30 minutes. Check for leaks in oil, fuel, water and air induction systems.

Special Information

Specifications

Oil Pump	
Type	Gerotor
Drive	Crankshaft
End clearance inner and outer	0.066 to 0.142 mm (0.0026 to 0.0056 in)
Diametrical clearance between outer rotor housing	0.470 to 0.622 mm (0.0185 to 0.0245 in)
Minimum engine oil pressure at low idle speed (700 rpm)[1]	103 kPa (15 psi)
Minimum engine oil pressure at high idle speed*	276 to 483 kPa (40 to 70 psi)
Pressure Regulator Valve Assembly	
Location	In crankcase, behind filter header
Setting	331 kPa (48 psi)
Valve assembly diameter	26.949 ± 0.038 mm (1.0610 ± 0.0015 in)
Valve clearance in bore	0.038 to 0.089 mm (0.0015 to 0.0035 in)
Crankcase bore diameter	27.00 to 27.05 mm (1.063 to 1.065 in)

[1] Run engine until normal operating temperature is reached. Take oil pressure measurement with an oil gallery tap.

Special Torque

Oil pan drain plug	68 N·m (50 lbf·ft)
Oil pan mounting bolts	32 N·m (24 lbf·ft)
Oil pickup tube bolts	20 N·m (15 lbf·ft)
Oil pickup tube bracket bolts (front sump)	20 N·m (15 lbf·ft)
Oil pickup tube bracket bolt (rear sump)	32 N·m (24 lbf·ft)
Oil level gauge tube clamp	3.4 N·m (30 lbf·in)
Oil temperature control valve	34 N·m (25 lbf·ft)
Oil cooler mounting bolts	26 N·m (19 lbf·ft)

Special Service Tools

Bevelled Edge Straightedge	OEM1293
Crankshaft Front Oil Wear Sleeve Installer	ZTSE3004B
Feeler Gauge	Obtain locally
Lubriplate™	Obtain locally
Oil Cooler Test Plate	ZTSE4376

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Exploded View

Fan Drive, Thermostat, and Water Pump

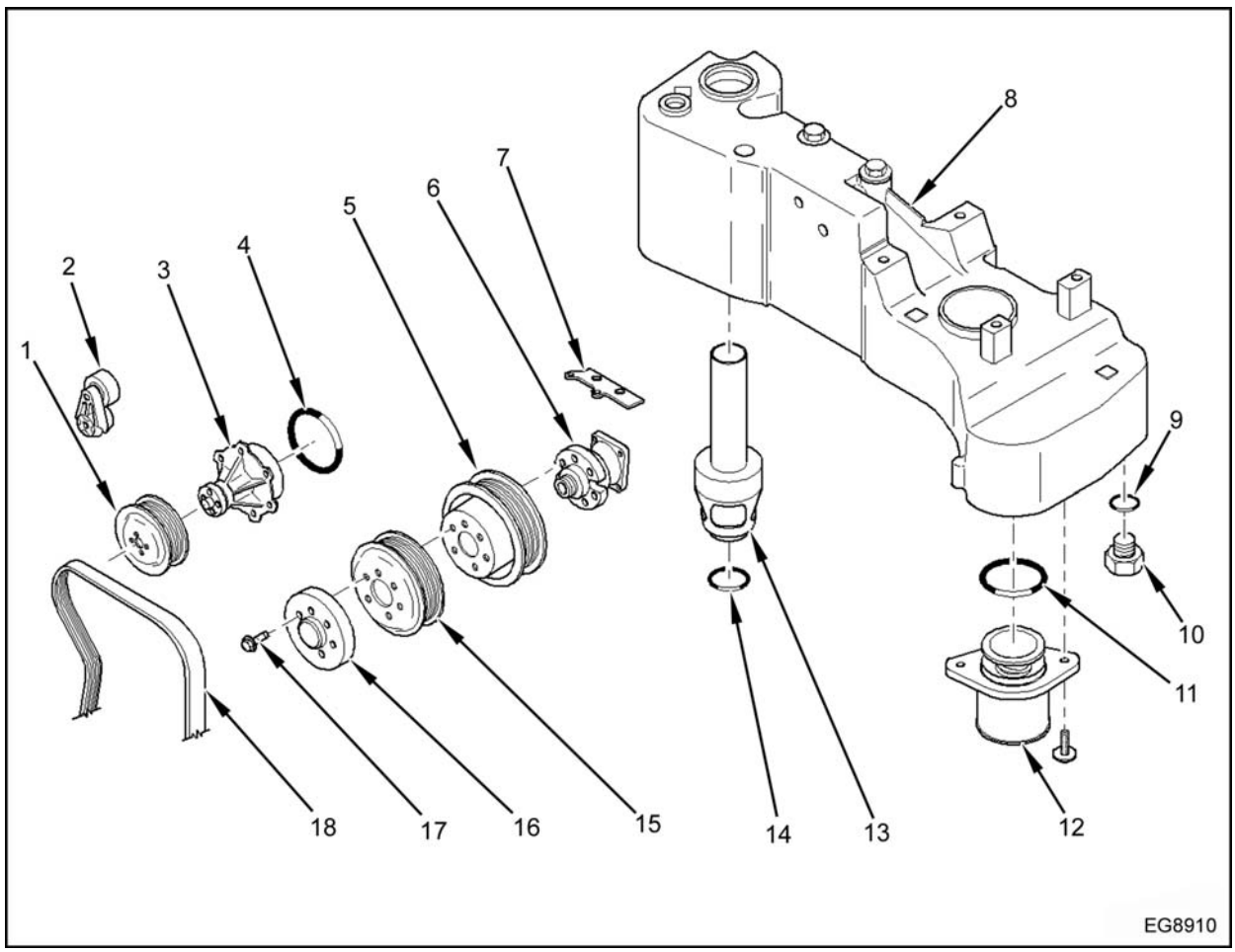

Figure 428 Fan drive, thermostat with housing (NGV) and water pump

1. Water Pump Pulley
2. Auto Tensioner
3. Water Pump Assembly
4. Water Pump O-ring
5. Fan Pulley
6. Fan Mounting Bracket w/Hub
7. Fan Mounting Support Bracket (Use with 465 mm [18.3 in.] Fan Center only. Not with item 14.)
8. Thermostat Housing
9. O-ring, not used with Retarder Transmission
10. Plug for Retarder Port, not used with Retarder Transmission
11. O-ring
12. Thermostat Assembly
13. Coolant Bypass Tube
14. O-ring
15. Freon Compressor Drive Pulley
16. Fan Spacer (If equipped)
17. Special Flange Bolt
18. Fan Drive Belt

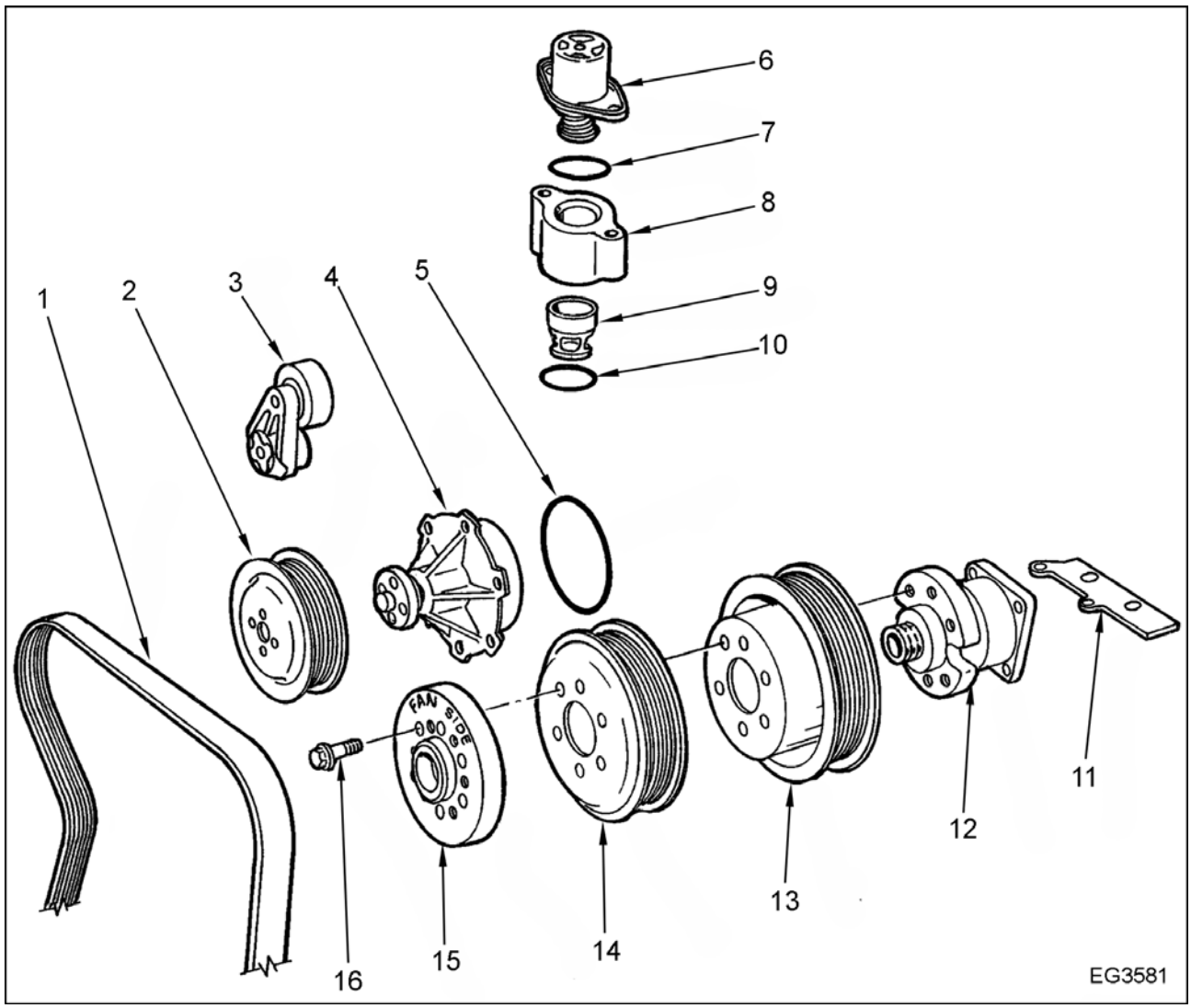

Figure 429 Fan drive, thermostat, and water pump

1. Fan drive belt
2. Water pump pulley
3. Auto tensioner
4. Water pump assembly
5. Water pump O-ring
6. Thermostat
7. O-ring
8. Thermostat housing bypass *
9. Coolant passage insert *
10. O-ring *
11. Fan mounting support bracket - used with 465 mm (18.3 in) fan center
12. Fan mounting bracket with hub
13. Fan pulley
14. A/C and Freon compressor drive pulley
15. Fan spacer
16. Special flange bolt

*Used only with retarder equipped automatic transmission

Remove

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, read all safety instructions in the "Safety Information" section of this manual.

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, make sure the transmission is in neutral or park, parking brake is set, and wheels are blocked before doing diagnostic or service procedures on engine or vehicle.

WARNING: To avoid personal injury or death from hot coolant or steam scalding, use the following procedure to remove the pressure cap from the cooling system. Allow the engine to cool. Wrap a thick cloth around the cap. Unscrew cap slowly, then pause to allow pressure to release.

NOTE: Before removing water pump, coolant filter header, or water inlet elbow, first drain coolant from engine.

Coolant filter header must be removed prior to mounting engine on an engine stand.

Remove Pressure Cap from Deaeration Tank

1. Allow the engine to cool.
2. Wrap a thick, heavy cloth around the cap.
3. Loosen the cap slowly.
4. Pause for a moment to allow the pressure and or steam to escape. This will avoid possible scalding by hot water or steam.
5. Continue to turn the cap and remove it.

Thermostat and NGV Thermostat Housing (If Installed)

1. Remove hose from thermostat.
2. Remove two thermostat flanged head mounting bolts.

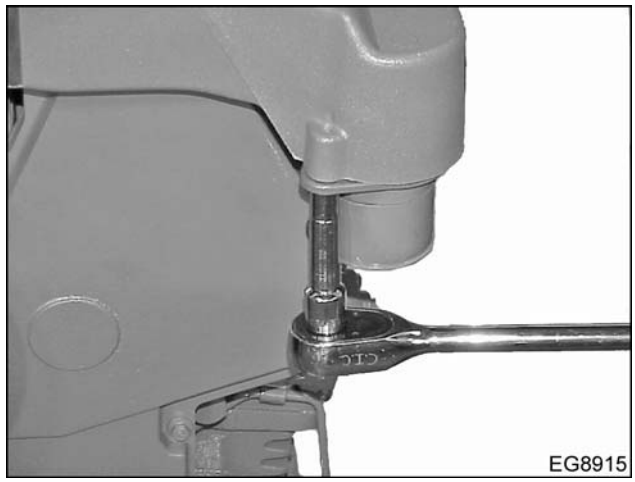

Figure 430 Remove thermostat mounting bolts

3. Remove two M12 flanged head mounting bolts and two M8 flanged head mounting bolts fastening thermostat housing to cylinder head.

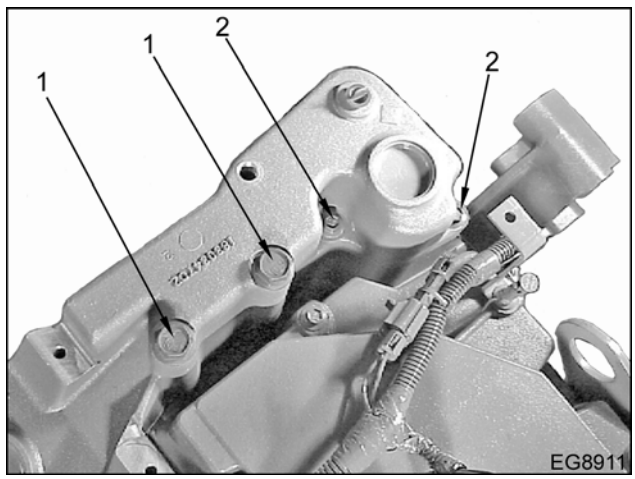

Figure 431 Remove thermostat housing mounting bolts

1. M12 flanged head bolts
2. M8 flanged head bolts

4. Remove thermostat housing from cylinder head.
5. Remove coolant bypass tube from thermostat housing. Remove and discard O-ring.

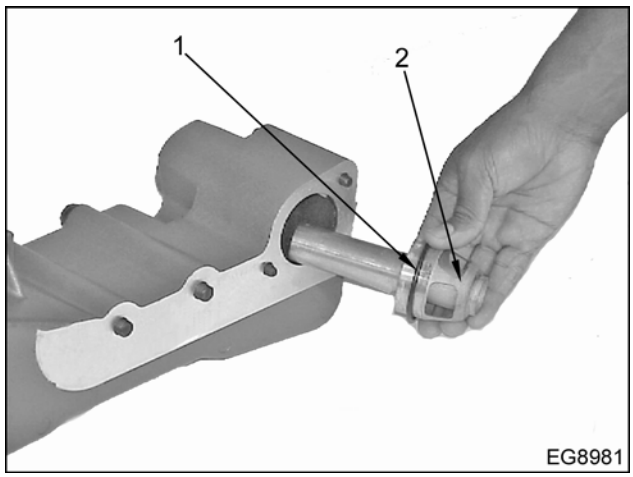

Figure 432 Remove coolant bypass tube

1. O-ring
2. Coolant bypass tube

Thermostat (No NGV Thermostat Housing)

1. Relieve cooling system pressure by removing deaerating tank cap, if not already removed.
2. Loosen worm clamp on water outlet hose and remove hose from thermostat.
3. Remove two thermostat flanged head bolts from cylinder head.

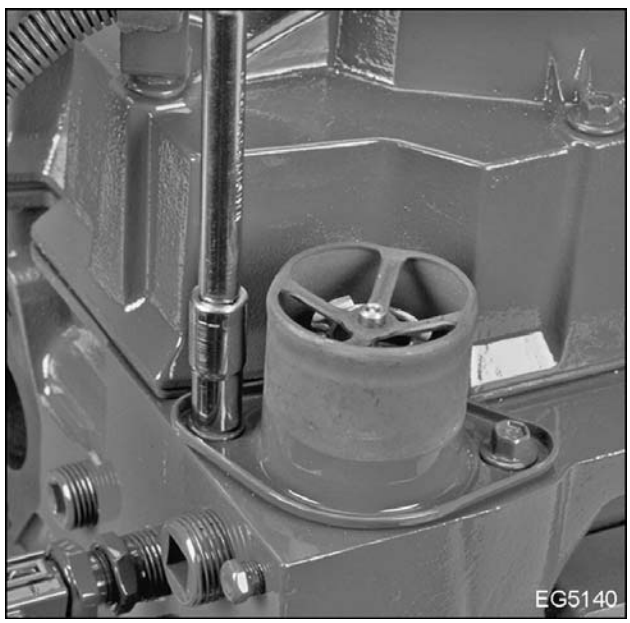

Figure 433 Remove thermostat mounting bolts

4. Remove thermostat from cylinder head or from the retarder housing (if installed). Remove and discard O-ring from the thermostat.

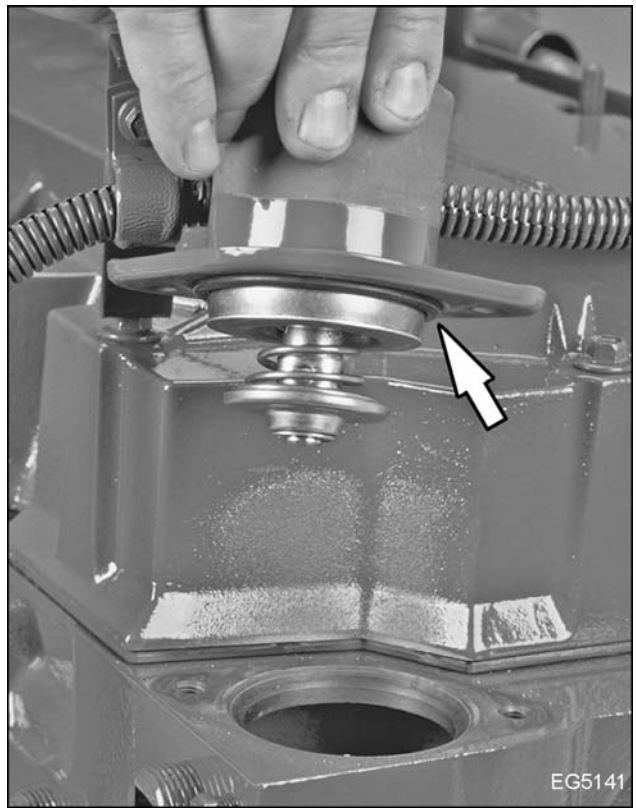

Figure 434 Remove thermostat

5. Remove retarder housing and coolant passage insert (if installed) and coolant passage insert. Remove and discard retarder housing O-ring (if installed).

Water Pump

1. Relieve cooling system pressure by removing deaerating tank cap if not already done. See “Remove Pressure Cap from Deaeration Tank” for cap removal procedure.
2. Remove four water pump pulley bolts. Place oil filter strap around water pump pulley to hold water pump pulley when removing pulley mounting bolts.

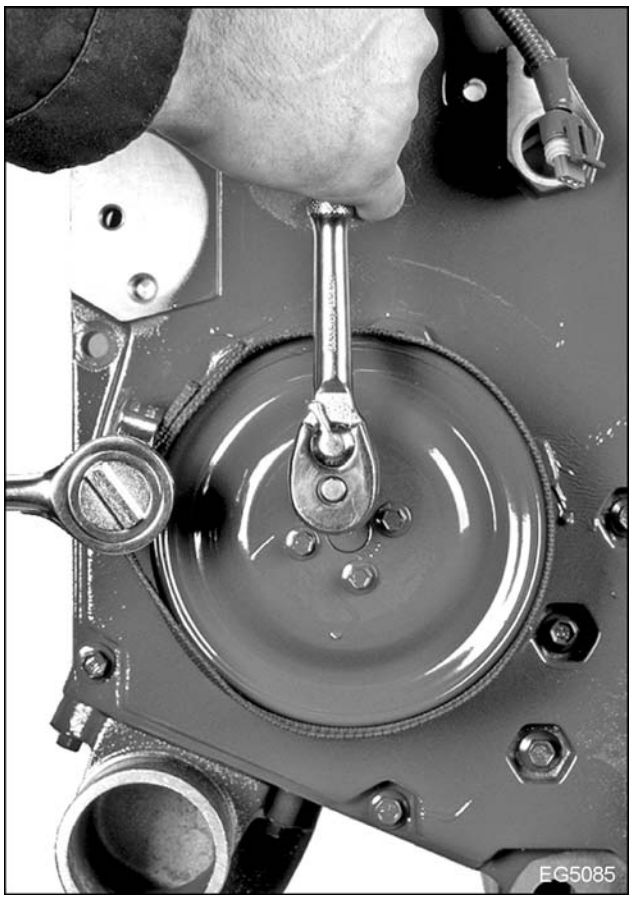

Figure 435 Remove water pump pulley

3. Remove pulley from water pump hub.
4. Remove seven water pump bolts from front cover. Bolt at 12 o'clock position goes through front cover and is held with a nut on backside of front cover.

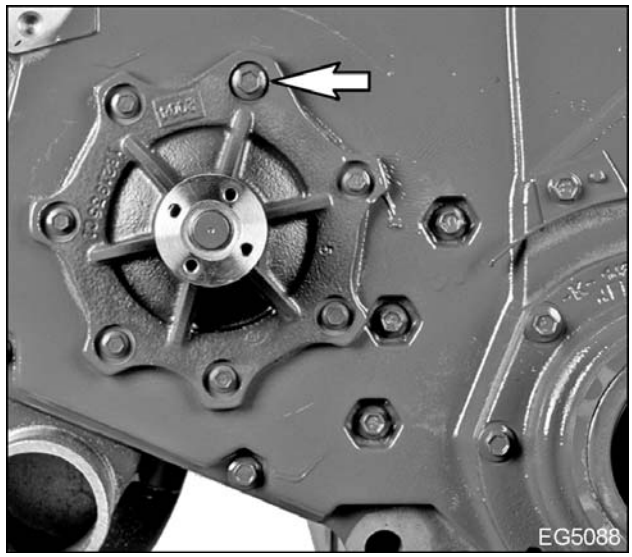

Figure 436 Remove water pump

5. Remove water pump from front cover. Remove and discard O-ring.

Coolant Filter (If Equipped)

The coolant filter must be removed prior to mounting engine on a stand.

1. Relieve cooling system pressure by removing deaerating tank cap, if not already removed.
2. Close manual shutoff valve on coolant filter header by turning handle clockwise. In closed position, handle will be pointing straight up.

Figure 437 Close manual shutoff valve

3. Loosen and remove coolant filter with a filter wrench or strap wrench. Filter is located on rear right side of front cover.

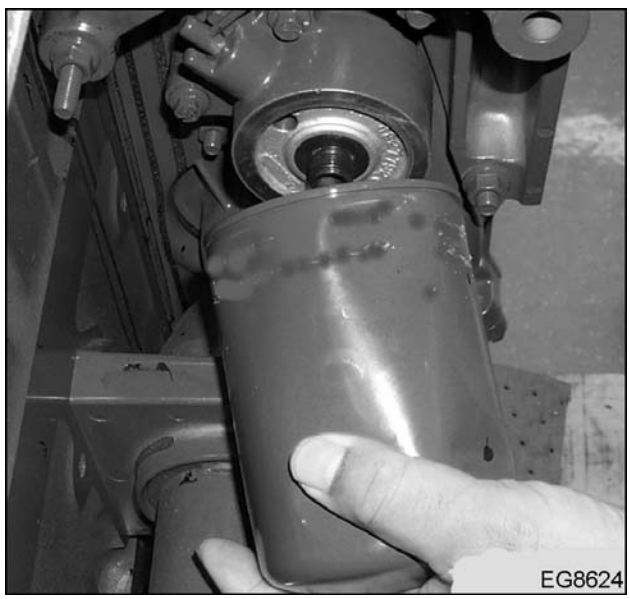

Figure 438 Remove coolant filter

4. Loosen and remove three coolant filter header mounting bolts. Remove coolant filter header and discard seal and O-ring.

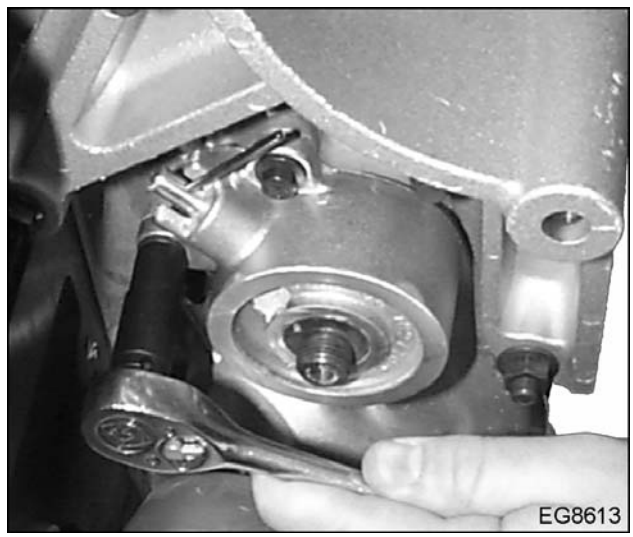

Figure 439 Remove coolant filter header

NOTE: Coolant filter header with manual shutoff valve has no serviceable components. If damaged or leaking, replace entire filter header.

