Table of Contents

Problems and Conditions

Diagnostic test procedures help technicians systematically find problems quickly to avoid unnecessary repairs. In this section, diagnostic and test procedures help identify causes for known problems and conditions.

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, read all safety instructions in the foreword of this manual. Follow all warnings, cautions, and notes.

Combustion Leaks to Coolant

Symptom

Combustion leaks can be identified by coolant overflowing from deaeration tank or air bubbles in the coolant.

Cause

- Failed injector sleeve
- Failed air compressor
- Failed head gasket
- Failed EGR cooler
- Porous or cracked cylinder sleeve

The likely cause of combustion gas leakage to the cooling system is past the injector sleeve in the cylinder head. A failed cylinder head gasket or porous / cracked cylinder sleeve is possible. However, this should not be considered unless there is evidence of engine overheating or high engine mileage without proper coolant conditioning.

Tools

- Radiator pressure testing kit
- Plastic surge tank cap adapter
- Cylinder head test plate
- Water supply housing pressure adapter
- Thermostat opening pressure adapter (cylinder head)
- Hose pinch-off pliers (2)

Procedure

1. Is the engine equipped with an air compressor?
   - If yes, do step 2.
   - If no, do step 3.

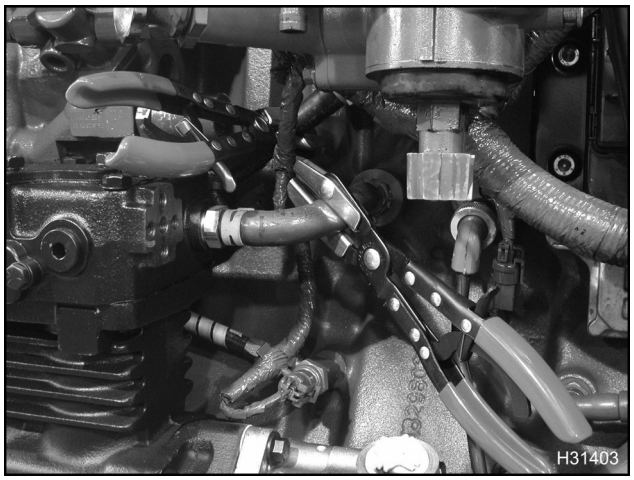

Figure 110 Air compressor coolant hoses

2. Close off both coolant hoses for the air compressor with hose pinch-off pliers. Test the system again.
   - If coolant continues overflowing from the deaeration tank, do step 3.
   - If coolant stops overflowing from deaeration tank, repair or replace the air compressor.
3. Remove injectors following the procedure in the *Engine Service Manual*.

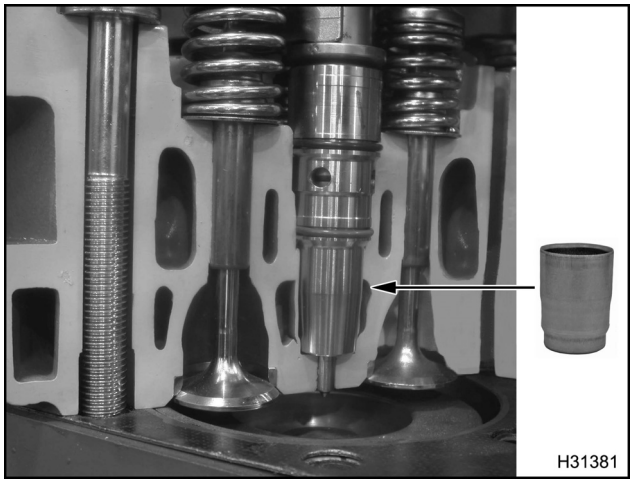

Figure 111 Cylinder head cut-away with injector sleeve

4. Install radiator pressure tester with the appropriate adapter.

   WARNING: To avoid serious personal injury, possible death and damage to the engine:

   - **Always allow the engine to cool for 15 minutes.**
   - **Wrap a thick cloth around the cap.**
   - **Loosen cap slowly a quarter to half turn.**
   - **Pause for a moment to avoid water or steam scalding.**
   - **Continue to turn the cap and remove.**
   - **Never add cold coolant to a hot engine. This can result in a cracked cylinder head or crankcase.**
   - **Never use water as a coolant substitute.**

5. Pressurize cooling system to 96 kPa (14 psi).
6. Look for coolant leaking around the injector sleeve and into the cylinder bore.
   - If a leak is noticed, replace the leaking injector sleeve and test again.
   - If no leak is noticed, replace all six injector sleeves and test again.
   - If coolant continues to flow into cylinders after all injector sleeves were replaced, do step 7.
7. Remove cylinder head from engine, perform all inspections, and pressure test cylinder head to verify leak path. Follow the procedure in the *Engine Service Manual*.
   - Inspect cylinder head gasket for coolant leaks.
   - Verify crankcase and cylinder head surface flatness using a straight edge and feeler gauge.
   - Check cylinder liner protrusion.
8. Test the cylinder head with pressure test plate to validate the repair.

Aerated Fuel

Symptom

Fuel aeration will exhibit one or more of the following characteristics:

- Engine stall during operation
- White to black smoke during cranking
- Rough running engine
- Extended engine crank time (hard start)
- Fuel pressure slow to build while cranking
- Excessive fuel pressure while cranking
- Pulsating fuel pressure during crank or engine running at idle.
- Difficulty priming fuel system

Cause

- Leaks in fuel supply to fuel pump
- Loose fuel injector hold down
- Missing/damaged stainless steel injector gasket

Tools

- Fuel Pressure Test Gauge
- 1 to 5 gallon bucket
- Fuel pump supply line
- Fuel filter housing supply line fitting (Part No. 3533425C2)
- Fuel Pressure Test Adapter
- Fuel/Oil Pressure Test Coupler

Aerated Fuel Inspection

NOTE: If directed to this procedure from “Hard Start and No Start Diagnostics” section, go to “Alternate Fuel Source Supply to Fuel Pump” (page 106) in this section.

CAUTION: Be sure to place a rag or suitable container under the fuel pressure test valve when bleeding the fuel rail. Dispose of fuel in a correct container clearly marked DIESEL FUEL according to local regulations.

NOTE: Engine fuel can be a threat to the environment. Never dispose of engine fuel by putting it in the trash, pouring on the ground, in the sewers, in streams, or bodies of water.

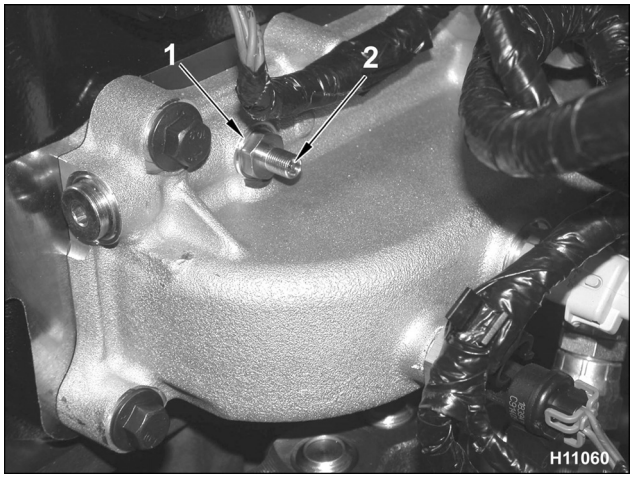

Figure 112 Shrader valve assembly

1. Valve
2. Center stem

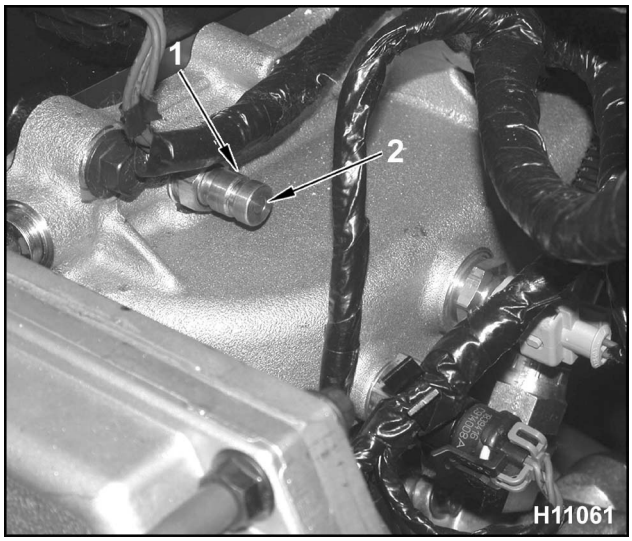

Figure 113 Diagnostic coupling

1. Valve
2. Center section

NOTE: Engines are equipped with a fuel pressure test valve in the form of either a Shrader valve or a diagnostic coupling.