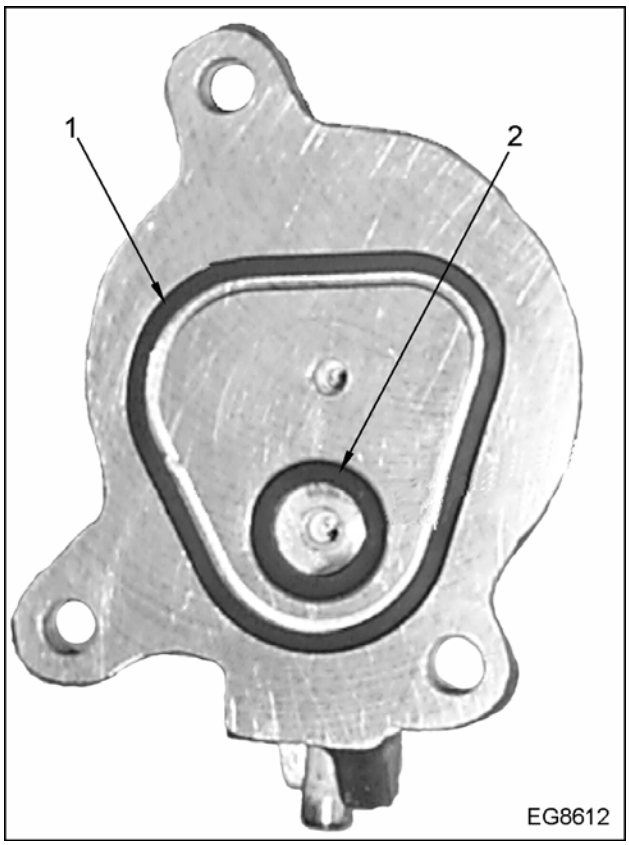

Figure 440 Coolant filter header seal and O-ring

1. Seal
2. O-ring

Water Inlet Elbow

1. Remove three mounting bolts fastening water inlet elbow to crankcase cover.
2. Remove water inlet elbow and gasket. Discard gasket.

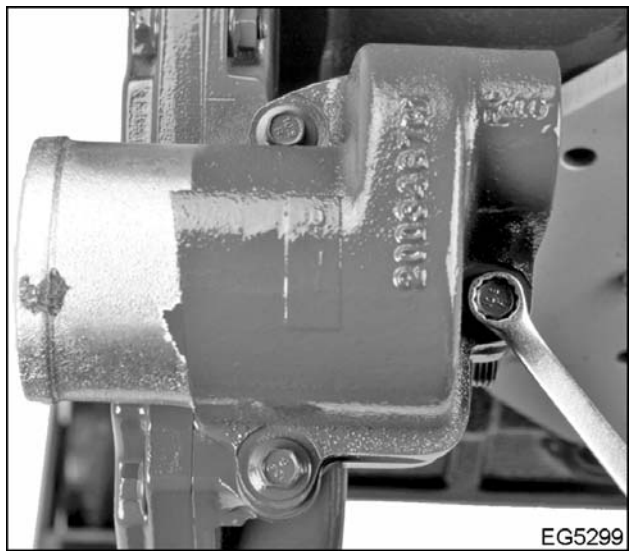

Figure 441 Remove water inlet elbow

Clean and Inspect

⚠ WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit the air pressure to 207 kPa (30 psi).

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

Water Pump

Clean Water Pump and Cooling System

1. If debris, corrosion or contamination of cooling system appear excessive, flush entire cooling system.

Inspect Water Pump

1. Inspect water pump for a damaged impeller, cracks or other problems. If any defects are noted, replace water pump as an assembly.

Thermostat

WARNING: To avoid possible personal injury, use caution and good judgment when dealing with hot water and hot objects. Use heat resistant gloves and wear appropriate eye protection.

CAUTION: To avoid engine damage, when servicing thermostat, it is essential that thermostat opens fully at specified temperature to avoid an overheating condition.

Only genuine International® thermostats assure proper coolant flow and positive sealing characteristics that are required to provide proper engine cooling.

Inspect Thermostat

1. Inspect thermostat for cracks and pitting.
2. Inspect thermostat for conditions that may cause improper closure:

   Debris, foreign deposits, pitting, or loose fit at seat

   Rough or uneven wear at seal seat location

   Uneven seat

   Broken or worn springs or pistons

3. Replace thermostat if it does not operate as described or if it does not meet inspection criteria.

Test Thermostat

1. Manually open thermostat enough to insert nylon ribbon under valve seat. Suspend thermostat in container filled with water. Suspend thermometer in water on opposite side of container.

NOTE: Make sure thermostat and thermometer are suspended in water and not lying directly on bottom of container. Make sure thermostat will not rest directly on bottom when it falls off ribbon.

2. Heat container filled with water to START TO OPEN temperature of 86 to 89 °C (187 to 192 °F). Observe thermometer as soon as thermostat drops off nylon ribbon.

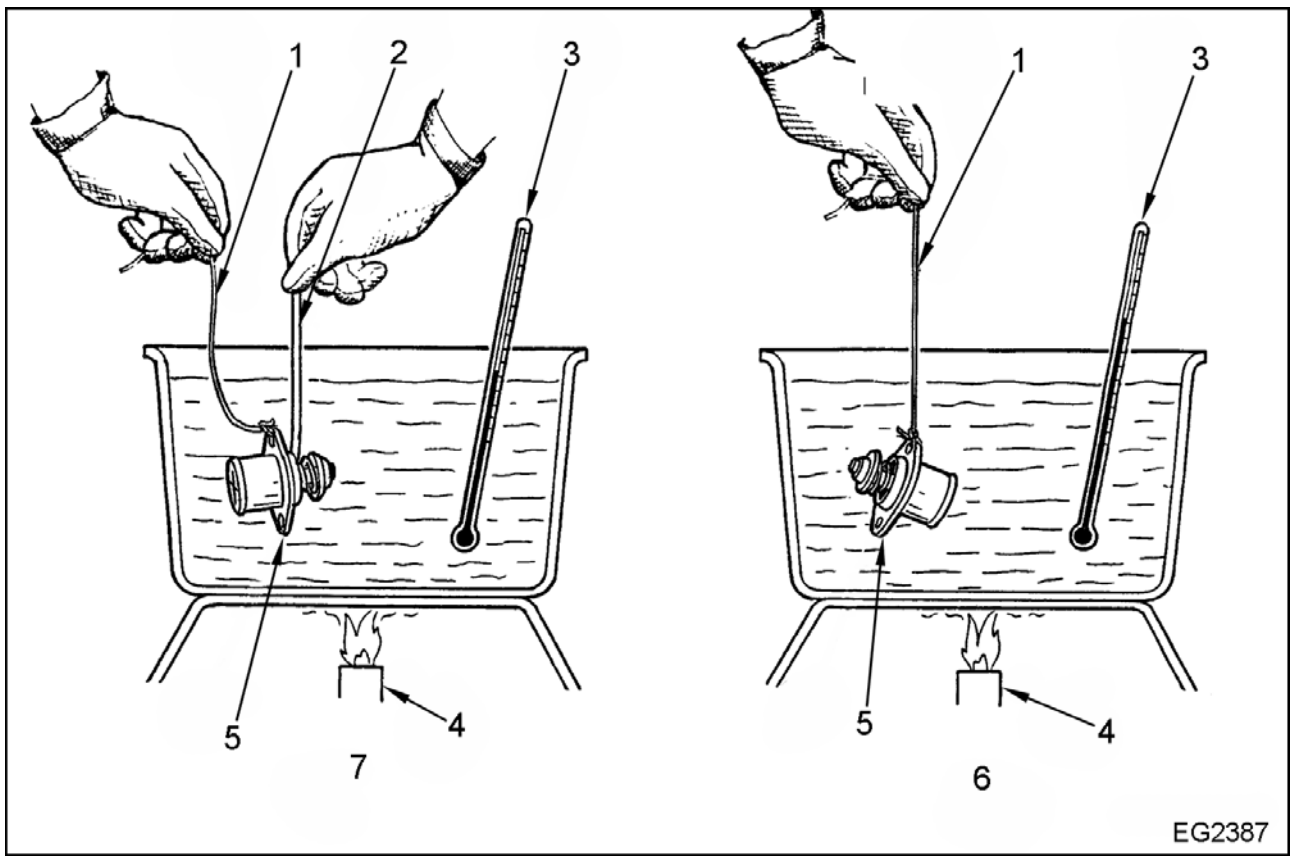

Figure 442 Test thermostat

1. Suspension line
2. Ribbon
3. Thermometer
4. Heat source
5. Thermostat
6. FULL OPEN temperature (minimum sleeve travel test)
7. START TO OPEN temperature (ribbon test)

3. Continue heating water to FULL OPEN temperature of 96 °C (205 °F) while thermostat is suspended from mounting hole. Observe thermometer and movement of thermostat when FULL OPEN temperature is reached. Minimum travel at FULL OPEN temperature is 10.16 mm (0.400 in).

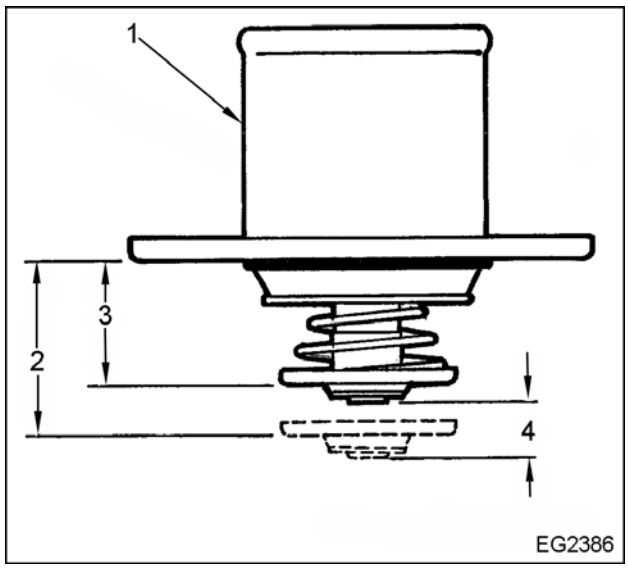

Figure 443 Thermostat position

1. Thermostat
2. Minimum open dimension: 39.98 mm (1.574 in)
3. Closed dimension: 29.82 mm (1.174 in)
4. Minimum travel: 10.16 mm (0.400 in)

4. Remove thermostat from water.
5. Replace thermostat if it does not operate as described.

Install

Install Thermostat and Thermostat Housing (If Applicable)

1. Install coolant bypass tube in inner bore. Fully seat coolant bypass tube in outer bore.

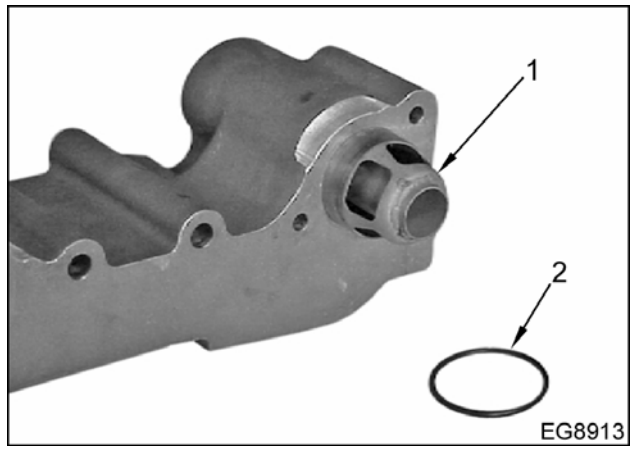

Figure 444 Install coolant bypass tube

1. Coolant bypass tube
2. O-ring

2. Install new O-ring over protruding coolant bypass tube, O-ring should be flush against thermostat housing mounting surface.

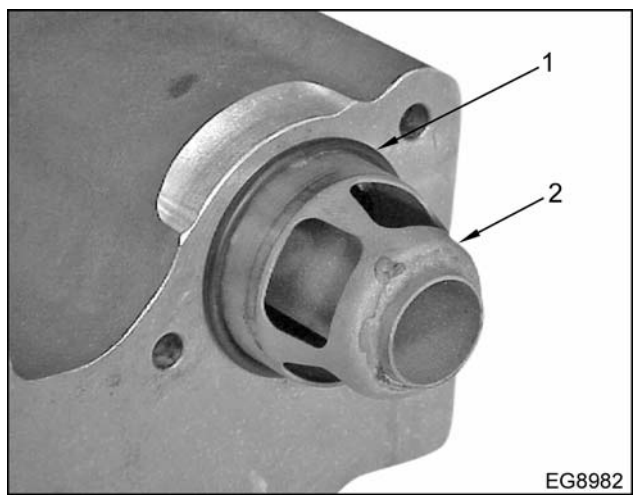

Figure 445 Install coolant bypass tube O-ring

1. O-ring
2. Coolant bypass tube

3. Install thermostat housing on top of cylinder head with two M8 flanged head bolts and two M12 flanged head bolts. Tighten two M8 flange head bolts to “Standard Torque (page 343),” tighten two M12 flange head bolts to “Special Torque (page 241).”

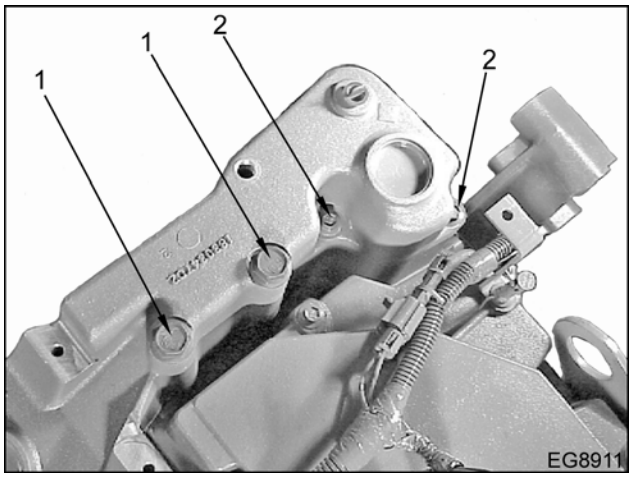

Figure 446 Install thermostat housing

1. M12 flanged head bolts
2. M8 flanged head bolts

4. Install new O-ring on thermostat assembly.

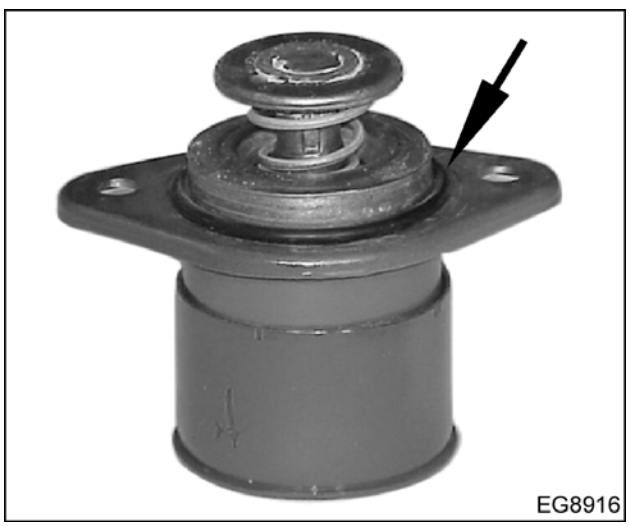

Figure 447 Install O-ring

5. Install thermostat assembly in opening in thermostat housing assembly with two M8 flanged head bolts. Tighten two thermostat housing bolts to “Standard Torque (page 343).”

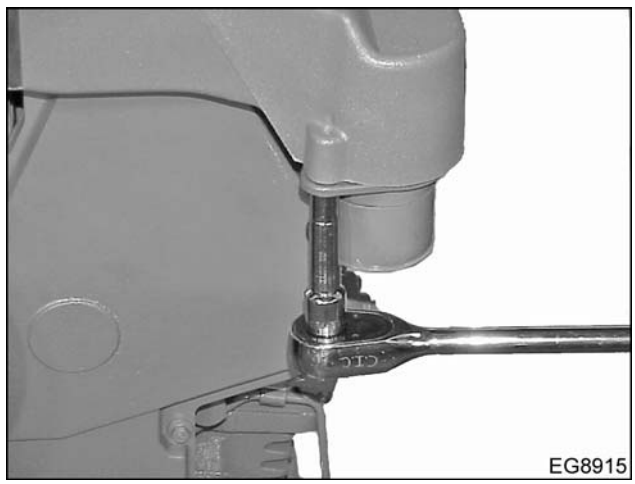

Figure 448 Install thermostat

Thermostat (No NGV Thermostat Housing)

1. Install new O-ring on thermostat assembly.
2. Install new O-ring on retarder housing (if installed).
3. Install thermostat assembly in opening on top of cylinder head. Install thermostat assembly in opening on top of retarder housing (if installed). Install retarder housing and coolant passage insert (if installed) in opening on top of cylinder head.
4. Install two flanged head bolts. Tighten bolts to “Standard Torque (page 343).”

Figure 449 Install thermostat

Water Inlet Elbow

Install water inlet elbow with new gasket on crankcase. Install three flanged bolts and tighten bolts to ”Special Torque (page 275).”

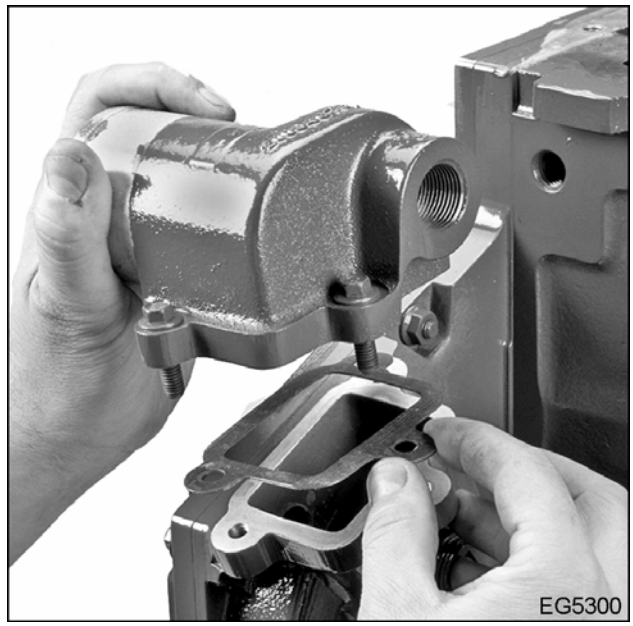

Figure 450 Install water inlet elbow

Coolant Filter

Coolant filter can only be installed if engine is off stand.

1. Install new O-ring and seal in rear of coolant filter header.
2. Install coolant filter header on mounting pad of front cover and fasten with mounting bolts. Tighten bolts to “Special Torque (page 275).”
3. Lubricate coolant filter gasket with clean engine oil and install new coolant filter. Tighten coolant filter until gasket contacts coolant filter header. Tighten filter one additional full turn.
4. Open manual shutoff valve by turning it counterclockwise. When open, handle will be pointing rearward.

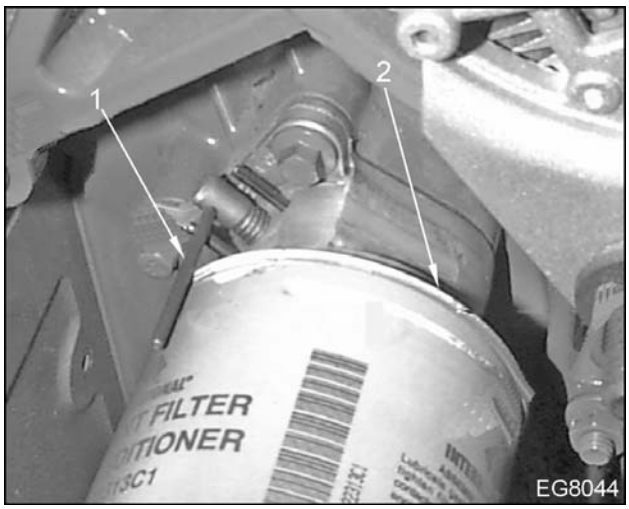

Figure 451 Install coolant filter

1. Lever
2. Coolant filter

Water Pump

1. Apply small amount of assembly grease to water pump O-ring seal groove. Install new O-ring on water pump assembly.

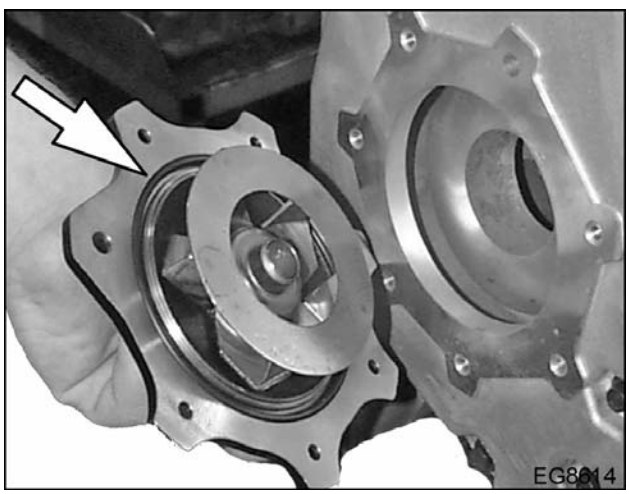

Figure 452 Water pump O-ring

2. Install water pump on front cover. Install one bolt and nut at 12 o'clock position and other mounting bolts in remaining bolt holes. Tighten mounting bolts to "Special Torque (page 275)."

NOTE: Make sure water pump rotates freely after installation.

Figure 453 Torque water pump bolts

3. Slide water pump pulley over water pump hub. Place oil filter strap over pulley and hold water pump hub. Fasten pulley to hub with four mounting bolts. Tighten mounting bolts to "Special Torque" (page 275).