1. Check fuel pressure and aeration from fuel pressure test valve located at the front of the intake manifold.
2. Check fuel pressure and aeration from fuel pressure test valve located at the front of the intake manifold.

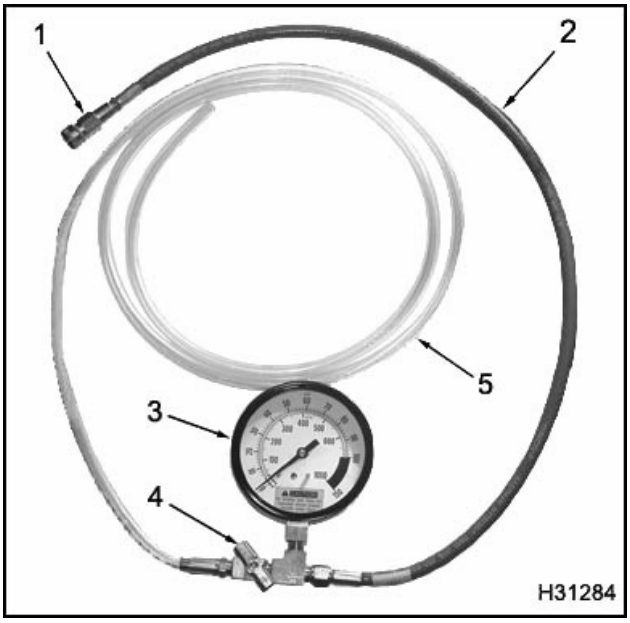

Figure 114 Fuel Pressure Gauge

1. Quick disconnect check valve
2. Fuel test line
3. Fuel Pressure Gauge
4. Inline shut-off valve
5. Clear test line

Figure 115 Fuel Pressure Test Adapter

NOTE: If the engine is equipped with a Shrader valve, use the Fuel Pressure Test Adapter.

Figure 116 Fuel/Oil Pressure Test Coupler

NOTE: If the engine is equipped with a diagnostic coupling, adapt the Fuel/Oil Pressure Test Coupler to the Fuel Pressure Gauge.

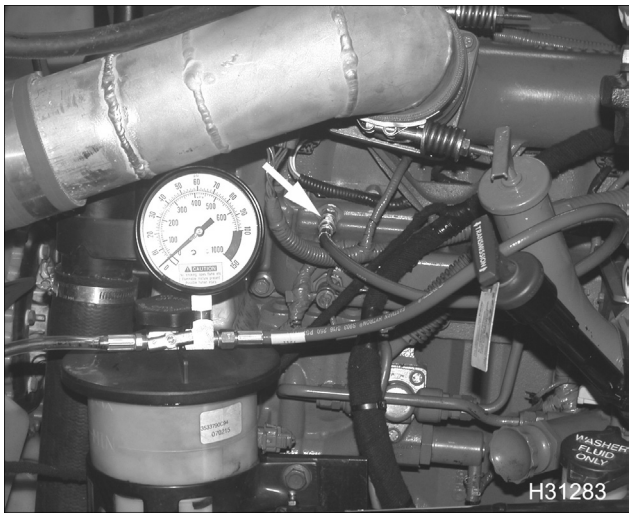

Figure 117 Fuel Pressure Gauge to fuel pressure test adapter

3. Connect Fuel Pressure Gauge with shut-off valve and clear 3/8” diameter hose to test valve.
4. Route the clear hose into a drain pan.
5. Start or crank the engine for 20 seconds. Measure fuel pressure with the shut-off valve closed. Open the shut-off valve to check for aeration.

   NOTE: Breaking any fuel system joint will induce air into the fuel system. The air should pass in a short period of time. As fuel pressure is relieved, a steady stream of fuel without air bubbles indicates the fuel is not aerated.

   - If fuel pressure is in specification and fuel is not aerated, do not continue with this test.
   - If the fuel is aerated, go to “Alternate Fuel Source Supply to Fuel Pump” (page 106) in this section.

Alternate Fuel Source Supply to Fuel Pump

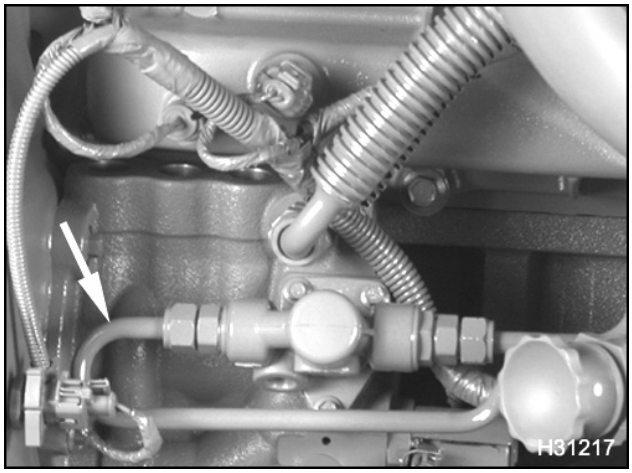

Figure 118 Fuel supply line

1. Remove fuel pump supply line.

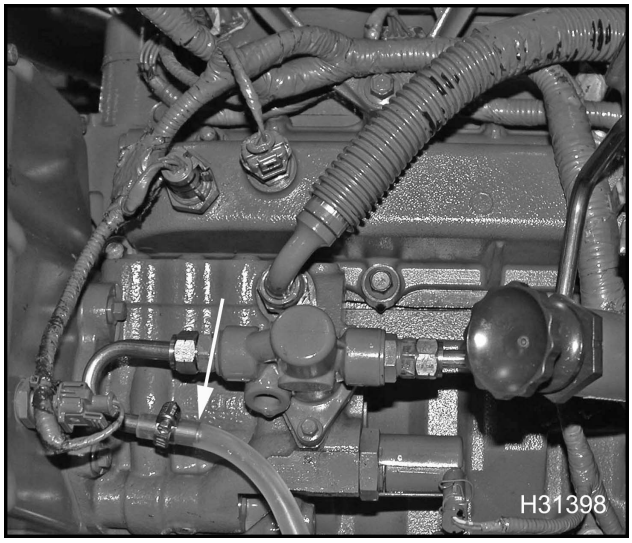

Figure 119 Fuel test line

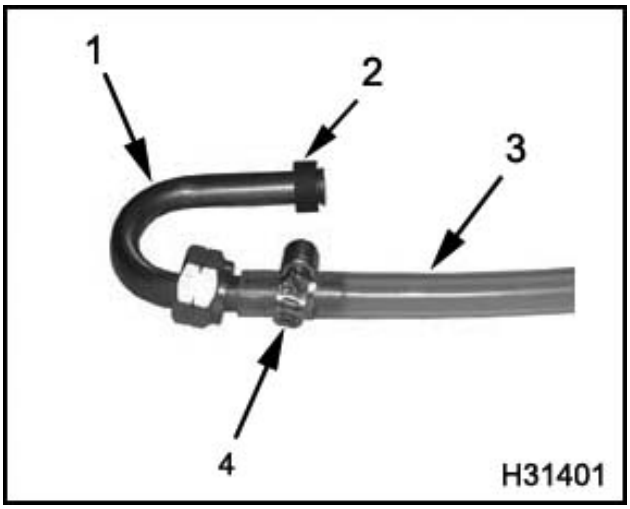

Figure 120 Test fuel line

1. Fuel line
2. Sleeve seal
3. Clear plastic tube
4. Clamp

2. Make a test fuel line.

   - Use spare fuel line. (Make sure the sleeve seal is in good condition.) Cut the line in half. Use the test fuel line portion that supplies the fuel pump. Install clear plastic line in place of removed section and secure plastic line with a clamp.