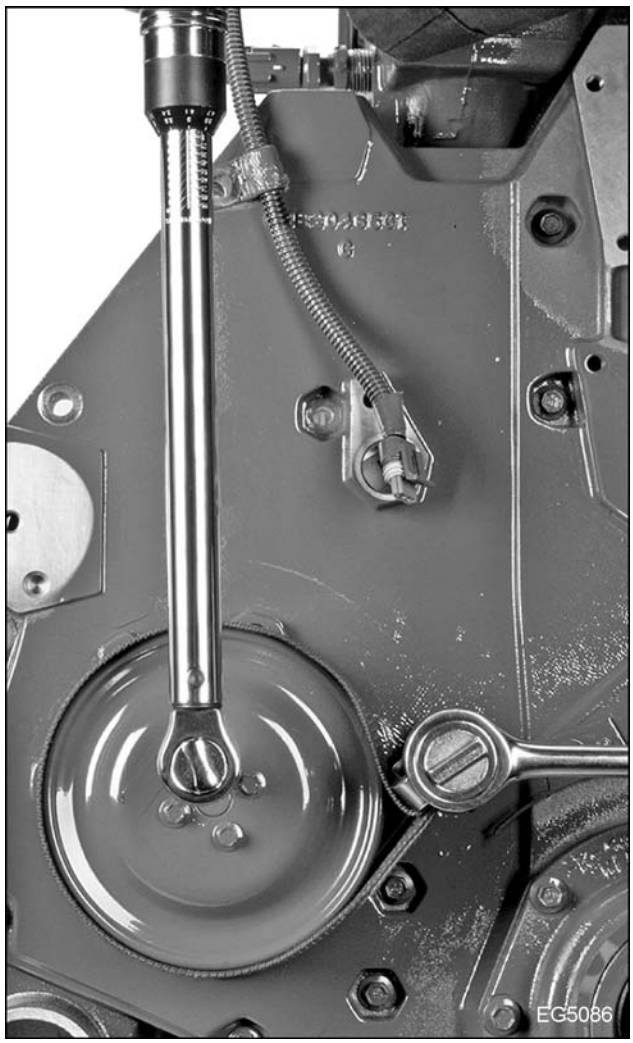

Figure 454 Torque water pump pulley bolts

Special Information

Specifications

Thermostat	
Type	Poppet Valve, Pellet Operated
Operating temperature range:	
Start-to-open temperature	86 to 89 °C (187 to 192 °F)
Full-open temperature	96 °C (205 °F)

Special Torque

Water pump (6 mm)	7.5 N·m (66 lbf·in)
Water pump pulley (6 mm)	7.5 N·m (66 lbf·in)
Water pump mounting bolts (8 mm)	17 N·m (13 lbf·ft)
Belt tensioner (front cover)	50 N·m (37 lbf·ft)
Belt tensioner (Freon compressor)	50 N·m (37 lbf·ft)
Fan drive	18 N·m (13 lbf·ft)
Coolant filter header mounting bolts	26 N·m (19 lbf·ft)

Special Service Tools

Container filled with water	Obtain locally
Thermometer	Obtain locally
Heating Plate	Obtain locally

Table of Contents

Locations

Engine Sensors

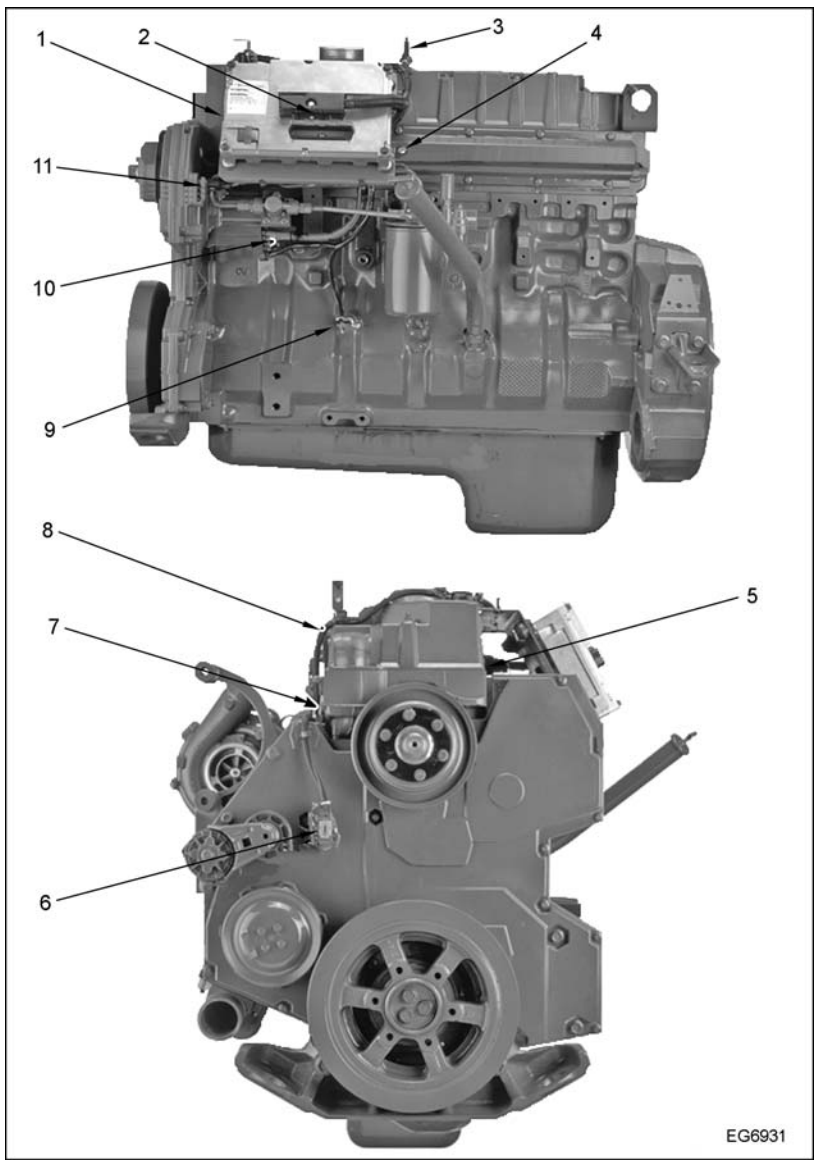

Figure 455 Engine sensors (front mounted ECM)

1. Electronic Control Module (ECM)
2. ECM connector
3. Manifold Absolute Pressure (MAP) sensor
4. Injection Control Pressure (ICP) sensor
5. Valve cover wiring harness connector
6. Camshaft Position (CMP) sensor
7. Engine Coolant Temperature (ECT) sensor
8. Main wiring harness
9. Engine Oil Pressure (EOP) sensor
10. Injection Pressure Regulator (IPR)
11. Engine Oil Temperature (EOT) sensor

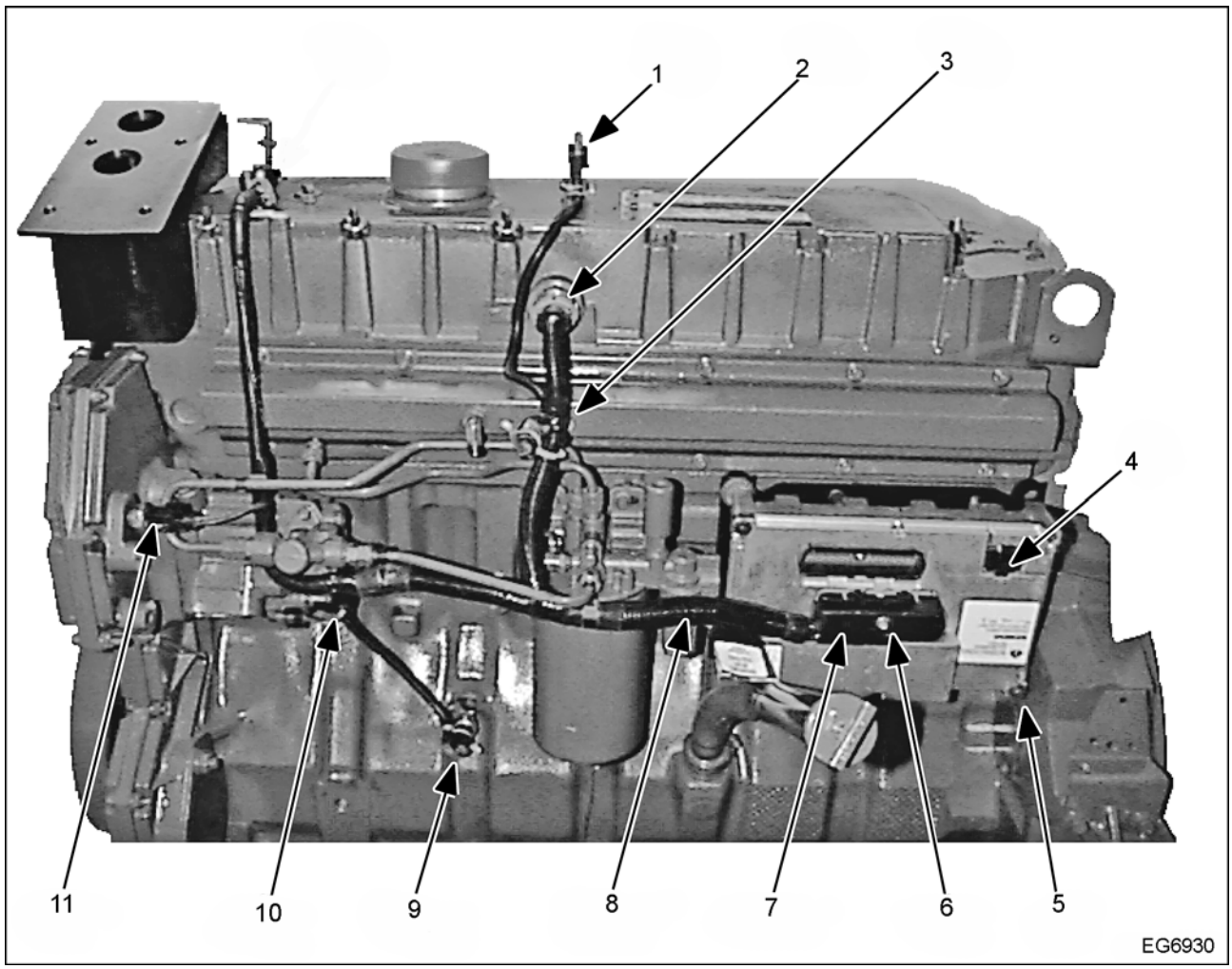

Figure 456 Engine sensors (rear mounted ECM)

1. Manifold Absolute Pressure (MAP) sensor
2. Valve cover wiring harness connector
3. Injection Control Pressure (ICP) sensor
4. Electronic Control Module (ECM)
5. ECM mounting bolt
6. ECM connector mounting bolt
7. ECM connector
8. Wiring harness
9. Engine Oil Pressure (EOP) sensor
10. Injection Pressure Regulator (IPR)
11. Engine Oil Temperature (EOT) sensor

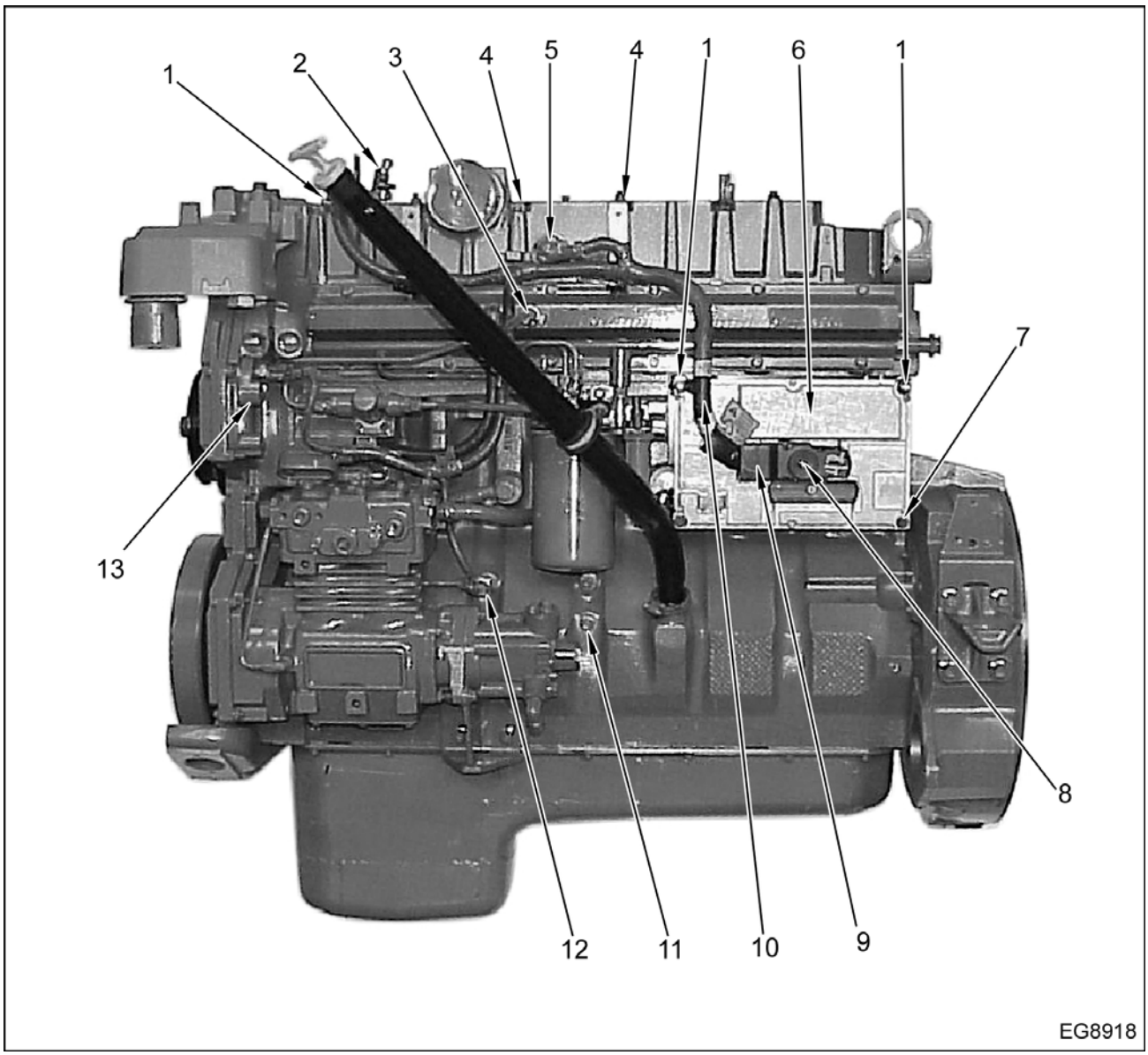

Figure 457 Engine sensors (International® High Performance 4000 Series Trucks)

1. “L” Bracket
2. Manifold Absolute Pressure (MAP) sensor
3. Injection Control Pressure (ICP) sensor
4. “Z” Bracket
5. Valve cover wiring harness connector
6. Electronic Control Module (ECM)
7. ECM mounting bolt
8. ECM connector mounting bolt
9. ECM connector
10. Engine wiring harness
11. Electrical grounding bolt
12. Engine Oil Pressure (EOP) sensor
13. Engine Oil Temperature (EOT) sensor

Engine Sensors and Connectors

Camshaft Position (CMP) Sensor

The CMP sensor is a Hall Effect sensor stacked in front of a magnet with a signal conditioning integrated circuit. The CMP sensor responds to a rotating actuator positioned on the camshaft gear. The camshaft actuator has 24 stamped windows. This produces a rectangular wave pulse for each tooth as the actuator rotates past the CMP sensor. The pulses are used to indicate engine speed and camshaft position for control of fuel quantity, injection timing and overspeed shutdown. The CMP sensor is located above the water pump pulley on the right side of the engine front cover.

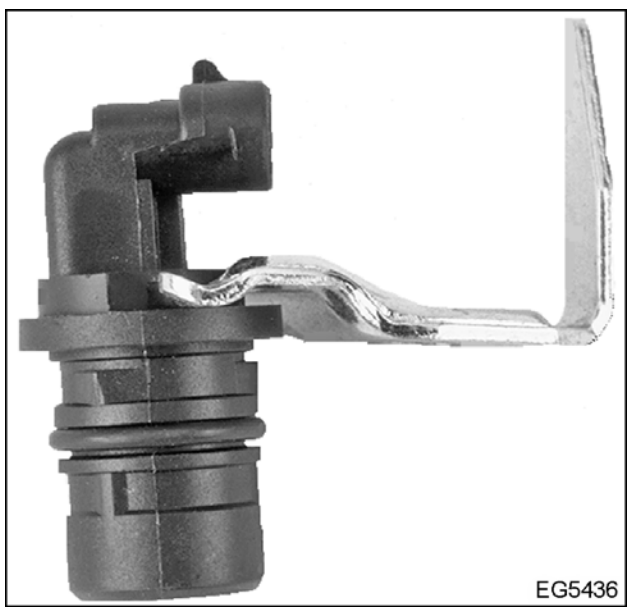

Figure 458 CMP sensor

Temperature Sensors

Engine Coolant Temperature (ECT) Sensor

The ECT sensor is a thermistor type sensor that senses changes in engine coolant temperature. The ECT sensor is located on the right front side of the cylinder head, below the thermostat.

Engine Oil Temperature (EOT) Sensor

The EOT sensor is a thermistor type sensor that is used to sense engine oil temperature. The EOT sensor provides an engine temperature signal to the ECM, which uses the information for fuel rate and timing adjustments. The EOT sensor is located above the high-pressure pump housing on left rear side of the front cover.

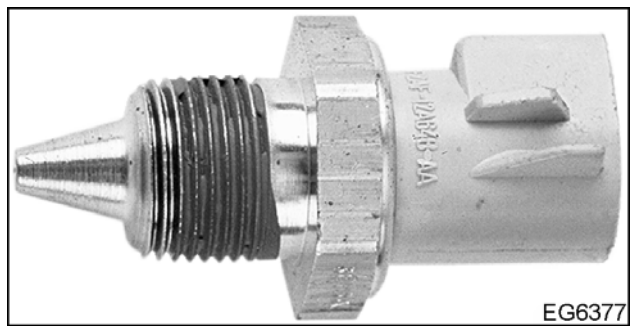

Figure 459 ECT and EOT sensor

Pressure Sensors

Engine Oil Pressure (EOP) Sensor (Front and Rear Mount ECM)

EOP sensor is a variable capacitance sensor that is used to indicate low engine oil pressure via a signal from ECM. EOP sensor is located below fuel filter on the left side of the crankcase.

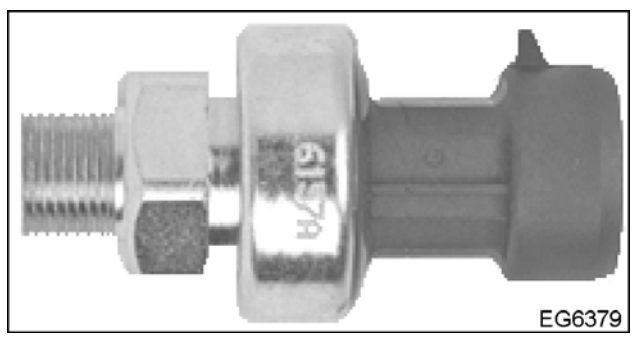

Figure 460 EOP sensor (front mount ECM)

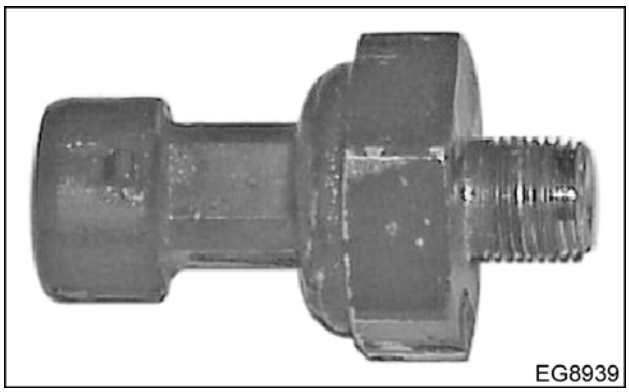

Figure 461 EOP sensor (rear mount ECM)

Injection Control Pressure (ICP) Sensor

The ICP sensor is a variable capacitance sensor that measures injection control and rail pressure. The ICP sensor provides injection control pressure feedback to the ECM for closed loop control of injector oil pressure. The ICP sensor is mounted in the middle of the supply manifold on the left side of the engine .

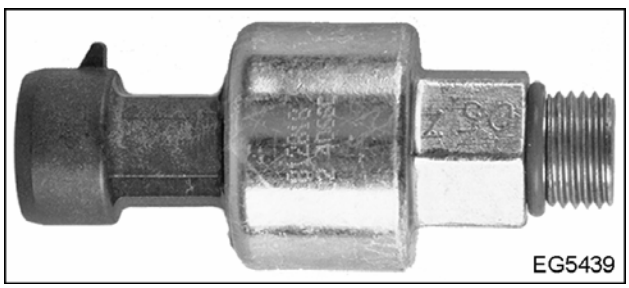

Figure 462 ICP sensor

Manifold Absolute Pressure (MAP) Sensor

The MAP sensor is a variable capacitance sensor that indicates intake manifold (boost) pressure. The MAP sensor is located on the top center of the valve cover intake manifold.

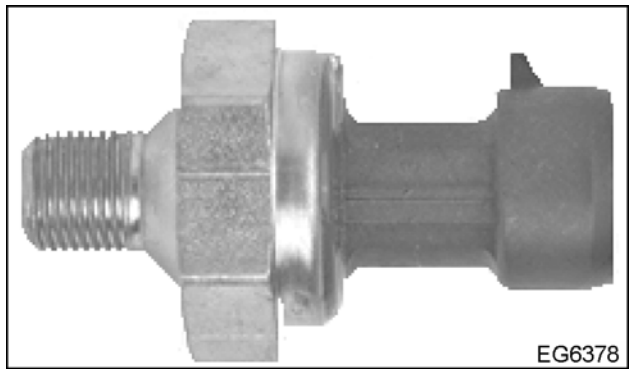

Figure 463 MAP sensor

Injection Pressure Regulator (IPR)

The IPR is a Pulse Width Modulated (PWM) valve that controls injector oil pressure via a signal from the ECM. The IPR is located on the left side of the high-pressure pump. See EGES 175-1 *Diagnostic Manual* for further information.

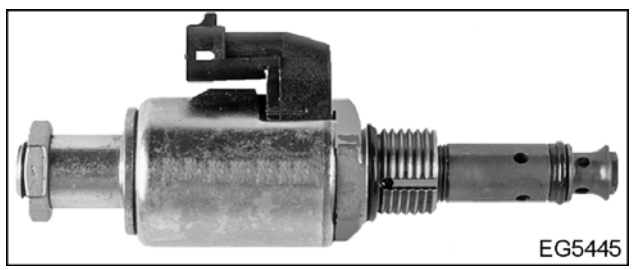

Figure 464 IPR

Remove

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, read all safety instructions in the "Safety Information" section of this manual.

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, make sure the transmission is in neutral or park, parking brake is set, and wheels are blocked before doing diagnostic or service procedures on engine or vehicle.

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, disconnect the main negative battery terminal before removing or installing any electrical components.

CAUTION: To avoid engine damage, make sure the key is in the OFF position before unplugging a connector or relay for the ECM, IDM, and EGR drive module. Failure to turn the key to the OFF position will cause a voltage spike and damage the electrical components.

CAUTION: To avoid engine damage, do not tug on any wiring harnesses while trying to remove them. If resistance is felt, find the source of resistance and free up any connectors or clips that are caught before proceeding.

NOTE: Make sure each connector has its ribbed seal in place before connecting to sensor. In some cases, during disassembly, a ribbed seal may pull out of its connector and remain on the mating socket of a sensor or actuator. A connector assembled without appropriate ribbed seal can become contaminated with moisture and corrode terminals, resulting in poor electrical connection.

NOTE: Removal procedures for the front-mounted or rear-mounted ECMs are identical except where noted.

NOTE: When servicing Diamond Logic® controller, applying an approved dielectric grease to disconnected ECM connectors is encouraged. This will provide a protective, moisture tight seal that ensures ECM connectors will continue to perform effectively.

ECM

1. Disconnect batteries.
2. Remove screws and connector cover shields from ECM connector covers.
3. Remove ECM connector covers from wiring harness connectors.

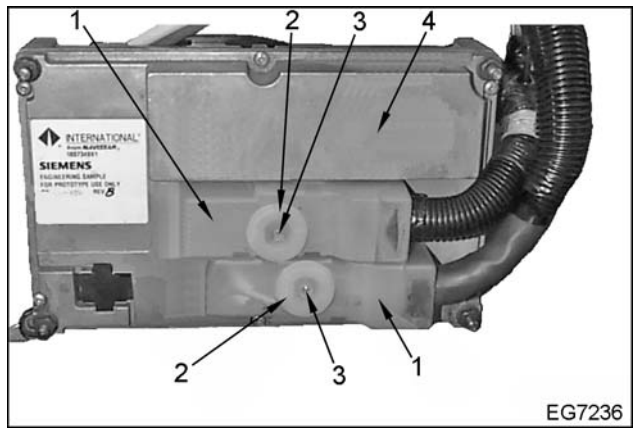

Figure 465 Remove ECM connector covers

1. Connector cover
2. Connector shield
3. Connector shield screw
4. ECM

4. Loosen chassis wiring harness connector mounting bolt and remove wiring harness from ECM.
5. Loosen engine wiring harness connector mounting bolt.

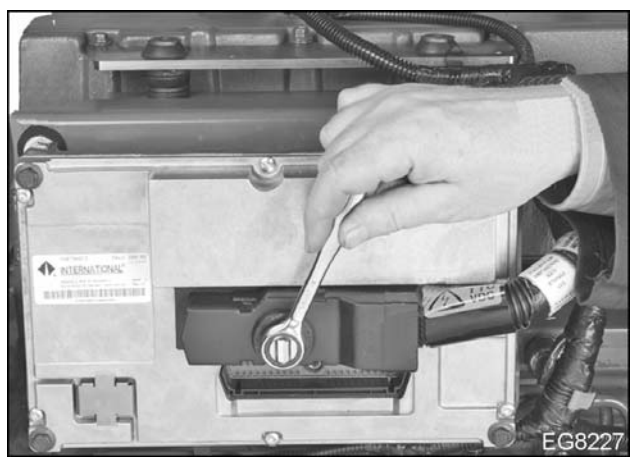

Figure 466 Loosen wiring harness connector (front mount ECM)

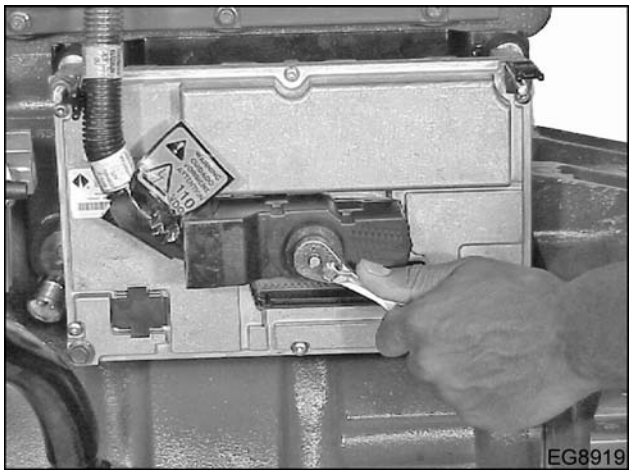

Figure 467 Loosen wiring harness connector (rear mount ECM)

6. Remove engine wiring harness from ECM.

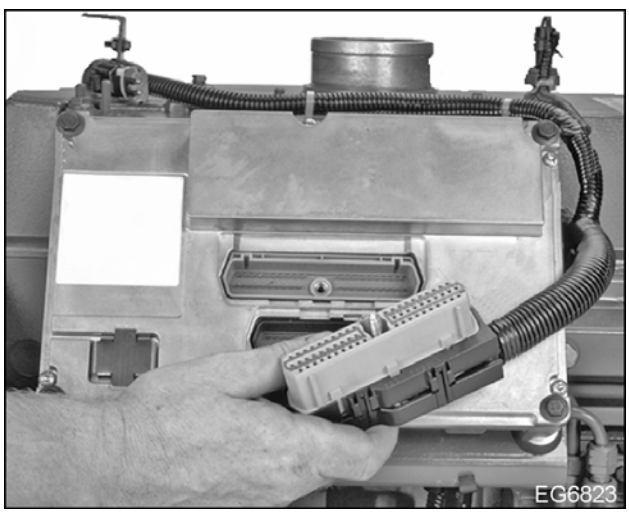

Figure 468 Remove engine wiring harness (front mount ECM)

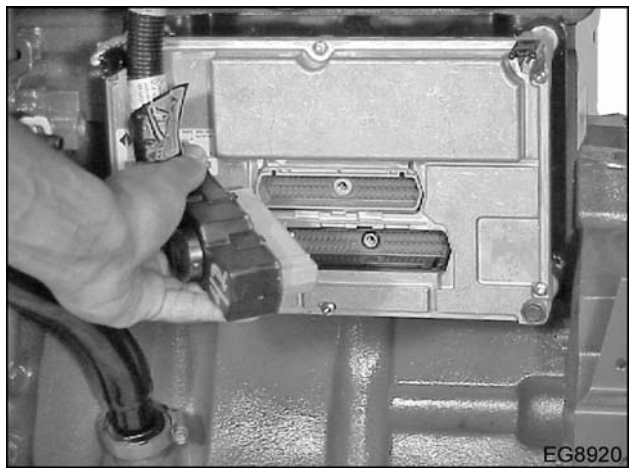

Figure 469 Remove engine wiring harness (rear mount ECM)

NOTE: If ECM does not have to be removed from mounting bracket, proceed to Step 9.