   NOTE: The mechanic is expected to keep the fuel test line for future diagnostics. Expense the fuel test line as an essential tool and keep it with other diagnostic tools. Warranty will not cover the cost of the fuel test line.

3. Connect the fuel test line between the fuel pump inlet and an alternate fuel source.

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle – comply with the following:

When routing test line, do not crimp the line, run the line too close to moving parts, or let the line touch hot engine surfaces.

4. Start or crank the engine for 20 seconds. Measure fuel pressure with the shut-off valve closed. Open the shut-off valve to check for aeration.

   NOTE: Breaking any fuel system joint will induce air into the fuel system. The air should pass in a short period of time. As fuel pressure is relieved, a steady stream of fuel without air bubbles indicates the fuel is not aerated.

   - If the fuel is aerated, go to “Combustion Leaks to Fuel” (page 108) in this section.
   - If the fuel is not aerated, remove test setup from the fuel pump inlet. Connect the fuel pump supply line. Go to “Alternate Fuel Source Supply to Fuel Filter Housing” in this section.

Alternate Fuel Source Supply to Fuel Filter Housing

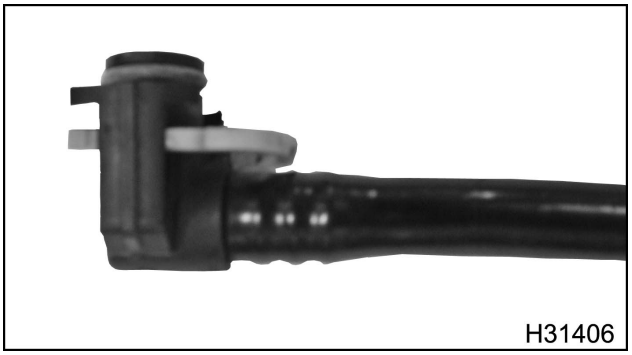

Figure 121 Fuel filter inlet test line

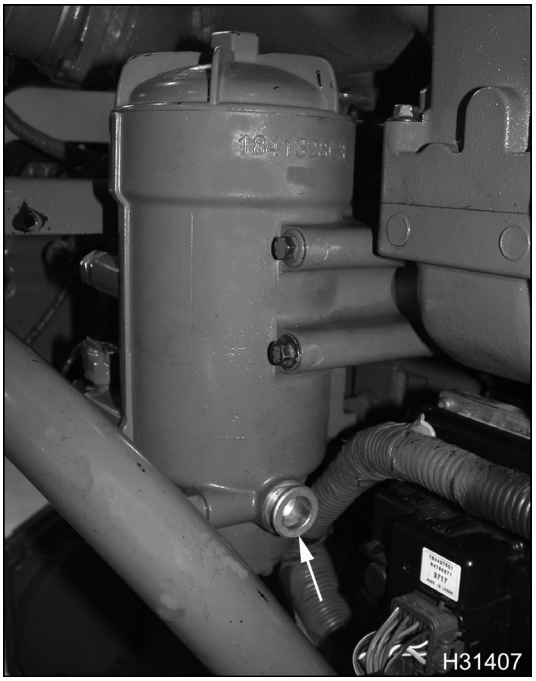

Figure 122 Fuel filter housing inlet

1. Disconnect the supply line from the fuel filter housing.
2. Make a test fuel line.
   - Use a 90° fuel line male fitting and install a clear plastic line that is long enough to reach an alternative fuel source.

   NOTE: The mechanic is expected to keep the fuel test line for future diagnostics. Expense the fuel test line as an essential tool and keep it with other diagnostic tools. Warranty will not cover the cost of the fuel test line.
3. Connect the alternate fuel source to the fuel filter housing inlet.

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle – comply with the following:

When routing test line, do not crimp the line, run the line too close to moving parts, or let the line touch hot engine surfaces.

4. Start or crank the engine for 20 seconds. Measure fuel pressure with the shut-off valve closed. Open the shut-off valve to check for aeration.

   NOTE: Breaking any fuel system joint will induce air into the fuel system. The air should pass in a short period of time. As fuel pressure is relieve, a steady stream of fuel without air bubbles indicates the fuel is not aerated.

   NOTE: If a fuel pressure gauge with shut-off valve and clear 3/8” diameter hose is not available, refer to the alternative test “Checking for Aerated Fuel using Spare Fuel Line.”

   - If the fuel pressure is in specification and the fuel is not aerated, repair the leak between the fuel filter housing and the fuel tank.
   - If the fuel is aerated, repair or replace the fuel filter housing.

Combustion Leaks to Fuel

1. Remove the valve cover following the procedure in the *Engine Service Manual*.
2. Check all injector hold-down clamps for correct torque.
3. Remove any loose injectors. Inspect and clean following the procedure in the *Engine Service Manual*. Replace injector O-rings and install injectors following the procedure in the *Engine Service Manual*.
4. Test for fuel aeration to validate the repair. Go to “Aerated Fuel Inspection” (page 105) in this section.

Coolant in Lube Oil

Symptom

When the crankcase lube oil is contaminated with coolant, the oil will have a dark-gray or black sludgy appearance. The crankcase may also be overfilled.

Cause

- Accessory leak (water cooled air compressor)
- Injector sleeve leak
- Cylinder head cup plug failure
- Crevice seal (liner O-ring)
- Cylinder head gasket leak
- Front cover gasket damage
- Front cover, cylinder head or crankcase porosity

Tools

- Radiator pressure testing kit
- Plastic surge tank cap adapter
- Cylinder head test plate
- Water supply housing pressure adapter
- Thermostat opening pressure adapter (cylinder head)
- Straightedge
- Feeler gauge

Coolant System Inspection

Procedure

1. Check oil level to verify oil contamination complaint.
   - The presence of coolant in the oil will generally give the oil a dark-gray or black sludgy appearance.
   - If coolant in the oil is not verified, an oil sample can be taken for analysis.
2. When oil contamination is verified, plug in cylinder block heater to warm coolant.
3. Is the engine equipped with an air compressor?
   - If yes, do step 4.
   - If no, do step 8.

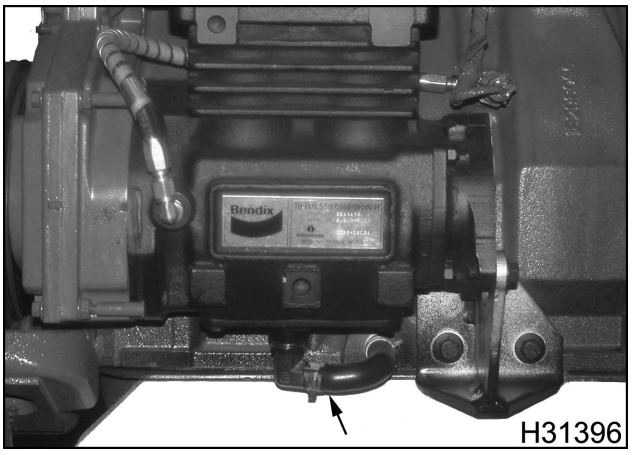

Figure 123 Air compressor oil drain-back hose

4. Remove air compressor oil drain-back hose from the bottom of compressor.
5. Install radiator pressure tester with the appropriate adapter.

   WARNING: To avoid serious personal injury, possible death and damage to the engine:
   - **Always allow the engine to cool for 15 minutes.**
   - **Wrap a thick cloth around the cap.**
   - **Loosen cap slowly a quarter to half turn.**
   - **Pause for a moment to avoid water or steam scalding.**
   - **Continue to turn the cap and remove.**
   - **Never add cold coolant to a hot engine. This can result in a cracked cylinder head or crankcase.**
   - **Never use water as a coolant substitute.**
6. Pressurize the cooling system to 96 kPa (14 psi).
7. Look for coolant leaking from the air compressor oil drain-back port.
   - If coolant is leaking from air compressor, repair or replace air compressor.
   - If coolant is not leaking from the air compressor oil drain-back port, do step 8.
8. Drain engine oil and remove the oil filter.

9. Remove the oil pan following the procedure in the *Engine Service Manual*.
10. Install radiator pressure tester with the appropriate adapter.