7. If it is necessary to remove ECM from mounting bracket, remove four ECM mounting bolts and lift ECM from bracket.

Figure 470 Remove mounting bolts (front mount ECM)

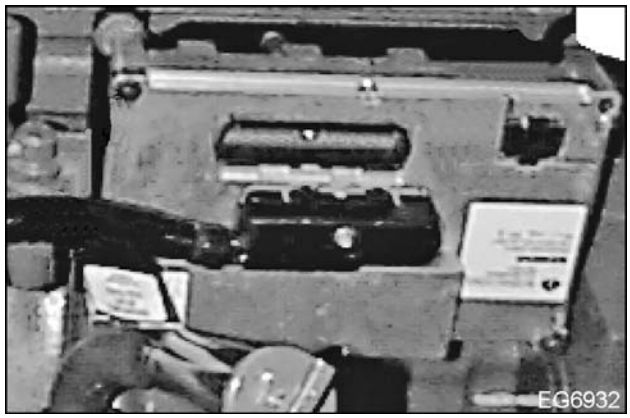

Figure 471 Remove mounting bolts (rear mount ECM)

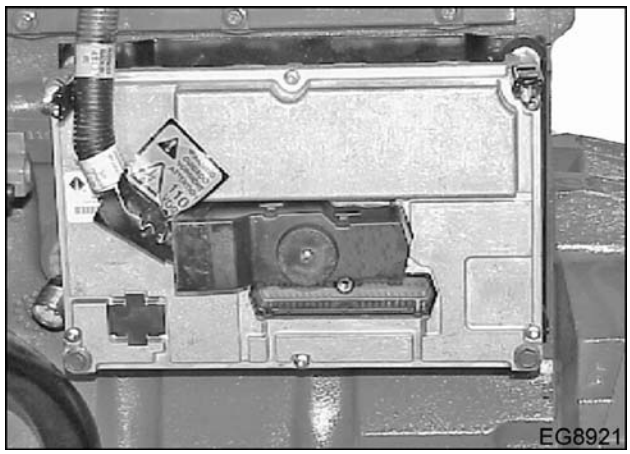

Figure 472 Remove mounting bolts (rear mount ECM)

8. Remove bottom ECM bracket bolts.

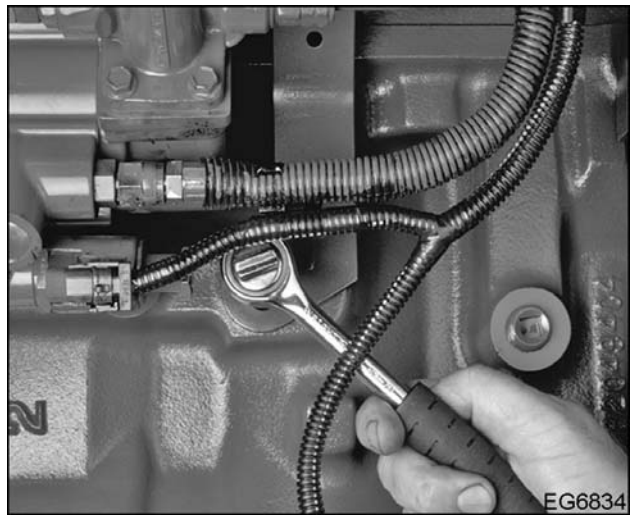

Figure 473 Remove bottom bracket bolts (front mount ECM)

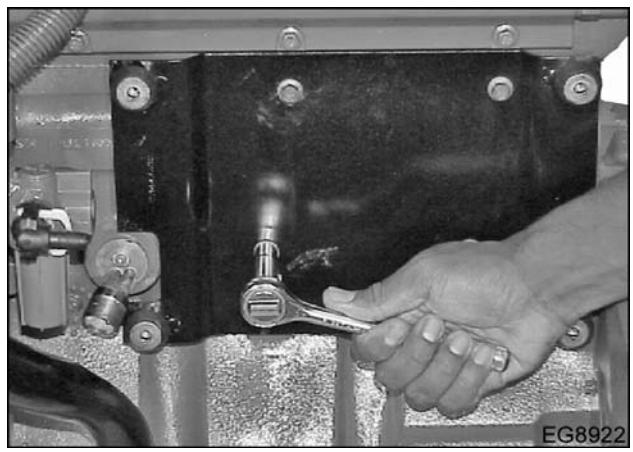

Figure 474 Remove bottom bracket bolts (rear mount ECM)

9. (Front mounted ECM) Remove three ECM mounting bracket top mounting nuts. Lift bracket away from engine.

   (Rear mounted ECM) Remove two ECM mounting bracket top mounting bolts. Lift bracket away from engine.

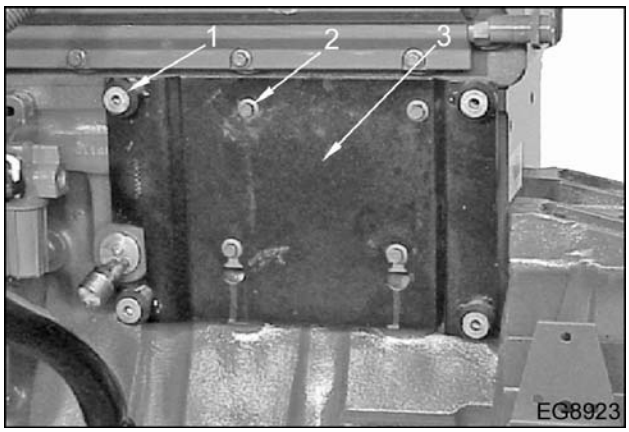

Figure 475 ECM bushings, pins, and bolts (rear mount ECM)

1. Bushing and pin location
2. ECM mounting bracket bolts
3. ECM mounting bracket

10. Remove mounting bracket bushings and pins, If required. See “Inspect and Test” in this section.

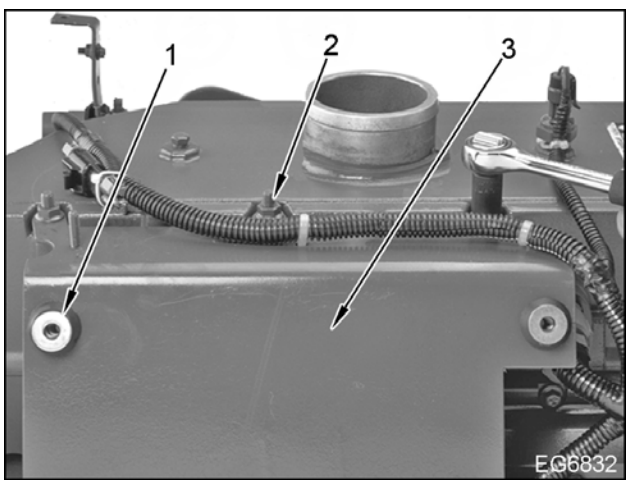

Figure 476 ECM bushings, pins and nuts (front mount ECM)

1. Bushings and pin location
2. ECM mounting bracket nuts
3. ECM mounting bracket

Main Engine Wiring Harness (Engine Mounted ECM)

NOTE: See EGES 175 *Diagnostic Manual* for details on troubleshooting engine electrical system.

NOTE: Remove main wiring harness for front mount or rear mount ECM is identical except where noted.

1. Disconnect batteries.
2. Disconnect and remove ECM. See “ECM” in this section.
3. Pull wiring harness connector out of valve cover fuel injector wiring harness connector.

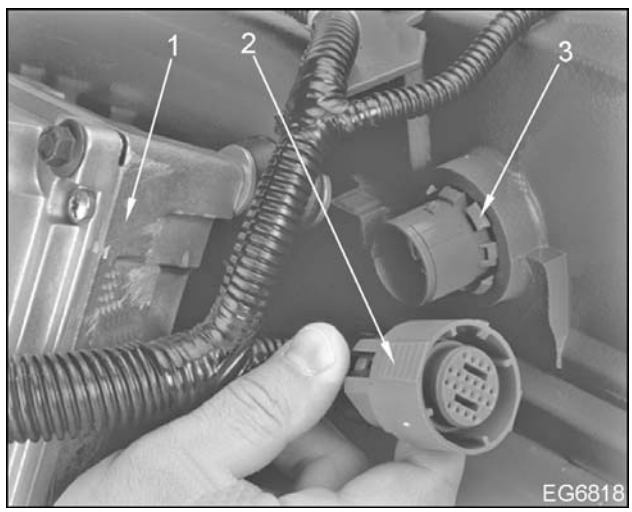

Figure 477 Disconnect main wiring harness

1. ECM (front mount unit)
2. Valve cover and intake manifold connector
3. Valve cover and intake manifold connector tabs

4. Unlatch and separate ICP sensor connector. If necessary, remove sensor from supply manifold.

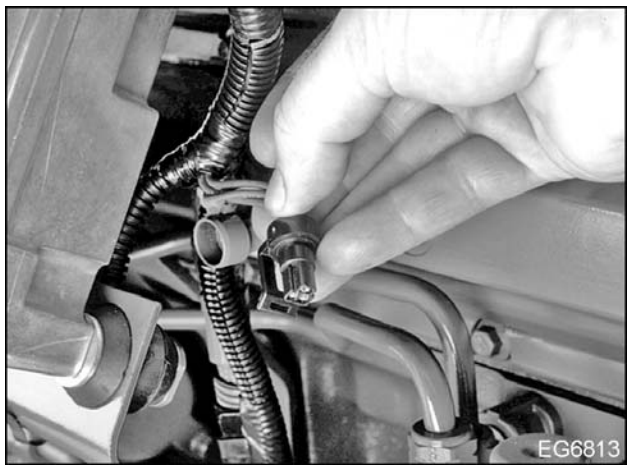

Figure 478 Remove ICP sensor connector

5. Unlatch and separate IPR connector. For proper IPR removal, see “Injection Pressure Regulator (IPR) (page 303)” in the “High-pressure Lube Oil System” section in this manual.

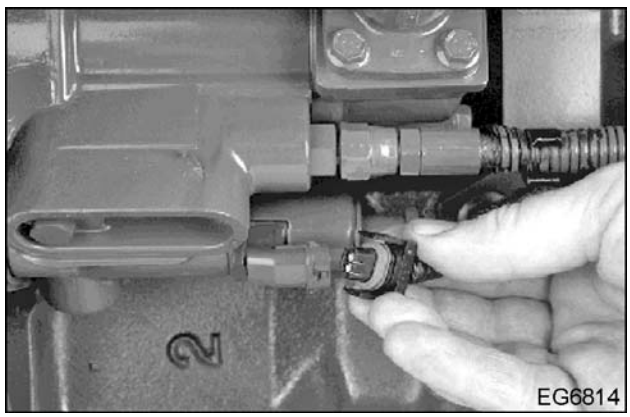

Figure 479 Remove IPR connector

6. Unlatch and separate EOP sensor connector.

Figure 480 Remove EOP connector (front mount ECM)

7. Unlatch and separate MAP sensor connector (located on top of valve cover).
8. Unlatch and separate EOT sensor connector.

NOTE: When EOT sensor is removed from front cover, oil will leak out.

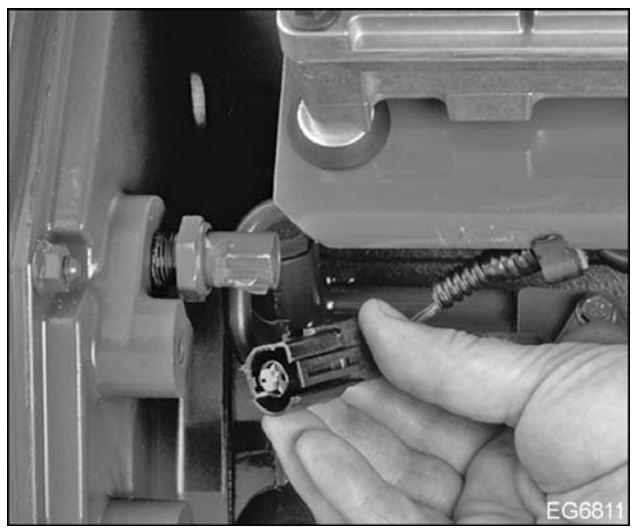

Figure 481 Remove EOT connector

9. Unlatch and separate ECT sensor connector.
10. Unlatch and separate CMP sensor. If necessary, remove mounting bolt and CMP sensor from front cover.

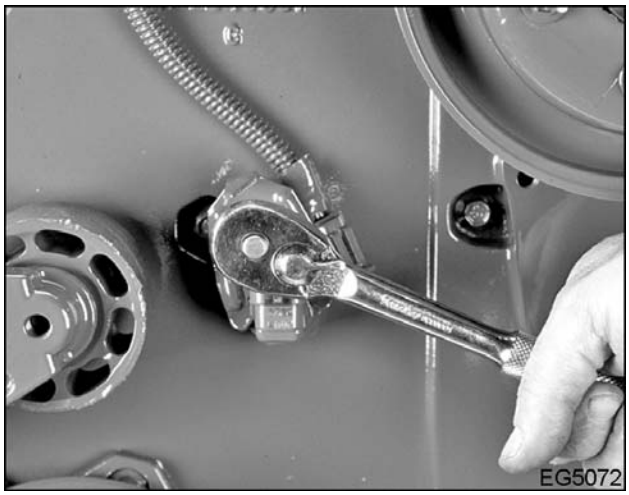

Figure 482 Remove CMP Sensor

11. Remove any wiring harness clamps holding wiring harness to engine.
12. Carefully lift the entire main wiring harness off engine.

CAUTION: To avoid engine damage, if there is any resistance, do not tug on wiring harness to free it. Find source of resistance and free connector or clip, then remove wiring harness from engine.

Inspect and Test

Inspect ECM

1. Inspect ECM mounting bushings and pins for cracks, cuts, and worn areas. Replace as required.
2. Inspect engine wiring harness connectors, connector covers and cover shields for cracks, cuts, or worn areas. Replace as required.

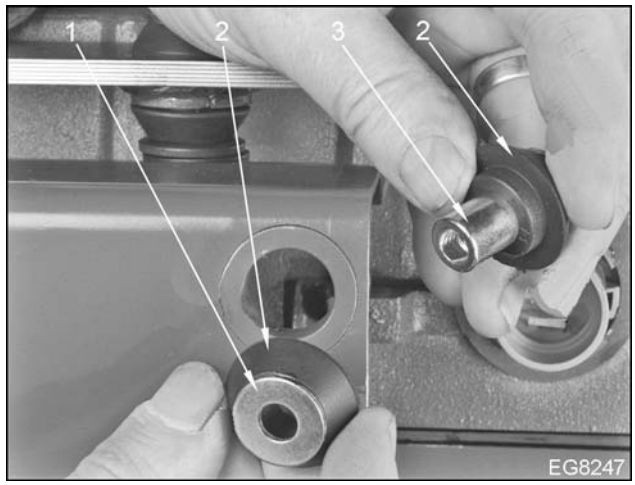

Figure 483 ECM bushing and pin

1. Washer
2. Bushing
3. Pin

Inspect Main Engine Wiring Harness (Engine Mounted ECM)

1. Clean any Loctite® from threads of sensors.
2. Check all connector pins on sensors. If bent or corroded, replace sensor.
3. Carefully inspect wiring harness for worn conduit, frayed insulation, or heat damage on wires. See following repair section if repairs are necessary.
4. Inspect each connector. Replace connectors as required.
   - Corroded connectors - green or gray-white deposits on metal terminals
   - Female connector sleeves spread open
   - Terminals incorrectly latched in connector body or “pushed back” relative to other terminals in same connector

Measure CMP Sensor Clearance

NOTE: Use worksheet to complete CMP sensor air gap analysis to obtain correct CMP sensor clearance.

NOTE: Use proper combination of shims to achieve the desired air gap of 0.635 to 0.762 mm (0.025 to 0.030 in).

Determine CMP Sensor Clearance

1. Rotate crankshaft in clockwise direction (viewed from front) at least two revolutions. Do not turn backwards.

   Install calibrated depth gage tool.

2. Measure distance from CMP sensor mounting surface to trigger wheel tooth.

   NOTE: When making following measurement, measure up to tooth on trigger wheel. Do not measure window between teeth.

3. Rotate crankshaft clockwise (viewed from front) 1/2 turn. Repeat Step 2.

4. Rotate crankshaft clockwise 1/2 turn. Repeat Step 2.

5. Rotate crankshaft clockwise 1/2 turn. Repeat Step 2.

6. Add measurements from Steps 2 through 5. Total of 4 measurements.

7. Obtain average dimension by dividing sum obtained in step 6 by 4.

8. Measure CMP sensor length from tip to surface of mounting flange.

9. Determine CMP air gap, subtract Step 8 from Step 7.

10. Desired air gap: 0.635 to 0.762 mm (0.025 to 0.030 in)

11. Determine CMP air gap interference, subtract Step 10 from Step 9.

12. Select shims as required from shim kit (two 1.5 mm (0.005 in) and two 3.0 mm (0.010 in) shims provided). Use one or more shims from kit to get as close as possible to desired air gap in Step 10. Measure thickness of shim(s).

13. Place shims over CMP sensor tip. Make sure shims are centered on CMP sensor flange. Install CMP sensor and shim assembly in front cover. Tighten clamp bolt to 20 N·m (15 lbf·ft) and connect wiring harness.

CMP Air Gap Analysis Worksheet

Step	Operation	Measurement
2	Record initial measured distance from CMP sensor mounting surface to trigger wheel tooth.	
3	Record measured distance after crankshaft rotation.	
4	Record measured distance after crankshaft rotation.	
5	Record measured distance after crankshaft rotation.	
6 and 7	Record average dimension.	
8	Record CMP sensor length.	
9	Record actual air gap.	
11	Record CMP air gap interference between actual and desired air gap.	
12	Enter measured shim pack thickness.	

Method One

1. Remove CMP sensor mounting bolt from front cover and pull CMP sensor out. Clean sensor mounting surface.

Figure 484 Remove CMP Sensor

2. Note part number on connector end of sensor (underside of sensor). Compare part number to Calibration Chart. Calibrate using Camshaft Sensor Air Gap tool (ZTSE4414) (page 298).

Calibration Chart

C91	1.152 / Red
C92	1.142 / Blue

3. Insert Camshaft Sensor Air Gap tool in calibration cup of selected color. Keep firm downward pressure on tool and zero dial indicator.
4. Tighten lock tab on dial ring. Tool is now calibrated for length of CMP sensor to be installed in engine.

Figure 485 Calibrate Camshaft Sensor Air Gap tool in calibration cup

5. Install Camshaft Sensor Air Gap tool in front cover and tighten clamp screw to 1.13 N·m (10 lbf·in).

6. Rotate engine with starter, or bar engine over by hand, for at least two complete revolutions of crankshaft before observing any readings.
7. Observe needle sweep on dial indicator. Range sweep is an indication of timing wheel runout, should be less than 0.20 mm (0.008 in).

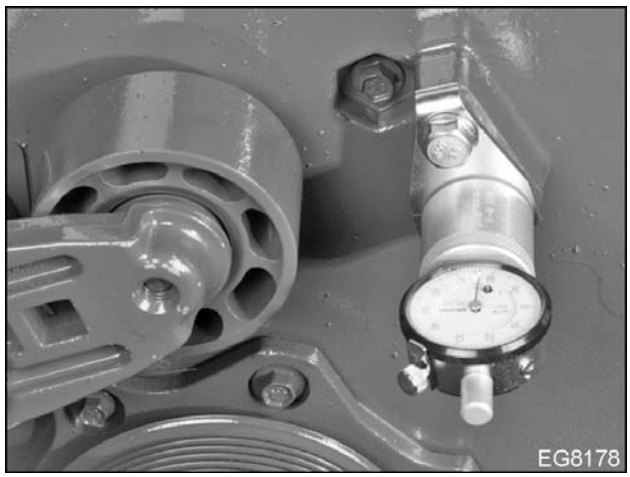

Figure 486 Measure CMP sensor clearance

8. Crank engine long enough to get an average reading on dial indicator. If interference is observed during cranking, CMP sensor may have been damaged and must be replaced.
9. Install CMP sensor with required shims. Make sure that shims are centered on CMP sensor flange. Use a small amount of grease to hold them, if necessary.
10. Connect sensor wiring harness and test engine.

Method Two

1. Carefully measure the CMP sensor from tip to mounting flange with a Depth Micrometer or Precision Caliper (page 298). Record dimension in appropriate box on work sheet.

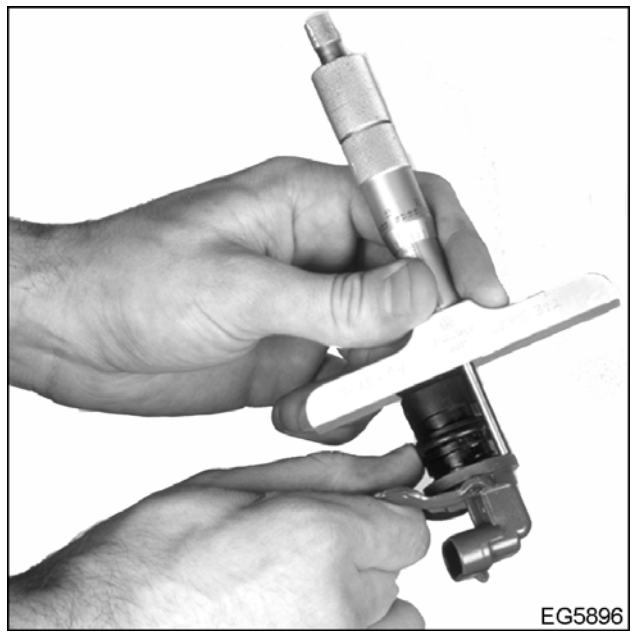

Figure 487 Measure with depth micrometer

2. Perform math as directed on work sheet. Then select appropriate combination of shims from Shim Kit (page 298), if required.
3. Install CMP sensor with required shims. Make sure shims are centered on CMP sensor flange. Use small amount of grease to hold them, if necessary.
4. Connect sensor wiring harness and test engine.

Install

ECM

NOTE: Installation procedures for front-mount and rear-mount ECMs are identical except where noted.

Install ECM and Mounting Bracket as Single Unit

1. Install ECM and mounting bracket on engine. Tighten three top mounting nuts to “Special Torque (page 298).”

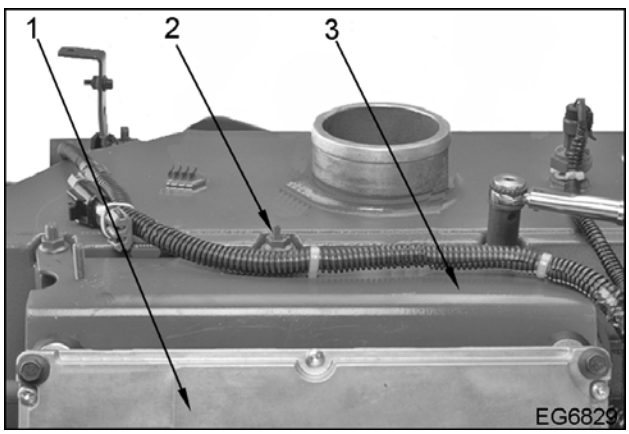

Figure 488 ECM bushings, pins and nuts

1. ECM
2. ECM mounting bracket nuts
3. ECM mounting bracket

2. Install bottom ECM bracket bolt and tighten bracket bolt to “Special Torque (page 298).”

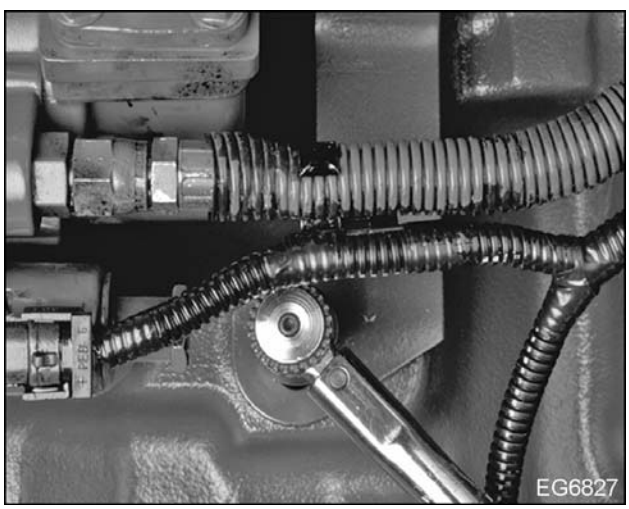

Figure 489 Bottom ECM bracket bolt

Install Mounting Bracket and ECM as Separate Unit

NOTE: Installation procedures for front-mount and rear-mount ECMs are identical except where noted.

1. (Front mount ECM) Install four nut and spacers and eight mounting bushings on mounting bracket.
2. Install mounting bracket on engine. Tighten top three mounting bolts to “Special Torque (page 298).”
3. (Rear mount ECM) Install top bolts for mounting bracket and tighten to “Special Torque (page 298).”

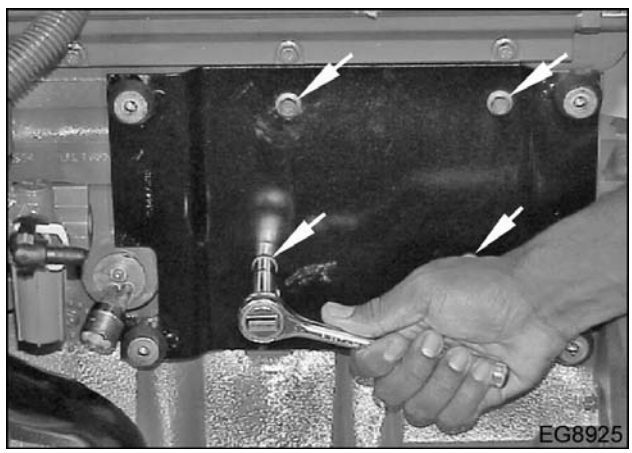

Figure 490 Mounting bracket bolts (rear mount ECM)

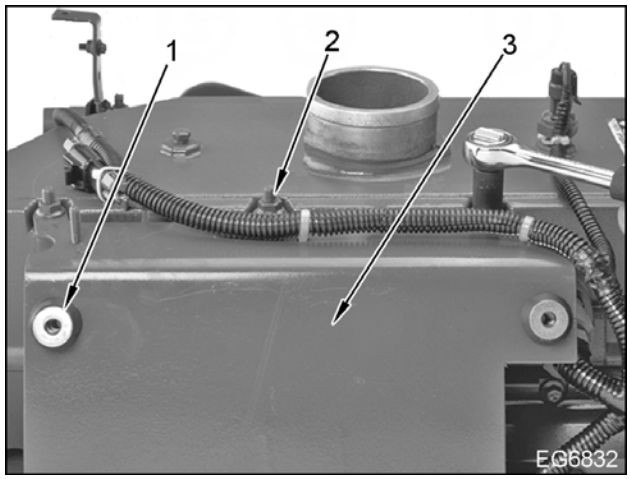

Figure 491 ECM bushings, pins and nuts (front mount ECM)

1. Bushings and pin
2. ECM mounting bracket nuts
3. ECM mounting bracket

4. (Rear mount ECM) Attach “L” shaped brackets and ECM to mounting bracket with two upper bolts.

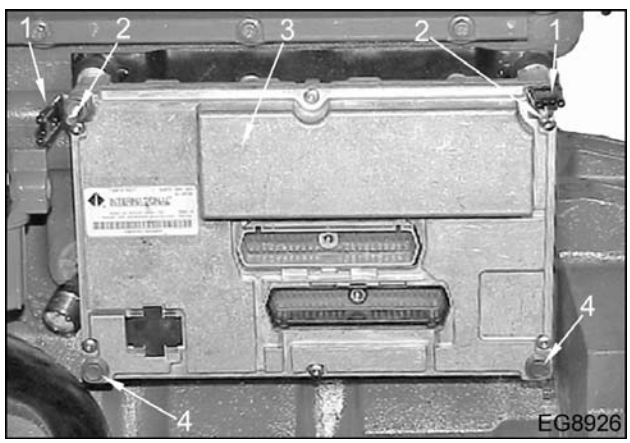

Figure 492 ECM mounting bolts, brackets, and connector (rear mount ECM)

1. “L” shaped brackets
2. Upper mounting bolts
3. ECM
4. Lower bolts

5. (Front mount ECM) Install bottom ECM bracket bolt and tighten to “Special Torque (page 298).”

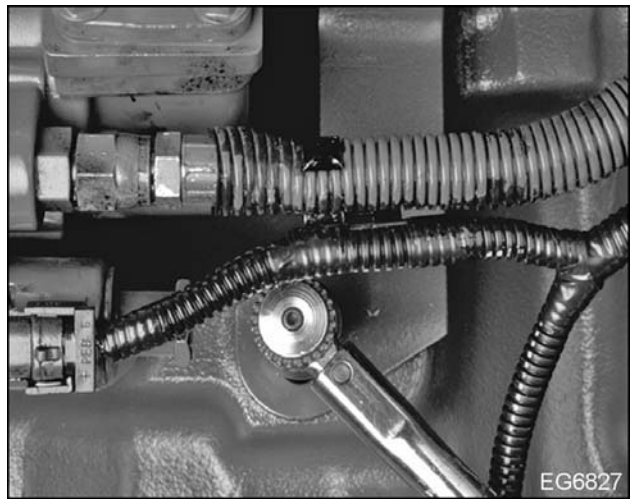

Figure 493 Bottom ECM bracket bolt

6. (Rear mount ECM) Install two lower bolts and tighten to “Special Torque (page 298).”
7. Install ECM on mounting bracket. Tighten four mounting bolts to “Special Torque (page 298).”

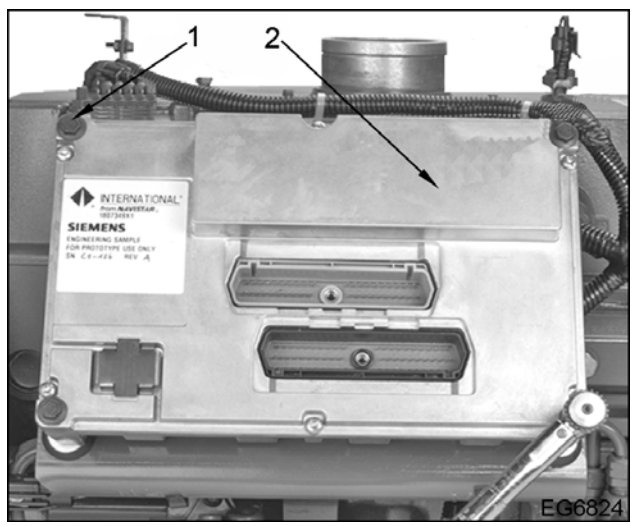

Figure 494 Install ECM (front mount ECM)

1. ECM mounting bolts
2. ECM

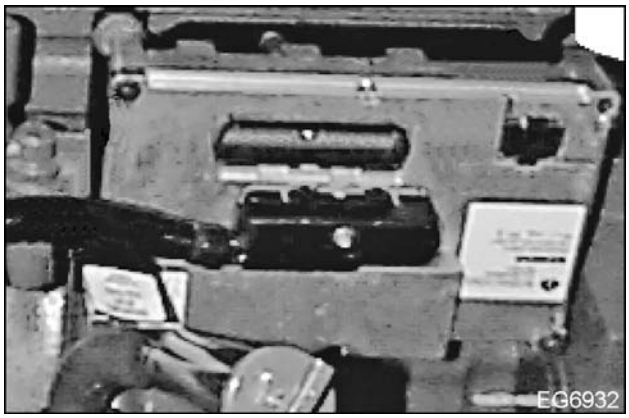

Figure 495 Install ECM (rear mount ECM)

Main Engine Wiring Harness - Engine Mounted ECM

1. Install and connect IPR in high-pressure pump. See “IPR (page 305)” in the “High-pressure Lube Oil System” section in this manual, for proper installation procedure for IPR.

NOTE: Installation of main wiring harness for front-mount or rear-mount ECM is identical except where noted.

2. If removed, install EOP, ECT, MAP and EOT sensors in their proper locations and tighten them.
3. Measure CMP sensor clearance, if required. See “Measure CMP Sensor Clearance” in this section.
4. Place new O-ring on CMP sensor, lubricate O-ring with clean engine oil. Install CMP sensor in front cover with mounting bolt.
5. Tighten CMP sensor mounting bolt to “Special Torque (page 298).”

Figure 496 Install CMP sensor

6. Apply Loctite™ #277 to ICP sensor threads.
7. Install ICP sensor with O-ring in supply manifold. Tighten ICP sensor to “Special Torque (page 298).”
8. Carefully inspect each connector. Make sure each connector has its ribbed seal in place. Replace connectors with ribbed seal missing.

NOTE: Make sure each connector has its ribbed seal in place before connecting to sensor. In some cases, during disassembly, a ribbed seal may pull out of its connector and remain on the mating socket of a sensor or actuator. A connector assembled without appropriate ribbed seal can become contaminated with moisture and terminals may corrode. This can result in poor electrical connections.

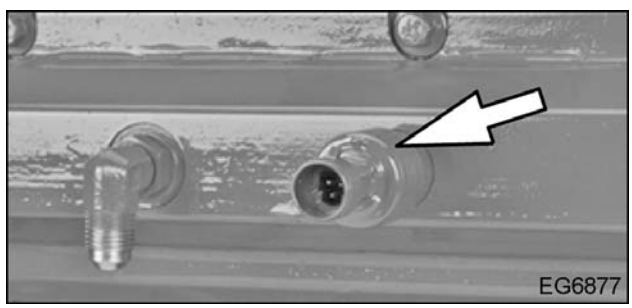

Figure 497 Install ICP sensor in supply manifold

9. Install wiring harness on engine and carefully align connectors to sensors. Push each

connector in its mating socket until locking tabs are fully latched.

NOTE: When servicing Diamond Logic® controller, application of an approved dielectric grease to disconnected ECM connectors is encouraged. This will provide a protective, moisture tight seal that ensures ECM connectors will continue to perform effectively.

10. Apply 9.5 mm (3/8 in) bead of approved dielectric grease to each ECM connector. Begin applying dielectric grease from bolt moving toward the ends of ECM connectors.

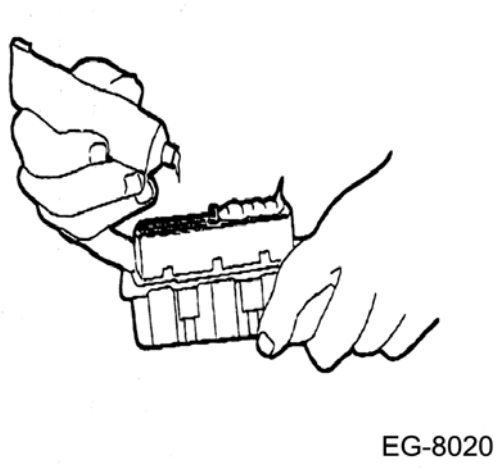

Figure 498 Apply dielectric grease

11. Apply Grease Instruction Label to identify ECM connectors and Diamond Logic® controller has been serviced and sealed with proper grease
12. Connect engine wiring harness to ECM.

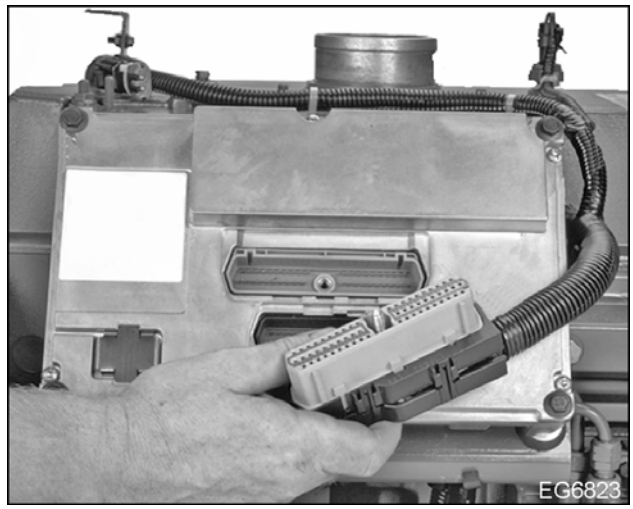

Figure 499 Install engine wiring harness (front mount ECM unit)

13. Tighten retaining screw to “Special Torque (page 298).”

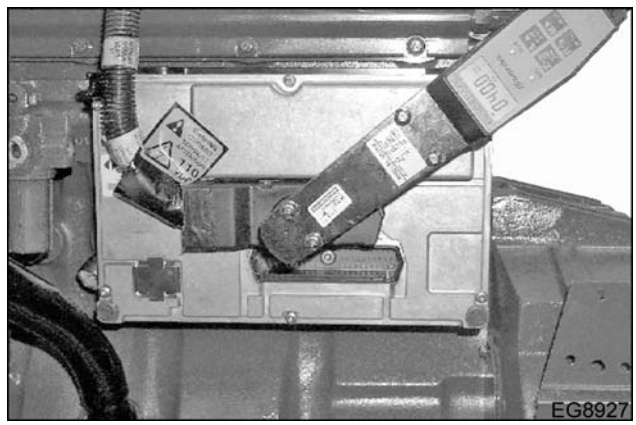

Figure 500 Torque ECM connector cover retaining screws (rear mount ECM)

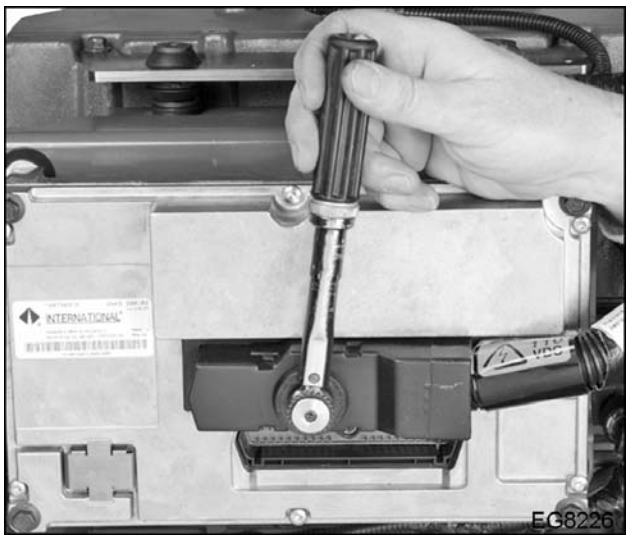

Figure 501 Torque ECM connector cover retaining screws (front mount ECM)

14. Install and connect second wiring harness to ECM. Tighten retaining screw to “Special Torque (page 298).”

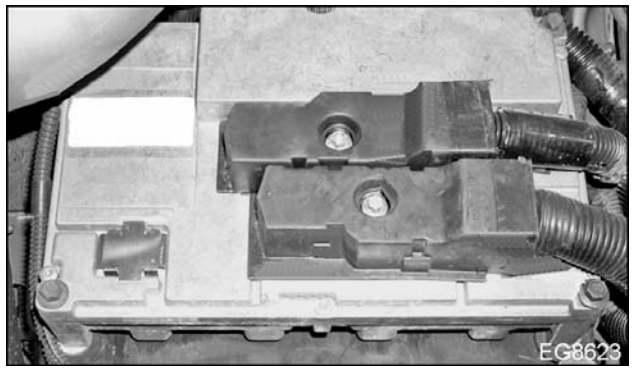

Figure 502 Install ECM Connector Covers (front mount ECM)

15. Install wiring harness routing clips.
16. Connect batteries.

Special Information

Specifications

Camshaft Position Sensor	
Location	Front Cover
Operating Actuator Speed	30 to 4000 rpm
Operating temperature	-40 to 130 °C (-40 to 266 °F)
CMP sensor clearance air gap	0.635 to 0.762 mm (0.025 to 0.030 in)
Depth: Crankshaft rotated clockwise	29.56 ± 0.356 mm (1.164 ± 0.014 in)
Depth: Crankshaft rotated counterclockwise	29.34 ± 0.356 mm (1.155 ± 0.014 in)

Special Torque

Injection Control Pressure Sensor (ICP)[1]	26 N·m (19 lbf·ft)
Injection Pressure Regulator (IPR)	47 N·m (35 lbf·ft)
Injection Control Pressure Valve Tinnerman Nut	6.8 N·m (60 lbf·in)
Engine Oil and Coolant Temperature Sensors	13.6 N·m (10 lbf·ft)
Diamond Logic® System (ECM) Connector Retaining Screw	6 N·m (50 lbf·in)
Diamond Logic® System (ECM) Mounting Hardware (all)	27 N·m (20 lbf·ft)
Camshaft Position (CMP) Sensor Bolt	17 N·m (13 lbf·ft)

[1] Apply Loctite® #277 to threads prior to assembly.

Special Service Tools

Camshaft Sensor Air Gap	ZTSE4414
Depth Gage Micrometer	OEM1013
Depth Micrometer or Precision Caliper	Obtain locally
Shim Kit	Obtain locally

Table of Contents

Components

High-pressure Lube Oil System

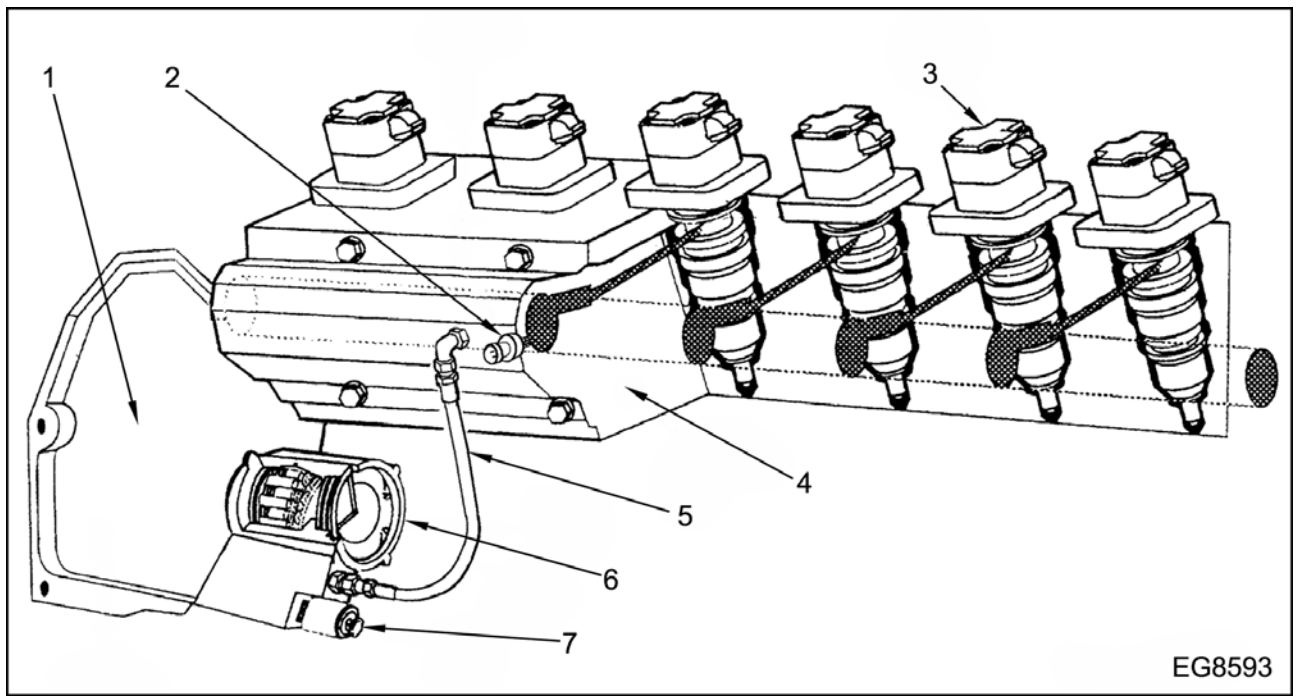

Figure 503 High-pressure lube oil system (with mid-mounted ICP sensor)

1. Oil reservoir
2. Injection Control Pressure (ICP) sensor
3. Fuel injector
4. Supply manifold
5. High-pressure hose
6. High-pressure pump
7. Injection Pressure Regulator (IPR)

Remove

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, read all safety instructions in the "Safety Information" section of this manual.

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, make sure the transmission is in neutral or park, parking brake is set, and wheels are blocked before doing diagnostic or service procedures on engine or vehicle.

CAUTION: To possible avoid engine damage or to prevent leakage to the cylinder bore, the supply manifold oil rail must be drained before removing the fuel injectors. If the drain plug cannot be removed and the fuel injectors must be removed, use a vacuum connected to a 12-inch section of steel tube that is small enough to fit through the injector hole. Syphon the oil out of the power cylinders before removing the fuel injectors. Failure to remove this oil can cause severe damage to the cylinders.

CAUTION: To avoid possible engine damage, bar the engine over two revolutions by hand before using starter to turn over the engine.

Miscellaneous

See the appropriate sections of this publication and remove supporting equipment as required:

Supply manifold end plug

Fuel filter header and supply pump assembly

ICP Sensor

Supply Manifold

1. Remove banjo connection from fuel return valve at rear of supply manifold.

Figure 504 Remove banjo connection

2. Remove fuel return valve from supply manifold.

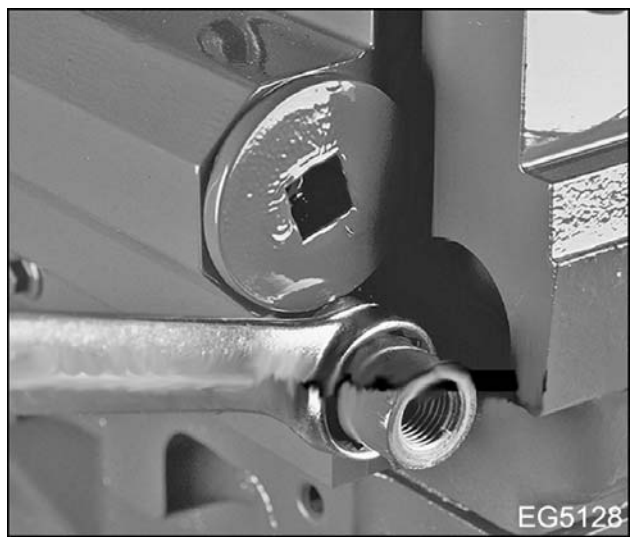

Figure 505 Remove fuel return valve

CAUTION: To avoid possible damage to engine, do not place supply manifold gasket surface down on any surface. Gasket surface could be scratched, preventing a good seal.

3. Remove 12 supply manifold mounting bolts from cylinder head. Remove supply manifold and gasket.

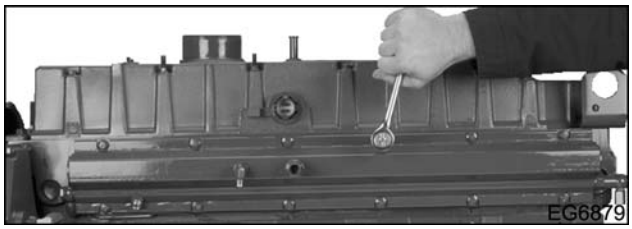

Figure 506 Remove supply manifold bolts

4. Place supply manifold gasket surface up on storage surface, leave gasket on gasket surface to protect surface from damage.

Injection Pressure Regulator (IPR)

NOTE: It is not necessary to remove Injection Pressure Regulator (IPR) from high-pressure pump before removing pump. Solenoid, sleeve, and Tinnerman nut can be removed for easy access to high-pressure pump mounting bolts.

1. Disconnect wiring harness from IPR.

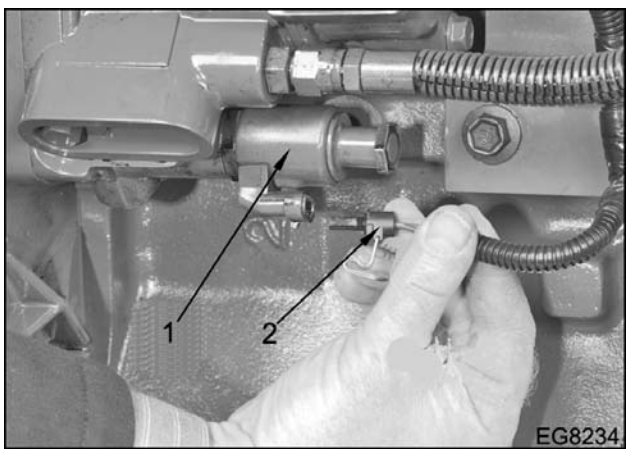

Figure 507 Disconnect IPR wiring harness

1. IPR
2. Wiring harness

2. Remove solenoid Tinnerman nut from IPR.

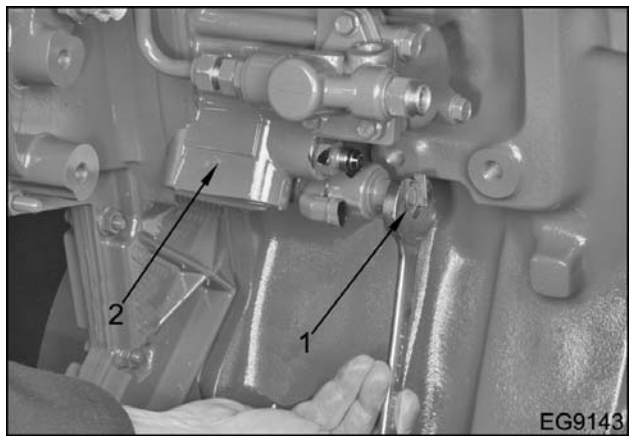

Figure 508 Remove Tinnerman nut

1. Tinnerman nut
2. Pump

3. Remove IPR sleeve and solenoid.

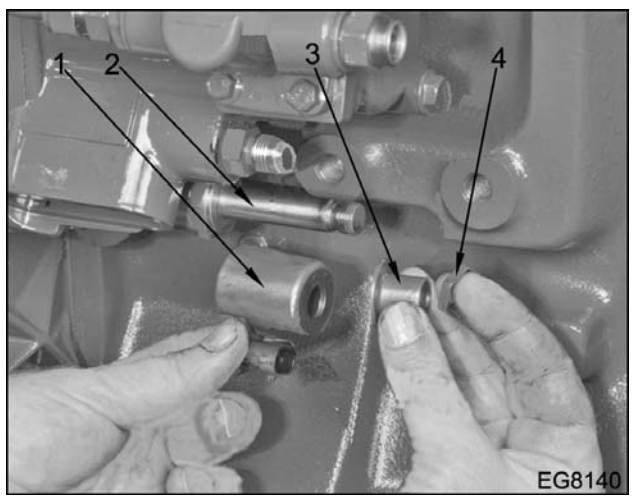

Figure 509 Remove IPR sleeve and solenoid

1. Solenoid
2. IPR
3. Sleeve
4. Tinnerman nut

4. Remove IPR from high-pressure pump. Use 28 mm (1-1/8 in) deep wall socket.

High-pressure Oil Pump

CAUTION: To avoid possible engine damage, make sure high-pressure pump reservoir has been drained of oil before performing this procedure.

1. Remove Engine Oil Temperature (EOT) sensor from rear half of front cover.

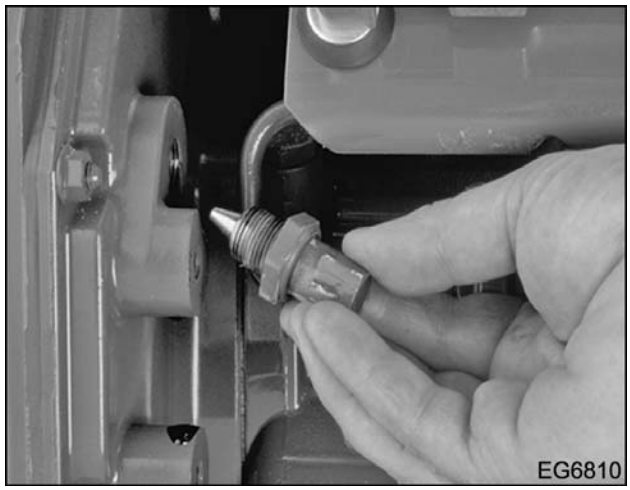

Figure 510 Remove EOT

2. Insert tube from Hand Operated Vacuum Pump (ZTSE2499) (page 307) through the EOT sensor hole. Remove oil from high-pressure pump reservoir. Dispose of oil according to local regulations.

Figure 511 Remove oil

3. Install EOT sensor in rear half of front cover.
4. Disconnect IPR solenoid wiring harness, if not already disconnected.
5. Remove high-pressure oil supply hose, if not already removed.
6. Remove two high-pressure oil pump cap screws from front cover. Remove high-pressure oil pump and gasket from front cover. Discard gasket according to local regulations.

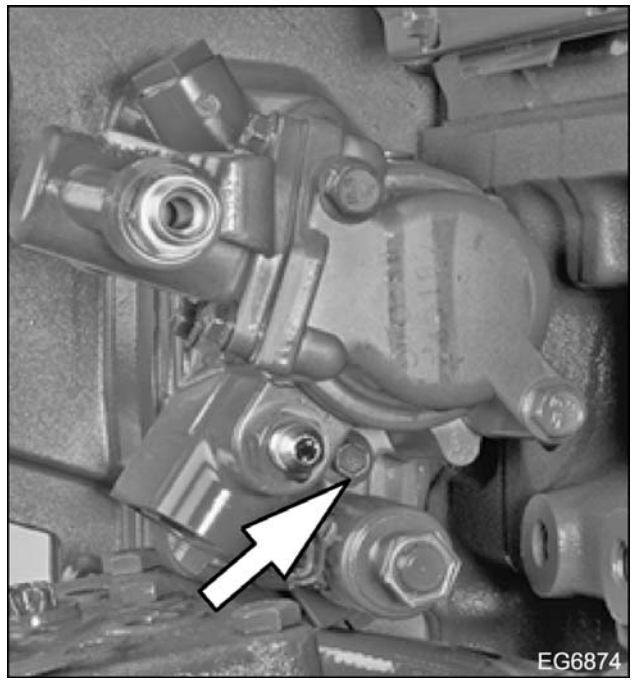

Figure 512 Remove high-pressure oil pump

Clean and Inspect

WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when using compressed air for cleaning to reduce the danger from flying debris. Limit the air pressure to 207 kPa (30 psi).

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

NOTE: Supply manifold seating surface condition must be evaluated. Inspect supply manifold seating surface for warping and cracks.

Supply Manifold

Clean Supply Manifold

1. Clean oil and fuel galleries of supply manifold. Use stiff nylon brush from Cleaning Brush Set (ZTSE4320) (page 307).
2. Use compressed air to clean debris from oil gallery.

Inspect Supply Manifold

1. Inspect supply manifold for cracks. If cracks are found in supply manifold, supply manifold must be replaced.

Measure Supply Manifold

1. Measure supply manifold gasket surface for warping; follow warp pattern. Use Bevelled Edge Straightedge and Feeler Gauge (page 307). See ”Specifications (page 307),” if measurements are not in specification supply manifold must be replaced.

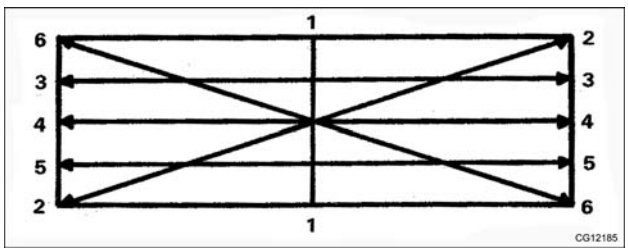

Figure 513 Warp pattern

Install

High-pressure Oil Pump

1. Install new face seal in groove of front cover; install high-pressure pump on face seal.
2. Fasten high-pressure pump to front cover with mounting bolts. Tighten mounting bolts to “Special Torque (page 307).”

IPR

1. If removed, install IPR in high-pressure pump. Tighten IPR to “Special Torque (page 307).”
2. Install IPR sleeve and solenoid on IPR.

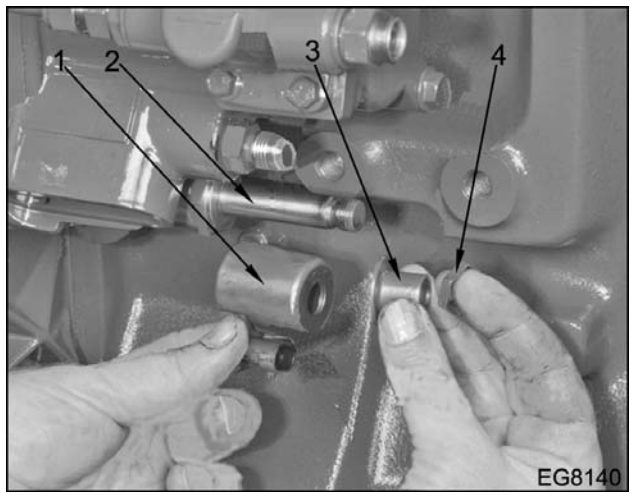

Figure 514 Install IPR sleeve and solenoid

1. Solenoid
2. IPR
3. Sleeve
4. Tinnerman nut

3. Install and tighten Tinnerman nut to “Special Torque (page 307).”

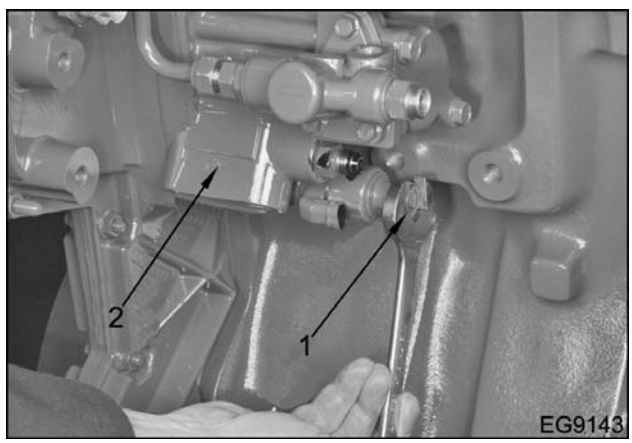

Figure 515 Installing Tinnerman nut

1. Tinnerman nut
2. High-pressure pump

Supply Manifold

CAUTION: To avoid possible damage to engine, do not place supply manifold gasket surface down on any surface. Gasket surface could be scratched, preventing a good seal.

NOTE: Install supply manifold gasket so tab stamped “FRONT” is facing manifold assembly. Tab must be located in lower front corner for correct placement.

1. Place new supply manifold gasket on cylinder head. Use temporary studs to hold gasket in place during assembly. Then remove studs.

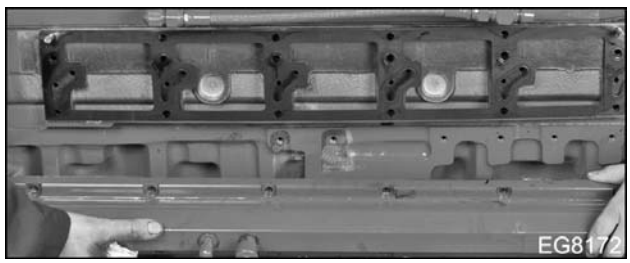

Figure 516 Install supply manifold

2. Install supply manifold with twelve bolts to cylinder head. Tighten bolts from center outward to “Special Torque (page 307).”

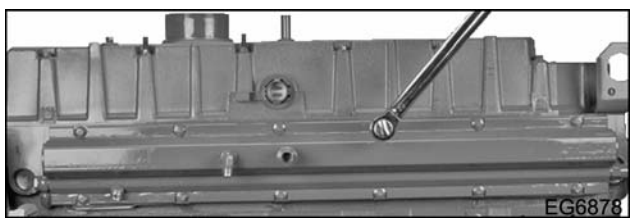

Figure 517 Install supply manifold

3. Install fuel return valve and new copper seals in rear of supply manifold. Tighten fuel return valve to “Special Torque (page 307).”

Figure 518 Install fuel return valve

4. Install banjo fitting on fuel return valve. Tighten banjo fitting to “Special Torque (page 307).”

Figure 519 Torque fuel return banjo fitting

Miscellaneous

See appropriate sections of this publication and install supporting equipment as required:

Supply manifold end plug

Fuel filter header and supply pump assembly

ICP Sensor

Special Information

Specifications

Injection Pressure Regulator	
Operating temperature range	-40 to 125 °C (-40 to 257 °F)
Maximum flow rate	17.5 L/min (4.62 gpm)
Maximum operating pressure	23.5 MPa (3400 psi)
High-pressure Pump Drive Gear	
Gear backlash	0.140 to 0.256 mm (0.0055 to 0.0101 in)
End play	0.45 to 1.22 mm (0.018 to 0.048 in)

Special Torque

High-pressure oil pump gear bolt	129 N·m (95 lbf·ft)
High-pressure oil hose nut	26 N·m (19 lbf·ft)
High-pressure oil pump mounting bolts	27 N·m (20 lbf·ft)
Injection Control Pressure (ICP) sensor[1]	26 N·m (19 lbf·ft)
ICP valve	47 N·m (35 lbf·ft)
IPR valve mounting bolts	28 N·m (20 lbf·ft)
IPR valve Tinnerman nut	6.8 N·m (60 lbf·in)
Supply manifold elbow fitting	26 N·m (19 lbf·ft)
Supply manifold end plug	81 N·m (60 lbf·ft)
Supply manifold mounting bolts	27 N·m (20 lbf·ft)
Fuel return valve assembly	35 N·m (26 lbf·ft)
Fuel return valve banjo fitting	35 N·m (26 lbf·ft)
Banjo fuel line connections	35 N·m (26 lbf·ft)

[1] Apply Loctite® #277 to sensor threads before installation.

Special Service Tools

Bevelled Edge Straightedge	OEM1293
Cleaning Brush Set (4)	ZTSE4320
Feeler Gauge	Obtain locally
Hand Operated Vacuum Pump	ZTSE2499
High-Pressure Oil System Cap Set	ZTSE4295

Table of Contents

General Description

Component Location

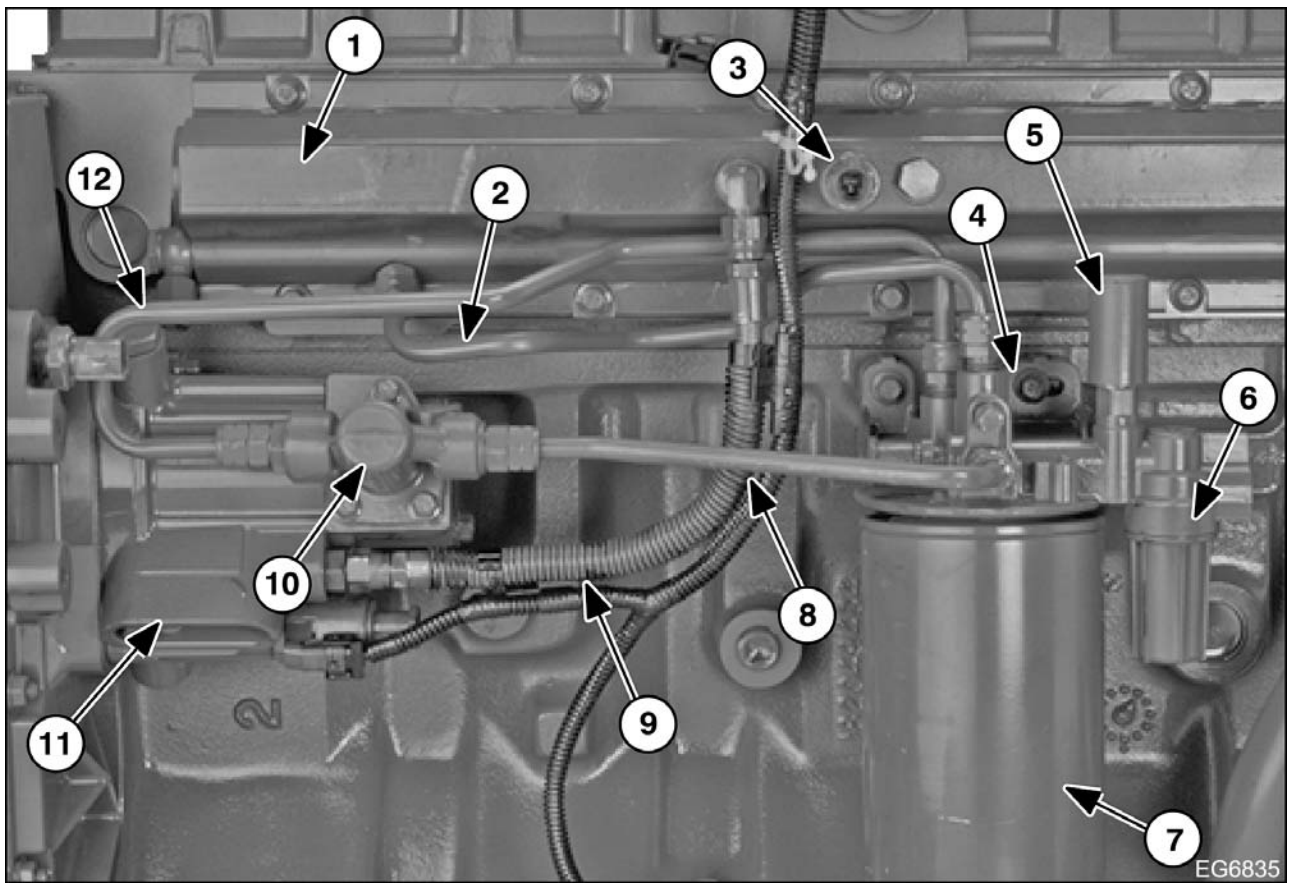

Figure 520 Fuel system

1. Supply manifold
2. Fuel filter header-to-supply manifold line
3. Injection Control Pressure (ICP) sensor
4. Fuel filter header
5. Hand primer pump
6. Fuel filter strainer
7. Fuel filter
8. Fuel filter header-to-supply pump line
9. High-pressure pump-to-supply manifold hose
10. Supply pump
11. High-pressure pump
12. Supply pump-to-fuel filter line

Component Locations (International® High Performance 4000 Series Trucks)

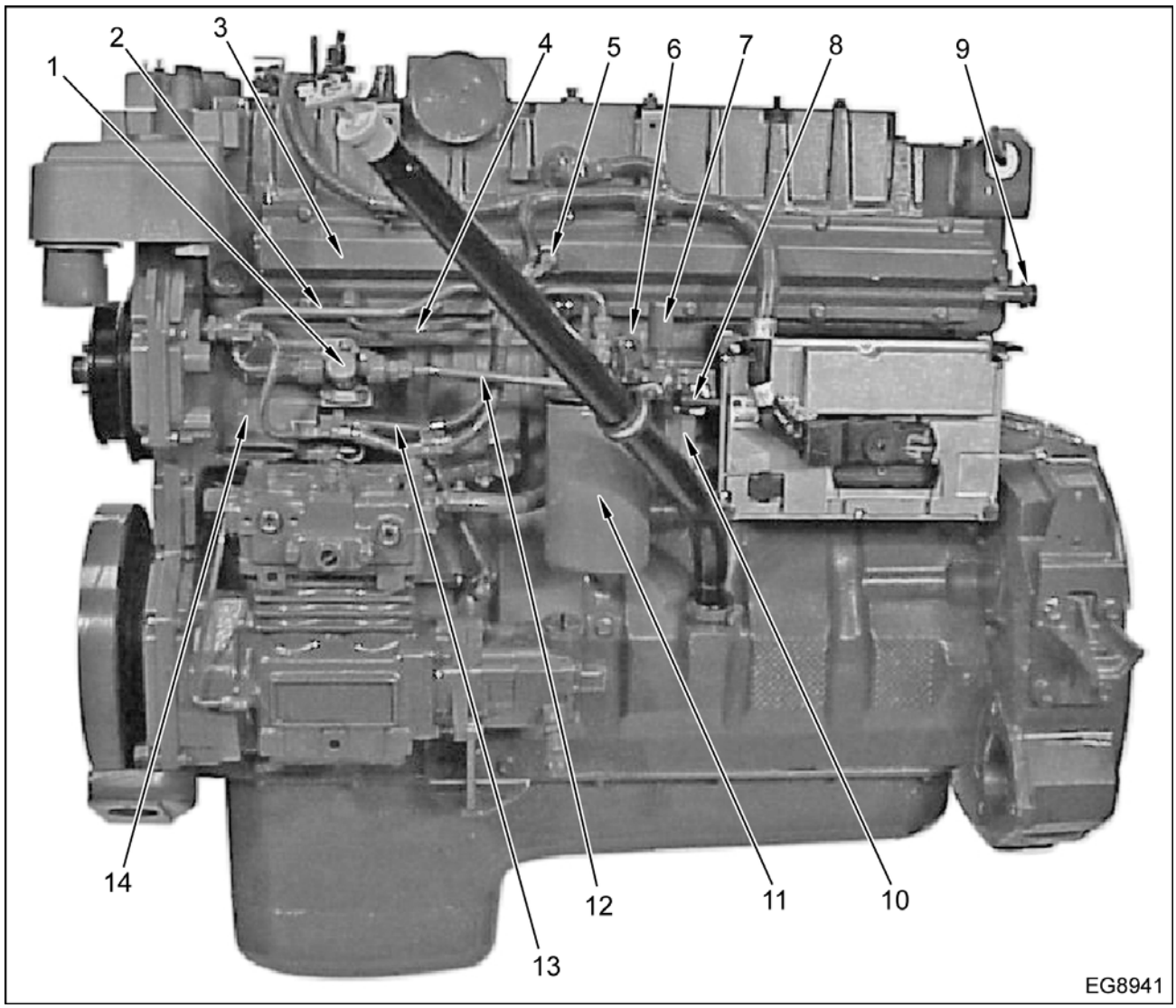

Figure 521 Fuel system (rear mount ECM)

1. Supply pump
2. Supply pump-to-fuel filter line
3. High pressure oil and fuel supply manifold
4. Fuel filter header-to-supply manifold line
5. Injection Control Pressure (ICP) sensor
6. Hand primer pump
7. Fuel filter header
8. Quick disconnect fuel inlet
9. Quick disconnect fuel return
10. Fuel filter strainer
11. Fuel filter
12. Fuel filter header-to-supply pump line
13. High-pressure pump-to-supply manifold hose
14. High-pressure pump

Remove

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, read all safety instructions in the "Safety Information" section of this manual.

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, make sure the transmission is in neutral or park, parking brake is set, and wheels are blocked before doing diagnostic or service procedures on engine or vehicle.

Fuel Filter and Fuel Strainer

1. Remove plastic strainer cover from filter strainer assembly. Use 29 mm (1-1/8 in) socket.
2. Remove fuel strainer.

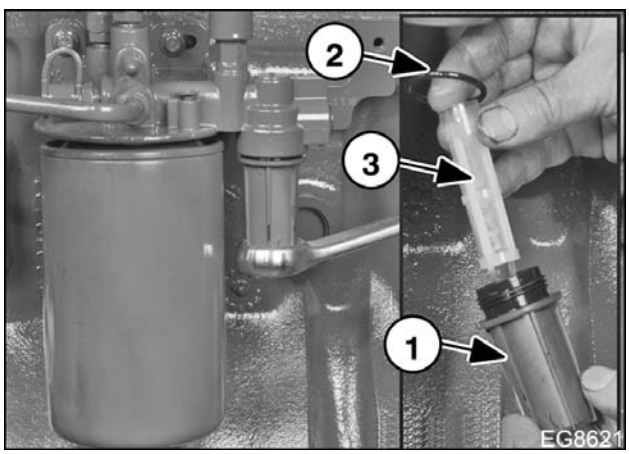

Figure 522 Remove fuel strainer

1. Strainer Cover
2. O-ring
3. Strainer

3. Clean and inspect fuel strainer. Replace fuel strainer as required, dispose of fuel strainer according to local regulations.
4. Remove fuel filter from fuel filter header. Use an appropriate filter wrench. Discard fuel filter according to local regulations.

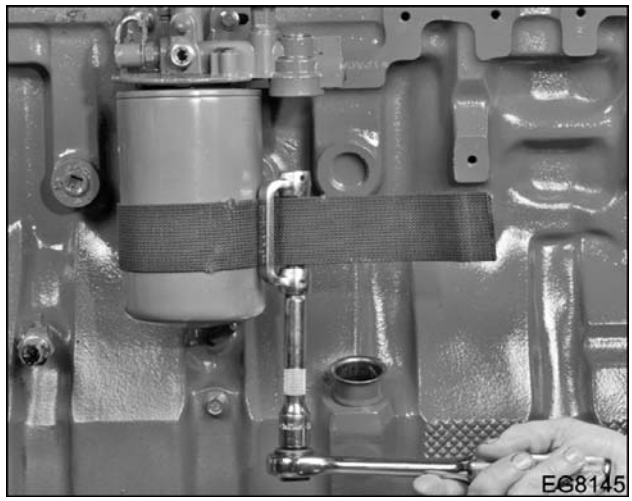

Figure 523 Remove fuel filter

5. Install fuel filter strainer with open end toward fuel filter header. Install plastic strainer cover on fuel filter header. See "Install" in this section.

Fuel Supply Header

1. Place rag or suitable container under supply pump inlet fuel line fitting.
2. Loosen supply pump inlet fuel line fitting; drain line. Disconnect and remove fuel filter header-to-supply pump line. Dispose of rags, containers, and engine fluids according to local regulations.

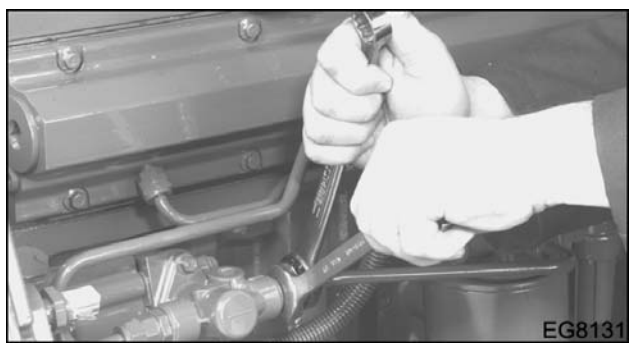

Figure 524 Disconnect fuel supply line

3. Cover fuel header openings. Use Fuel System Cap Set (ZTSE4294) (page 318).
4. Place rag or suitable container under final fuel filter inlet line.

5. Loosen fitting on final fuel filter inlet line; drain line. Remove final fuel filter inlet line. Dispose of rags, containers, and engine fluids according to local regulations.

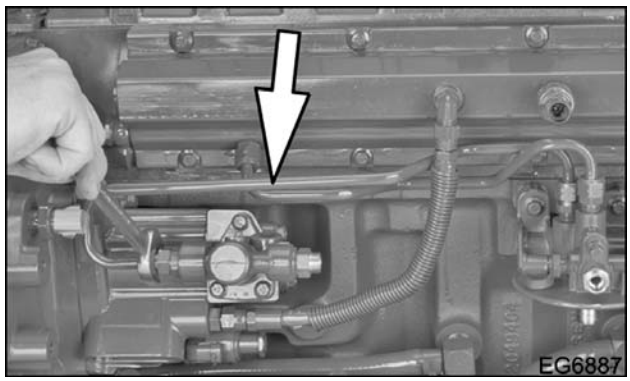

Figure 525 Remove final fuel filter

6. Cover fuel header openings. Use Fuel System Cap Set (ZTSE4294) (page 318).
7. Place rag or suitable container under fuel filter header-to-supply manifold.
8. Loosen fitting on fuel supply line from fuel filter header-to-supply manifold; drain line. Remove fuel filter header-to-supply pump line. Dispose of rags, containers, and engine fluids according to local regulations.

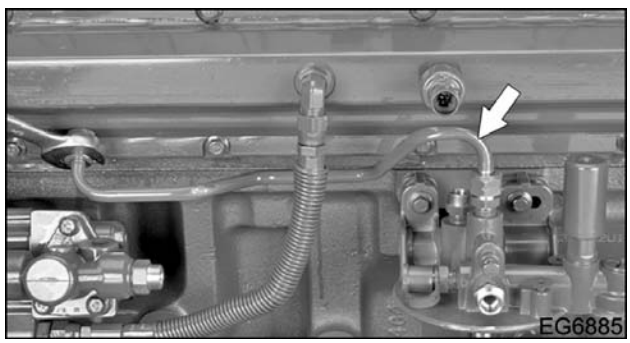

Figure 526 Remove fuel supply line

9. Cover additional fuel header openings. Use Fuel System Cap Set (ZTSE4294) (page 318).
10. Remove two fuel filter header (hand primer pump) mounting bolts from crankcase. Remove hand primer pump.

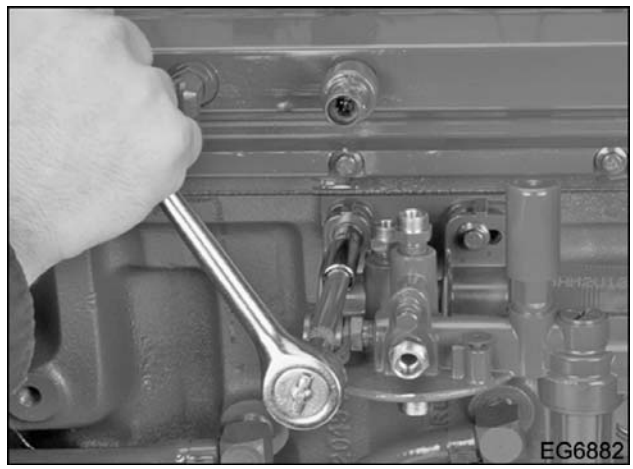

Figure 527 Remove hand primer pump

11. Loosen three supply pump bolts from high-pressure pump. Remove supply pump.

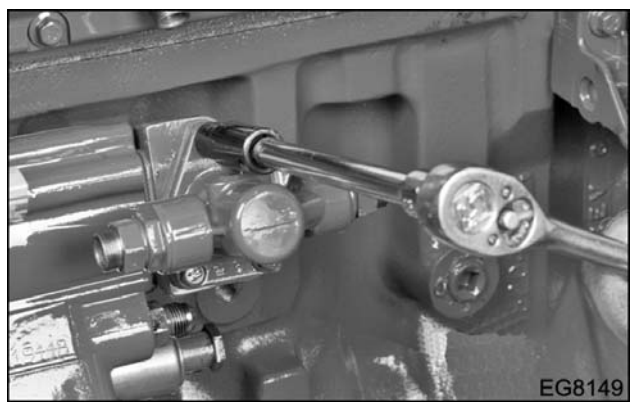

Figure 528 Remove supply pump

12. Remove fuel supply manifold, as required. See “Supply Manifold (page 302)” in the “High-pressure Lube Oil System” section in this manual.

Clean and Inspect

Fuel Supply Pump Tappet (Engines Equipped with Front Mount Hand Primer Pump)

1. Clean fuel supply pump tappet.

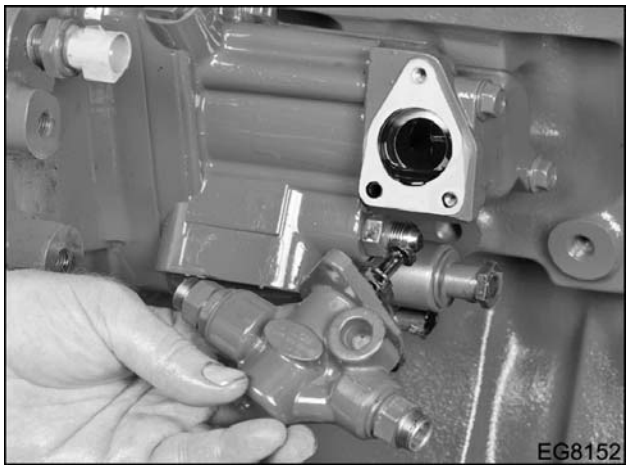

Figure 529 Fuel supply pump tappet

2. Inspect fuel supply pump tappet for straightness, burrs, and cracks.

Install

Fuel Supply Header

1. Install the fuel supply manifold (if removed). See “Supply Manifold (page 306)” in the “High-pressure Lube Oil System” section in this manual.
2. Install supply pump on high-pressure pump housing with three bolts. Tighten bolts to “Standard Torque (page 343).”

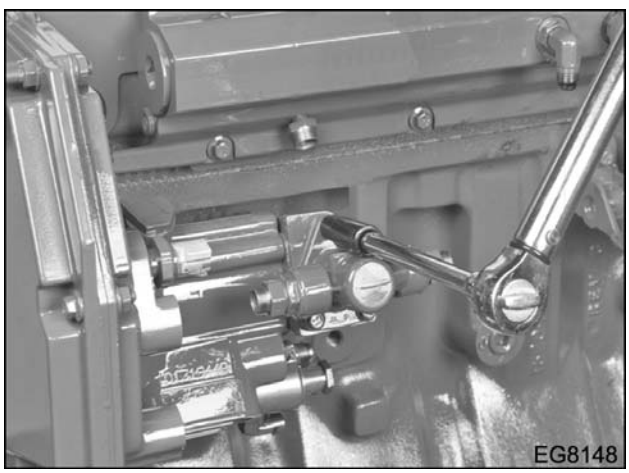

Figure 530 Install supply pump

3. Install fuel filter header on crankcase mounting pad using two mounting bolts and washers. Tighten mounting bolts to “Standard Torque (page 343).”
4. Remove nylon cap on top of fuel strainer. Verify priming pump check ball is in place.

   NOTE: If the check ball is not in place, the priming pump will not work.

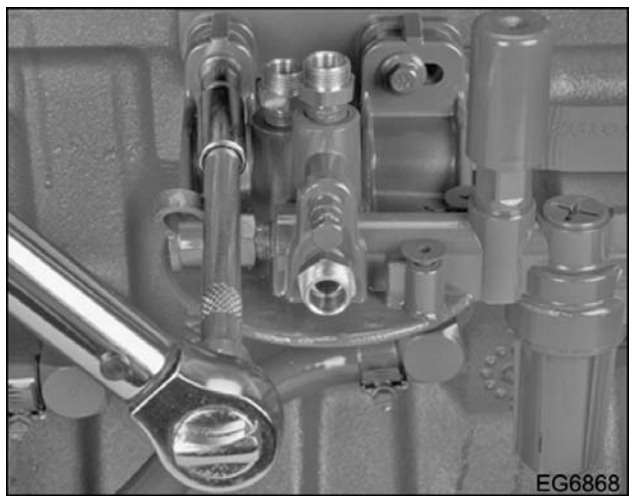

Figure 531 Install filter header

5. Remove protective caps from fuel supply pump and fuel filter header inlet ports.
6. (For fuel lines with banjo connections) Install supply pump return to fuel filter header return line with banjo connections and new copper sealing gaskets. Tighten banjo connections to “Special Torque (page 318).”
7. (For threaded fitting fuel line) Install supply pump return to fuel filter header return line fittings on supply pump and fuel filter header. Tighten fittings.

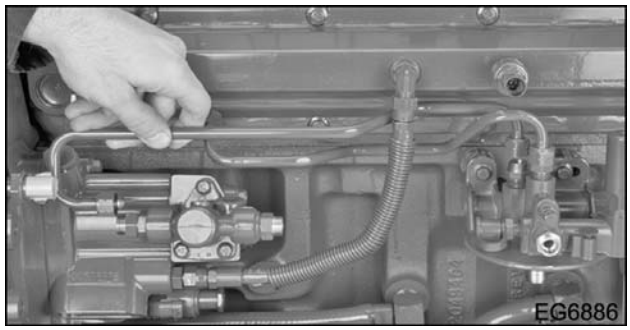

Figure 532 Install supply pump return

8. (For fuel lines with banjo connections) Install fuel filter header-to-supply manifold fuel line with banjo connections and new copper sealing gaskets. Tighten to “Special Torque (page 318).”
9. (For threaded fitting fuel line) Install fuel filter header-to-supply manifold fuel line fittings on supply pump and fuel filter header. Tighten fittings.

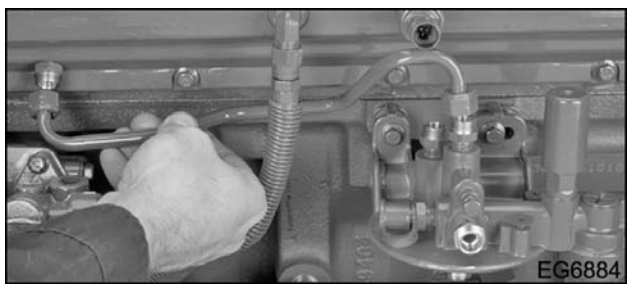

Figure 533 Install fuel filter header

10. (For fuel lines with banjo connections) Install fuel filter header to supply pump line with banjo connections and new copper sealing gaskets. Tighten to “Special Torque (page 318).”
11. (For threaded fitting fuel line) Install fuel filter header fittings supply pump and fuel filter header. Tighten fittings.

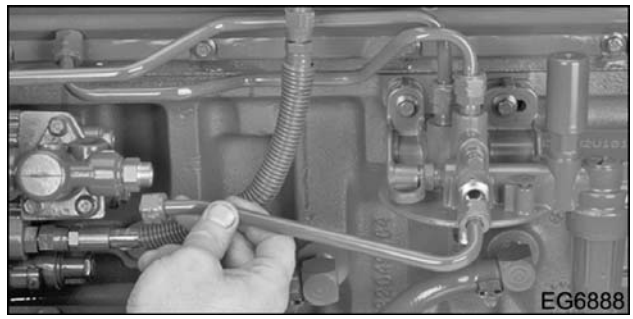

Figure 534 Install fuel filter line

Fuel Strainer and Fuel Filter

1. Lubricate and install new O-ring in strainer cover. Lubricate threads of strainer cover.
2. Install strainer in strainer cover. Make sure open end of strainer is toward filter header. Install strainer cover in fuel filter header. Hand tighten strainer cover.

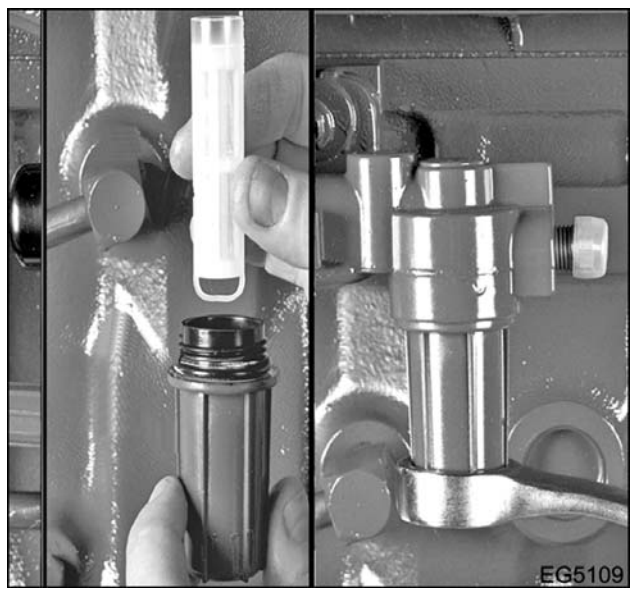

Figure 535 Install fuel filter strainer

3. Lubricate new filter gasket with clean diesel fuel.

NOTE: Do not add fuel to the new filter.

Figure 536 Install fuel filter

4. Install fuel filter; tighten filter by hand until gasket touches filter header. Tighten filter an additional 1/2 turn.

Prime Fuel System

After replacing fuel system components or fuel supply lines, fuel system must be primed.

1. Place rag or suitable container under bleed screw in fuel filter header.
2. Loosen bleed screw in fuel filter header.
3. Operate priming pump until pump discharges solid fuel at bleed screw. Tighten bleed screw. Dispose of rags, containers, and engine fluids according to local regulations.

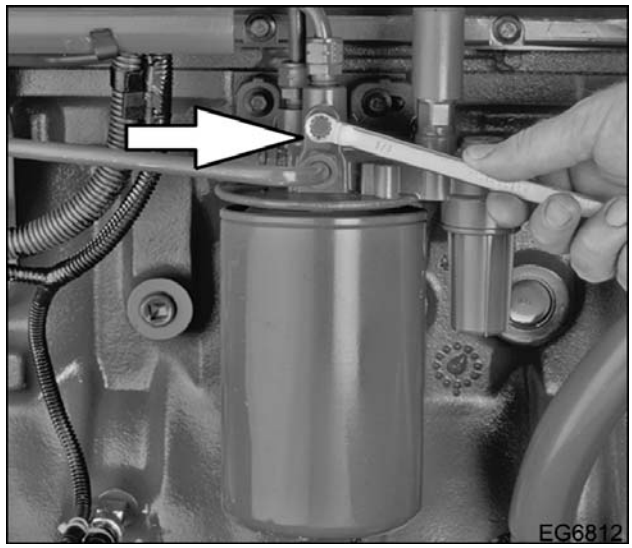

Figure 537 Loosen bleed screw

NOTE: Do not crank engine for more than 15 seconds.

4. Crank engine for 15 seconds or until engine starts.
5. Operate engine until it runs smoothly.

Special Information

Specifications

Pressure fuel return valve unseats	414 kPa (60 psi)
Fuel filter type	Spin-On Cartridge

Special Torque

Banjo fuel line connections	35 N·m (26 lbf·ft)
Fuel filter header mounting bolt	18 N·m (13 lbf·ft)
Fuel return valve assembly	35 N·m (26 lbf·ft)

Special Service Tools

Fuel System Cap Set	ZTSE4294

Table of Contents

Terminology

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

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

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

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

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

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

Analog – A continuously variable voltage.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Diesel fuel with a high cetane number self ignites shortly after injection into the combustion chamber. Therefore, it has a short ignition delay time. Diesel fuel with a low cetane number resists self ignition. 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 associated software.

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 Take Off (PTO), and remote hand throttle system.

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

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

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

Substrate – Material that supports the washcoating or catalytic materials.

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

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

Tachometer output signal – Engine speed signal for remote tachometers.

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

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

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

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

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

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

Variable capacitance sensor – A variable capacitance sensor 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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Mounting Engine on Stand

No specifications required for this section.

Turbochargers

Turbine shaft axial end play	0.02 to 0.10 mm (0.001 to 0.004 in)
Turbine shaft radial movement (play)	0.08 to 0.15 mm (0.003 to 0.006 in)
Wastegate actuator movement	0.37 mm at 196 kPa (0.015 in at 29 psi)
EVRT®	
Turbine shaft axial end play	0.05 to 0.13 mm (0.002 to 0.005 in)
Turbine shaft radial movement (play)	0.52 to 0.74 mm (0.020 to 0.029 in)
EVRT® axial linkage shaft	Must strike open and closed stops in actuator, 90° rotation

Manifolds

Maximum allowable warping (intake manifold)	0.254 mm (0.010 in)
Maximum allowable warping (exhaust manifold)	0.254 mm (0.010 in)
Maximum allowable removal of material	0.635 mm (0.025 in)
Minimum flange thickness	18.41 mm (0.725 in)

Cylinder Head and Valves

Exhaust Valves	
Stem Diameter	9.452 - 9.461 mm (0.37215 - 0.37250 in)
Stem to guide clearance (maximum allowable before replacement)	0.15 mm (0.006 in)
Face to stem runout (Total Indicated Runout (TIR) maximum)	0.038 mm (0.0015 in)
Valve face angle	45°
Valve face margin (minimum)	1.14 mm (0.045 in)
Valve lash	0.64 mm (0.025 in)
Intake Valves	
Stem diameter	9.452-9.461 mm (0.37215-0.37250 in)
Stem to guide clearance (maximum allowable before replacement)	0.15 mm (0.006 in)
Face to stem runout (TIR maximum)	0.038 mm (0.0015 in)
Valve face angle	30°
Valve face margin (minimum)	2.24 mm (0.088 in)

Valve Lash	0.64 mm (0.025 in)
Cylinder Head	
Valve guide length (overall)	66.294 ± .508 mm (2.61 ± 0.02 in)
Valve guide bore diameter in cylinder head for valve guide insert	15.844 - 15.880 mm (0.6238 - 0.6252 in)
Service valve guide outside diameter	15.898 - 15.918 mm (0.6259 - 0.6267 in)
Service valve guide inside diameter (after assembly)	9.50 - 9.525 mm (0.374 - 0.375 in)
Service valve guide interference fit dimension	0.018 - 0.074 mm (0.0007 - 0.0029 in)
Valve guide bore out-of-round (maximum)	0.05 mm (0.002 in)
Valve guide bore taper (maximum)	0.13 mm (0.005 in)
Valve guide height from cylinder head spring pocket (intake and exhaust)	22.05 - 22.56 mm (0.868 - 0.888 in)
Valve seat insert angle (intake)	30°
Valve seat insert angle (exhaust)	45°
Valve seat width (intake and exhaust)	1.91 - 2.16 mm (0.075 - 0.085 in)
Valve seat runout (TIR maximum)	0.05 mm (0.002 in)
Intake valve seat outside diameter:	50.787 mm (1.9995 in)
0.05 mm (0.002 in) oversize	50.838 mm (2.0015 in)
0.381 mm (0.015 in) oversize	51.168 mm (2.0145 in)
Exhaust valve seat outside diameter:	45.999 mm (1.811 in)
0.05 mm (0.002 in) oversize	46.050 mm (1.813 in)
0.38 mm (0.015 in) oversize	46.380 mm (1.826 in)
Valve seat insert cylinder head counterbore diameter:	
Intake (standard size)	50.648 - 0.724 mm (1.9940 - 1.9970 in)
0.05 mm (0.002 in.)	50.698 - 50.775 mm (1.9960 - 1.9990 in)
0.381 mm (0.015 in)	51.067 ± 0.038 mm (2.0105 ± 0.0015 in)
Exhaust (standard size)	45.860 - 45.935 mm (1.8055 - 1.8085 in)
0.05 mm (0.002 in)	45.910 - 45.986 mm (1.8075 - 1.8105 in)
0.381 mm (0.015 in)	46.278 ± 0.038 mm (1.8220 ± 0.0015 in)
Maximum valve head recession relative to deck surface (intake and exhaust)	0.36 mm (0.014 in)
Cylinder head surface flatness	0.10 mm (0.004 in) per 229 mm (9 in)
Deck-to-deck dimension (new head)	128.27 - 128.78 mm (5.050 - 5.070 in)
Minimum deck-to-deck dimension (after rework)	128.02 mm (5.040 in)
Valve Springs (Intake)	
Number of springs per valve	1

Identification color stripe	Orange
Valve spring free length	56.623 mm (2.308 in)
Test length (valve closed)	50.292 mm (1.980 in)
Test load (valve closed)	364 - 400 N (82 - 90 lbs)
Test length (valve open)	37.5 mm (1.480 in)
Test load (valve open)	943 - 987 N (212 - 222 lbs)
Wire diameter	5.26 mm (0.207 in)
Valve Springs (Exhaust)	
Number of springs per valve	1
Identification color strip	White
Valve spring free length	64.06 mm (2.522 in)
Test length (valve closed)	50.29 mm (1.980 in)
Test load (valve closed)	611 - 651 N (137.5 - 146.5 lbs)
Test length (valve open)	38.86 mm (1.530 in)
Test load (valve open)	1129 - 1183 N (254 - 266 lbs)
Wire diameter	5.26 mm (0.207 in)

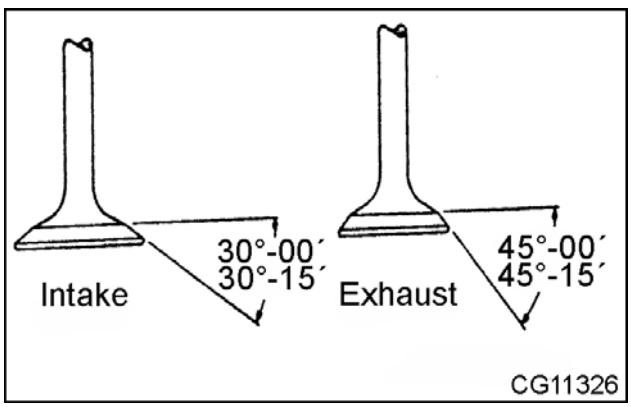

Figure 538 Valve face angles specifications

Rocker Arm Assembly, Camshaft Assembly, Tappets and Push Rods

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

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

New Style Valve Train Components

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

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

Power Cylinders

Connecting Rods	
Center-to-center distance between connecting rod bearing bore and piston pin bushing	219.5 to 219.4 mm (8.64 to 8.63 in)
Bushing bore diameter (pin end) (forged connecting rods)	48.91 to 48.86 mm (1.926 to 1.924 in)
Maximum bushing bore diameter (pin end) (fractured connecting rods)	49.90 mm (1.965 in)
Maximum connecting rod bushing outside diameter (forged connecting rods)	49.00 mm (1.930 in)
Maximum connecting rod bushing outside diameter (fractured connecting rods)	50.00 mm (1.969 in)
Piston pin bushing inside diameter (installed) (forged connecting rods)	46.38 to 46.37 mm (1.826 to 1.825 in)
Piston pin bushing inside diameter (installed) (fractured connecting rods)	46.39 mm (1.827 in)
Bearing bore diameter (crankshaft end)	85.16 to 85.13 mm (3.353 to 3.352 in)
Maximum out-of-round	0.051 mm (0.002 in)
Maximum taper per inch	0.13 mm (0.005 in)
Connecting rod bearing inside diameter (installed)	80.12 to 80.07 mm (3.154 to 3.152 in)
NOTE: Do not use service bolts from forged connecting rods with fractured connecting rods.	
Bearing running clearance	0.127 to 0.046 mm (0.0050 to 0.0018 in)

Maximum permissible bearing running clearance (before reconditioning)	0.18 mm (0.007 in)
Connecting rod side clearance on crankshaft	0.30 to 0.42 mm (0.012 to 0.17 in)
Connecting rod alignment twist	0.51 mm (0.020 in)
Bend	0.38 mm (0.015 in)
Pistons	
Running clearance between piston and cylinder sleeve	Steel 2-piece: 0.05 to 0.10 mm (0.002 to 0.004 in) Aluminum: 0.07 to 0.13 mm (0.003 to 0.005 in)
Aluminum Piston Measure 90° from pin bore at Skirt Diameter, 28.575 mm (1.125 in) from bottom of piston.	116.472 to 116.497 mm (4.5855 to 4.5865 in)
Steel Piston Measured 90° from pin bore at Skirt Diameter, 39.4 mm (1.55 in) from bottom of piston.	116.497 to 116.523 mm (4.5865 to 4.5875 in)
Number of rings per piston	3
Piston Ring Groove Widths:	
Top Compression Ring Measure over 2.92 mm (0.115 in) gauge pins	114.33 to 114.58 mm (4.501 to 4.511 in)
Intermediate Compression Ring - Keystone All Aluminum 466E above 215 bhp, and 530E pistons measured over 2.92 mm (0.115 in) gauge pins	116.84 to 116.92 mm (4.600 to 4.603 in)
Rectangular Groove Width 466E at 215 bhp and below and 530E at 300 bhp and above.	3.028 to 3.048 mm (0.1192 to 0.1200 in)
Side clearance: Oil control ring	0.05 to 0.10 mm (0.002 to 0.004 in)
Piston Rings - Compression	
Number of rings per piston	2
Type (face and finish): Top Ring	Full Keystone (barrel faced) - Plasma Coated
Intermediate Ring: For 466E engines rated at 215 bhp and below	Rectangular (Negative Twist) - Phosphate Coated
For engines rated above 215 bhp	Full Keystone (taper face)
Intermediate Ring: All 530E engines with aluminum pistons	Full Keystone (taper face)
All engines with steel pistons	Rectangular (negative twist) - Phosphate coated
Ring Gap With New Sleeve	
Top ring	0.40 to 0.66 mm (0.016 to 0.026 in)

Intermediate ring	1.65 to 1.91 mm (0.065 to 0.075 in)
Piston Rings - Oil Control	
Number of oil control rings per piston	1
Type (face and finish)	One piece slotted - Chrome
Ring gap	0.30 to 0.56 mm (0.012 to 0.022 in)
Piston Pins	
Outside diameter	46.352 to 46.357 mm (1.8249 to 1.8251 in)
Length	96.57 to 96.82 mm (3.802 to 3.812 in)
Clearance in rod	0.015 to 0.028 mm (0.0006 to 0.0011 in)
Maximum permissible clearance in rod, before replacing	0.08 mm (0.003 in)
Clearance in piston	0.0165 to 0.0292 mm (0.00065 to 0.00115 in)
Maximum permissible clearance in piston before replacing	0.064 mm (0.00258 in)
Cylinder Sleeves	
Inside Diameter (new)	116.57 to 116.60 mm (4.589 to 4.590 in)
Maximum permissible diameter sleeve wear at top of ring travel before replacement (sleeve taper)	0.10 mm (0.004 in)
Counterbore dimension in crankcase	8.84 to 8.89 mm (0.348 to 0.350 in)
Maximum allowable variation of counterbore depth (between four points)	0.025 mm (0.001 in)
Maximum cylinder sleeve counterbore allowable depth (used with shim kit)	10.49 mm (0.413 in)
Flange thickness	8.97 to 8.94 mm (0.0353 to 0.0352 in)
Protrusion above crankcase	0.13 to 0.05 mm (0.005 to 0.002 in)

Vibration Damper, Crankshaft, Main Bearings, Flywheel, and Crankcase

Crankshaft	
Type	**Steel forging, induction hardened, grindable**
Main bearing journal diameter:	
Standard size	89.8 ± 0.0152 mm (3.535 ± 0.0006 in)
0.254 mm (0.010 in) undersize	89.5 ± 0.0152 mm (3.525 ± 0.0006 in)
0.508 mm (0.020 in) undersize	89.3 ± 0.0152 mm (3.515 ± 0.0006 in)
0.762 mm (0.030 in) undersize	89.0 ± 0.0152 mm (3.505 ± 0.0006 in)
Main bearing width (except rear thrust)	33.0 ± 0.254 mm (1.286 ± 0.010 in)
Main bearing journal maximum out-of-round	0.05 mm (0.002 in)

Main bearing thrust face runout (TIR maximum)	0.025 mm (0.001 in)
Main bearing journal taper (maximum per inch)	0.0711 mm (0.0028 in)
Main bearing journal fillet radius	5.72/1.27 mm (0.225/0.050 in)
Rod journal fillet radius	5.72/1.27 mm (0.225/0.050 in)
Rear oil seal journal runout (maximum)	0.076 mm (0.003 in)
Damper mounting area runout (maximum)	0.013 mm (0.0005 in)
Flywheel mounting surface runout (maximum)	0.05 mm (0.002 in)
Number of main bearings	7
Thrust taken by	Rear main bearing
Thrust Bearing Journal Length:	
Standard size to 0.508 mm (0.020 in) undersize	34.4 ± 0.0254 mm (1.3545 ± 0.010 in)
0.762 mm (0.030 in) undersize	34.4043 ± 0.0254 mm (1.3545 ± 0.0010 in)
Main bearing to crankshaft running clearance	0.046 to 0.127 mm (0.0018 to 0.0050 in)
Connecting rod journal diameter standard size	80.0 ± 0.0152 mm (3.1500 ± 0.0006 in)
0.0254 mm (0.010 in) undersize	79.7 ± 0.0152 mm (3.1400 ± 0.0006 in)
0.508 mm (0.020 in) undersize	79.5 ± 0.0152 mm (3.1300 ± 0.0006 in)
0.762 mm (0.030 in) undersize	79.2 ± 0.0152 mm (3.1200 ± 0.0006 in)
Connecting rod bearing width	35.2 mm (1.385 in)
Connecting rod journal maximum out-of-round	0.0064 mm (0.00025 in)
Connecting rod journal taper (maximum per inch)	0.0069 mm (0.00027 in)
Connecting rod bearing to crankshaft running clearance	0.127 to 0.046 mm (0.0050 to 0.0018 in)
Crankshaft flange outside diameter	141 mm (5.550 in)
Crankshaft end play	0.152-0.305 mm (0.006-0.012 in)
Crankshaft end play maximum wear limit	0.508 mm (.020 in)
Rod to crankshaft side clearance	0.30 to 0.42 mm (0.012 to 0.017 in)
Crankshaft gear backlash	0.076 to 0.406 mm (0.003 to 0.016 in)
Face runout - measured at 177.8 mm (7.0 in) radius	0.18 mm (0.007 in)
Pot flywheel for clutch applications:	
Face runout-measured at 165.1 mm (6.5 in) radius	0.165 mm (0.0065 in)
Face runout (mounting surface for clutch cover plate) - measured at 190.5 mm (7.5 in) radius	0.19 mm (0.0075 in)
Flywheel concentricity (radial runout)	
Flat flywheel for clutch applications:	

Radial runout measured at clutch mounting holes	0.20 mm (0.008 in)
Pot flywheel for clutch applications:	
Radial runout of clutch pilot bore (inside diameter of pot flywheel)	0.13 mm (.005 in)
Flywheel resurfacing (for clutch applications):	
Requires measurement from crankshaft mounting surface of flywheel to clutch surface of flywheel.	
NOTE: DO NOT machine beyond minimum dimension shown.	
Flat flywheel	36.3 mm (1.430 in)
Pot flywheel	39.4 mm (1.550 in)
Flywheel housing bore concentricity	SAE 1 = 0.30 mm (0.012 in) SAE 2 = 0.28 mm (0.011 in)
Flywheel housing face runout	SAE 1 = 0.30 mm (0.012 in) SAE 2 = 0.28 mm (0.011 in)
NOTE: Must be measured per SAE specification J1033.	
Vibration damper maximum allowable member misalignment	1.5 mm (0.060 in)
Vibration damper wobble (maximum)	1.5 mm (0.060 in)
Crankcase deck flatness	0.076 mm (0.003 in)
Crankcase deck finish (micro inches)	125AA
Centerline of main bearing bore to head deck	368.3 ± 0.0381 mm (14.5 ± 0.0015 in)
Crankcase main bearing bore diameter	97.8 ± 0.0127 mm (3.8491 ± 0.0005 in)

Crankcase	
Tappet bore diameter	28.511 to 28.549 mm (1.1225 to 1.1240 in)
Valve and Roller tappet outside diameter	28.435 to 28.448 mm (1.1195 to 1.1200 in)
Oil jet tube bore (spray hole) diameter	1.22 to 1.24 mm (0.048 to 0.049 in)
Counterbore dimension in crankcase	8.860 ± 0.025 at 132 mm (0.349 ± 0.001at 5.1885 in)
Maximum allowable variation of counterbore depth (between four points)	0.025 mm (0.001 in)
Cylinder sleeve counterbore maximum allowable depth	9.25 to 10.49 mm (0.364 to 0.413 in)
Sleeve protrusion above crankcase	0.050 to 0.127 mm (0.002 to 0.005 in)
Main bearing type	Precision replaceable
Material	Steel-backed copper/lead
Thrust taken by	No. 7 rear
Cap attachment	2 bolts per cap
Camshaft Bushing Bore Diameter in Crankcase	
Front	65.513 to 63.550 mm (2.5005 to 2.5020 in)
Intermediate front	63.005 to 63.043 mm (2.4805 to 2.4820 in)
Intermediate rear	62.496 to 62.535 mm (2.4605 to 2.4620 in)
Rear	61.988 to 62.026 mm (2.4405 to 2.4420 in)

Timing Gear Train and Front Cover

Crankshaft to idler backlash (maximum)	0.356 mm (0.014 in)
Idler to camshaft backlash	0.457 mm (0.018 in)
Idler to idler backlash	0.482 mm (0.019 in)
Idler to air compressor or power steering pump backlash	0.508 mm (0.020 in)
Idler to high-pressure pump backlash	0.482 mm (0.019 in)

Lubricating Oil Pump, Oil Filter, and Cooler

Oil Pump	
Type	Gerotor
Drive	Crankshaft
End clearance inner and outer	0.066 to 0.142 mm (0.0026 to 0.0056 in)
Diametrical clearance between outer rotor housing	0.470 to 0.622 mm (0.0185 to 0.0245 in)
Minimum engine oil pressure at low idle speed (700 rpm)[1]	103 kPa (15 psi)
Minimum engine oil pressure at high idle speed*	276 to 483 kPa (40 to 70 psi)
Pressure Regulator Valve Assembly	
Location	In crankcase, behind filter header
Setting	331 kPa (48 psi)
Valve assembly diameter	26.949 ± 0.038 mm (1.0610 ± 0.0015 in)
Valve clearance in bore	0.038 to 0.089 mm (0.0015 to 0.0035 in)
Crankcase bore diameter	27.00 to 27.05 mm (1.063 to 1.065 in)

[1] Run engine until normal operating temperature is reached. Take oil pressure measurement with an oil gallery tap.

Water Pump and Thermostat

Thermostat	
Type	Poppet Valve, Pellet Operated
Operating temperature range:	
Start-to-open temperature	86 to 89 °C (187 to 192 °F)
Full-open temperature	96 °C (205 °F)

Engine Electrical

Camshaft Position Sensor	
Location	Front Cover
Operating Actuator Speed	30 to 4000 rpm
Operating temperature	-40 to 130 °C (-40 to 266 °F)
CMP sensor clearance air gap	0.635 to 0.762 mm (0.025 to 0.030 in)
Depth: Crankshaft rotated clockwise	29.56 ± 0.356 mm (1.164 ± 0.014 in)
Depth: Crankshaft rotated counterclockwise	29.34 ± 0.356 mm (1.155 ± 0.014 in)

High-pressure Lube Oil System

Injection Pressure Regulator	
Operating temperature range	-40 to 125 °C (-40 to 257 °F)
Maximum flow rate	17.5 L/min (4.62 gpm)
Maximum operating pressure	23.5 MPa (3400 psi)
High-pressure Pump Drive Gear	
Gear backlash	0.140 to 0.256 mm (0.0055 to 0.0101 in)
End play	0.45 to 1.22 mm (0.018 to 0.048 in)

Fuel System

Pressure fuel return valve unseats	414 kPa (60 psi)
Fuel filter type	Spin-On Cartridge

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General Torque Guidelines

CAUTION: To avoid 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 to 45), all phosphate coated.

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

NOTE: Visually inspect parts for cleanliness and obvious defects prior to assembly.

Standard Torques

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.

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.

Standard Torques - Class 12.9 Metric Bolts and Studs

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

1 Tolerances are ±10% of nominal value.

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

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Figure 539 Classification and Identification - Metric Fasteners

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

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Figure 540 Classification and Identification - Special Use Fasteners

Many conditions affect torque and the results of torque applications. The major purpose in tightening a fastener to a specified torque is to obtain tension in the fastener (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 proper torque application.

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

Using a Torque Wrench Extension

Occasionally the need will arise to use an extension, crowfoot, or other type of adapter with your torque wrench to torque a bolt or line fitting. Sometimes an extension or adapter is necessary to reach a bolt in a hard to reach location. Adding adapters or extensions will alter the actual clamping force at the faster. By using the following formula you can determine what the torque wrench setting should be to achieve the known standard or special torque value.

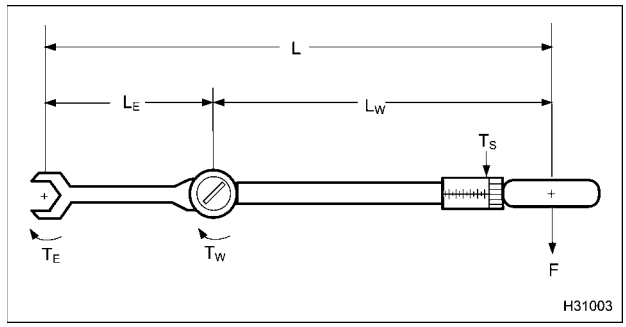

Figure 541 Torque wrench extension

- F - Force applied by service 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 to reach it. What will the torque wrench setting have to be in order to compensate for the additional extension?

- Torque wrench = 12 inches
- Extension = 6 inches

T_S = 65 lbf·ft (12 in / (12 in + 6 in)

T_S = 65 lbf·ft (12 in / 18 in)

T_S = 65 lbf·ft (0.666)

T_S = 43.3 lbf·ft or 58.9 N·m

Special Torques

Mounting Engine On Stand

Oil Pan Drain Plug	68 N·m (50 lbf·ft)

Turbochargers

Center Housing-to-Turbine Housing Cap screws	13 N·m (115 lb·in)
Wastegate housing to turbine housing cap screws	21 - 24 N·m (185 - 215 lbf·in)
Center Housing-to-Compressor Housing Cap screws	21 - 24 N·m (185 - 215 lbf·in)
Compressor housing to back plate	21 - 24 N·m (185 - 215 lbf·in)
Turbocharger Mounting Nuts	71 N·m (52 lbf·ft)
EVRT® Turbocharger mounting studs and nuts	71 N·m (52 lbf·ft)

NOTE: Apply clean engine oil to all threads.

Manifolds

Exhaust manifold bolts	81 N·m (60 lbf·ft)
Valve cover and intake manifold bolts	18 N·m (13 lbf·ft)
Road draft tube mounting bolts	49 N·m (36 lbf·ft)

Cylinder Head and Valves

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

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

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

Power Cylinders

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

Vibration Damper, Crankshaft, Main Bearings, Flywheel, and Crankcase

Connecting rod bolt	163 N·m (120 lbf·ft)
Crankshaft main bearing cap bolts	(page 218)
Vibration damper bolts (grade 12.9)	163 N·m (120 lbf·ft)
Pulley retainer bolts	136 N·m (100 lbf·ft)
Viscous damper mounting bolts	54 N·m (40 lbf·ft)
Flywheel bolts	136 N·m (100 lbf·ft)
Flywheel housing mounting bolts	108 N·m (80 lbf·ft)
Oil pan mounting bolts	32 N·m (24 lbf·ft)
Oil pan drain plug	68 N·m (50 lbf·ft)
Oil pickup tube bolts	20 N·m (15 lbf·ft)
Oil pickup tube bracket bolt (Rear Sump)	32 N·m (24 lbf·ft)
Oil pickup tube support bracket bolt (Front Sump)	20 N·m (15 lbf·ft)
Oil filler tube clamp	3.5 N·m (30 lbf·in)
Front engine mounting bracket mounting bolts	386 N·m (284 lbf·ft)
Rear engine mounting bracket mounting bolts	108 N·m (80 lbf·ft)
Special mounting nut (PTO application only)	108 N·m (80 lbf·ft)
Engine Block Heater Cap Screw	2.8 Nm (25 lb-in.)

Timing Gear Train and Front Cover

Crankcase front cover bolts (front and rear halves)	22 N·m (16 lbf·ft)
Crankcase front cover (rear half to crankcase)	26 N·m (19 lbf·ft)
Front Cover Bracket to Head Bolts (no air conditioning)	62 N·m (46 lbf·ft)
Idler gear retaining bolt (upper)	326 N·m (240 lbf·ft)
Idler gear retaining bolt (lower)	639 N·m (470 lbf·ft)
Camshaft thrust plate bolt	26 N·m (19 lbf·ft)
Cam gear timing disk plate screws	6.8 N·m (60 lbf·in)
Air compressor hose clamps	5 N·m (42 lbf·in)
Air compressor tail bracket mounting bolts (crankcase)	115 N·m (85 lbf·ft)
Air compressor tail bracket mounting bolt (compressor)	66 N·m (49 lbf·ft)
Air compressor drive gear nut	149 N·m (110 lbf·ft)
Air compressor mounting bolts	62 N·m (46 lbf·ft)
Belt tensioner (front cover)	50 N·m (37 lbf·ft)
Belt tensioner (Freon compressor)	50 N·m (37 lbf·ft)
Water pump pulley (6 mm)	6.8 N·m (60 lbf·in)
Water pump (6 mm)	6.8 N·m (60 lbf·in)
Water pump mounting bolts (8 mm)	18 N·m (13 lbf·ft)
Fan drive	18 N·m (13 lbf·ft)
Thermostat Housing Bolt (M12)	90 N·m (66 lbf·ft.)

Lubricating Oil Pump, Oil Filter and Cooler

Oil pan drain plug	68 N·m (50 lbf·ft)
Oil pan mounting bolts	32 N·m (24 lbf·ft)
Oil pickup tube bolts	20 N·m (15 lbf·ft)
Oil pickup tube bracket bolts (front sump)	20 N·m (15 lbf·ft)
Oil pickup tube bracket bolt (rear sump)	32 N·m (24 lbf·ft)
Oil level gauge tube clamp	3.4 N·m (30 lbf·in)
Oil temperature control valve	34 N·m (25 lbf·ft)
Oil cooler mounting bolts	26 N·m (19 lbf·ft)

Water Pump and Thermostat

Water pump (6 mm)	7.5 N·m (66 lbf·in)
Water pump pulley (6 mm)	7.5 N·m (66 lbf·in)
Water pump mounting bolts (8 mm)	17 N·m (13 lbf·ft)
Belt tensioner (front cover)	50 N·m (37 lbf·ft)
Belt tensioner (Freon compressor)	50 N·m (37 lbf·ft)
Fan drive	18 N·m (13 lbf·ft)
Coolant filter header mounting bolts	26 N·m (19 lbf·ft)

Engine Electrical

Injection Control Pressure Sensor (ICP)[1]	26 N·m (19 lbf·ft)
Injection Pressure Regulator (IPR)	47 N·m (35 lbf·ft)
Injection Control Pressure Valve Tinnerman Nut	6.8 N·m (60 lbf·in)
Engine Oil and Coolant Temperature Sensors	13.6 N·m (10 lbf·ft)
Diamond Logic® System (ECM) Connector Retaining Screw	6 N·m (50 lbf·in)
Diamond Logic® System (ECM) Mounting Hardware (all)	27 N·m (20 lbf·ft)
Camshaft Position (CMP) Sensor Bolt	17 N·m (13 lbf·ft)

[1] Apply Loctite® #277 to threads prior to assembly.

High-Pressure Lube Oil System

High-pressure oil pump gear bolt	129 N·m (95 lbf·ft)
High-pressure oil hose nut	26 N·m (19 lbf·ft)
High-pressure oil pump mounting bolts	27 N·m (20 lbf·ft)
Injection Control Pressure (ICP) sensor[1]	26 N·m (19 lbf·ft)
ICP valve	47 N·m (35 lbf·ft)
IPR valve mounting bolts	28 N·m (20 lbf·ft)
IPR valve Tinnerman nut	6.8 N·m (60 lbf·in)
Supply manifold elbow fitting	26 N·m (19 lbf·ft)
Supply manifold end plug	81 N·m (60 lbf·ft)
Supply manifold mounting bolts	27 N·m (20 lbf·ft)
Fuel return valve assembly	35 N·m (26 lbf·ft)
Fuel return valve banjo fitting	35 N·m (26 lbf·ft)
Banjo fuel line connections	35 N·m (26 lbf·ft)

[1] Apply Loctite® #277 to sensor threads before installation.

Fuel System

Banjo fuel line connections	35 N·m (26 lbf·ft)
Fuel filter header mounting bolt	18 N·m (13 lbf·ft)
Fuel return valve assembly	35 N·m (26 lbf·ft)

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Special Tools

Special tools for the International® DT 466E and 530E diesel engines can be ordered from the SPX Corporation, 1- 800- 520-2584.

Mounting Engine on Stand

Adapter Plate	ZTSE4151
Engine Stand	OEM4137
Guide Pins	Obtain locally

Turbocharger

Dial Indicator with Magnetic Base	Obtain locally
Turbo Intake Cap Set	ZTSE4296
Turbocharger Intake Shield	ZTSE4293

Manifolds

Feeler Gauge	Obtain locally

Cylinder Head and Valves

Bevelled Edge Straightedge	OEM1293
Cleaning Brush Set	ZTSE4320
Critical Metric Taps	ZTSE4386
Cylinder Head Bolt Gage	ZTSE4481
Cylinder Head Magnetic Intake Shield	PS94-831-1
Defect Detector Kit (Dye Penetrant)	OEM1272
Dial Caliper	Obtain locally
Feeler Gauge (2)	Obtain locally
Flashlight	Obtain locally
Front Seal / Injector Remover	ZTSE4300
Fuel Injector Holding Rack and Cups	ZTSE4299B
Fuel Injector Sleeve Installer	ZTSE4303
Fuel Injector Sleeve Remover	ZTSE4302A
Hammer	Obtain locally
Head Pressure Test Kit	ZTSE4289A
Injector Sleeve Brushes (2)	ZTSE4304
Inside Micrometer (0 - 1 in)	Obtain locally
Inspection Light	Obtain locally
Inspection Mirror	Obtain locally
Loctite® 262	Obtain locally
Mineral Spirits	Obtain locally
Nozzle Sleeve Seating Brush 3/4“	ZTSE4391
Outside Micrometer	Obtain locally
Pry Bar	Obtain locally
Rotary Wire Brush	Obtain locally
Sanding Block	Obtain locally
Slide Hammer Kit	ZTSE4398A
Small Hole Gauge Set	OEM1023
Tapered Wire Brush (Sleeve Bore)	ZTSE4394
Thermostat Opening Pressure Test Adapter (must be used with Head Pressure Test Kit)	ZTSE4647
Universal Valve Seat Extracting Kit	ZTSE1951C
Collet (part of Universal Valve Seat Extracting Kit ZTSE1951C)	ZTSE1951-20
Valve Guide Brush	OEM6343

Valve Guide Deburring Tool	ZTSE4393
Valve Guide Installer	ZTSE1943
Valve Guide Remover	ZTSE4377
Valve Seat Installer	ZTSE4164A
Valve Spring Compressor (“C” Type)	ZTSE1846
Valve and Clutch Spring Tester	ZTSE2241
Water Supply Housing Pressure Test Adapter (must be used with Head Pressure Test Kit)	ZTSE4648
Plastic Plug Set (6)	ZTSE43024

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

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

Power Cylinders

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

Vibration Damper, Crankshaft, Main Bearings, Flywheel, and Crankcase

Air Hammer	Obtain locally
Bevelled Edge Straightedge	OEM1293
Crankshaft, Front Oil Seal / Wear Sleeve Installer	ZTSE3004B
Crankshaft Oil Hole Brush	ZTSE4392
Critical Metric Taps	ZTSE4386
Damper Heater	ZTSE4384
Dial Indicator with Magnetic Base	Obtain locally
Gear and Pulley Puller (Large)	OEM4245
Guide Stud Set	ZTSE4375
Feeler Gauge	Obtain locally
Main Oil Gallery Brush	ZTSE4389
Muffler Chisel	Obtain locally
Rear Oil Seal and Wear Sleeve Installer	ZTSE2535C
Rear Wear Sleeve Remover	ZTSE4404
Slide Hammer Puller Set	ZTSE1879
Front Seal / Injector Remover	ZTSE4300
Telescopic gauge set	OEM1032
Thermo-melt Crayon 100 °C (212 °F)	Obtain locally
Flex Hone	ZTSE4349

Timing Gear Train and Front Cover

Dial Indicator with Magnetic Base	Obtain locally
Feeler Gauge	Obtain locally
Lower Idle Gear Socket	ZTSE4383
Special Pulley “C” Wrench	Obtain locally

Lubricating Oil Pump, Oil Filter, and Cooler

Bevelled Edge Straightedge	OEM1293
Crankshaft Front Oil Wear Sleeve Installer	ZTSE3004B
Feeler Gauge	Obtain locally
Lubriplate™	Obtain locally
Oil Cooler Test Plate	ZTSE4376

Water Pump and Thermostat

Container filled with water	Obtain locally
Thermometer	Obtain locally
Heating Plate	Obtain locally

Engine Electrical

Camshaft Sensor Air Gap	ZTSE4414
Depth Gage Micrometer	OEM1013
Depth Micrometer or Precision Caliper	Obtain locally
Shim Kit	Obtain locally

High-Pressure Lube Oil System

Bevelled Edge Straightedge	OEM1293
Cleaning Brush Set (4)	ZTSE4320
Feeler Gauge	Obtain locally
Hand Operated Vacuum Pump	ZTSE2499
High-Pressure Oil System Cap Set	ZTSE4295

Fuel System

Fuel System Cap Set	ZTSE4294

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