WARNING: To avoid serious personal injury, possible death and damage to the engine:

- **Always allow the engine to cool for 15 minutes.**
- **Wrap a thick cloth around the cap.**
- **Loosen cap slowly a quarter to half turn.**
- **Pause for a moment to avoid water or steam scalding.**
- **Continue to turn the cap and remove.**
- **Never add cold coolant to a hot engine. This can result in a cracked cylinder head or crankcase.**
- **Never use water as a coolant substitute.**

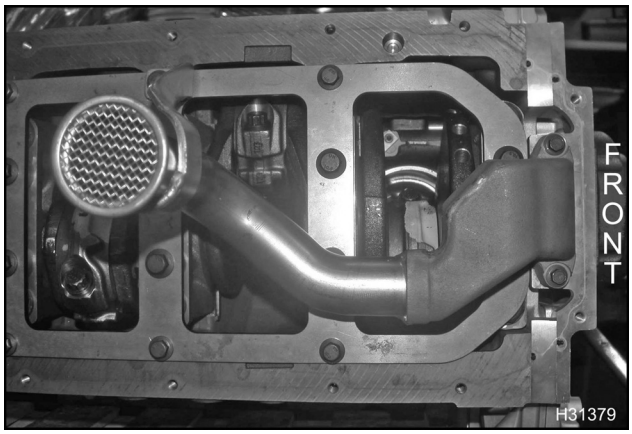

Figure 124 Bottom of engine

11. Pressurize cooling system to 96 kPa (14 psi). Look for coolant leaks.
    - If the engine is equipped with an air compressor, and is leaking from the compressor oil drain-back hose or from the left side of the front cover, do “Air Compressor Leak Test.”
    - If the engine does not have an air compressor, and is leaking from the front cover area or the oil pick-up tube, do “Front Cover Inspection” (page 111).
    - If a leak is noticed between the cylinder sleeve and piston, replace the injector sleeve for that cylinder. Follow the procedure in the *Engine Service Manual*.
    - If a leak is noticed between the cylinder sleeve and the engine block, replace the cylinder sleeve crevice seal for that cylinder. Follow the procedure in the *Engine Service Manual*.
    - If a leak is noticed from the oil drain-back ports (camshaft side), do “Cylinder Head Leak Test” (page 112).
    - If no leak is noticed, leave pressure on cooling system overnight and check the following day.
    - If no leak is noticed after overnight pressure test, do the following sequential tests until problem is found:
        A. “Front Cover Inspection” (page 111)
        B. “Cylinder Head Leak Test” (page 112)
12. After any repairs are complete, test the cooling system again to validate the repair.

Air Compressor Leak Test

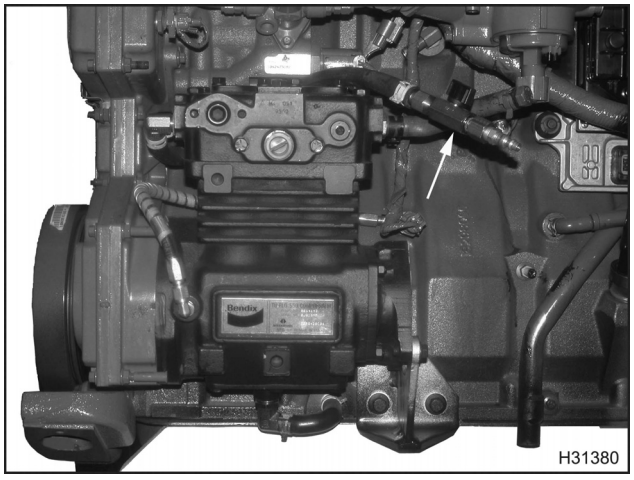

Figure 125 Air compressor test setup

1. Drain coolant from the system.

2. Remove the coolant inlet and outlet hoses for the air compressor from the crankcase.
3. Fill air compressor coolant passage and hoses with coolant.
4. Adapt air pressure fitting and regulator to one of the coolant hoses and block opposite hose.
5. Pressurize air compressor coolant hoses to 96 kPa (14 psi).
6. Inspect for coolant leakage from oil drain-back hose or left side of front cover. Listen for air escaping.
   - If a leak is noticed, repair or replace the air compressor.
   - If coolant is not leaking, do “Front Cover Inspection” (page 111).
7. Test the cooling system again after any repair to validate the repair.

Front Cover Inspection

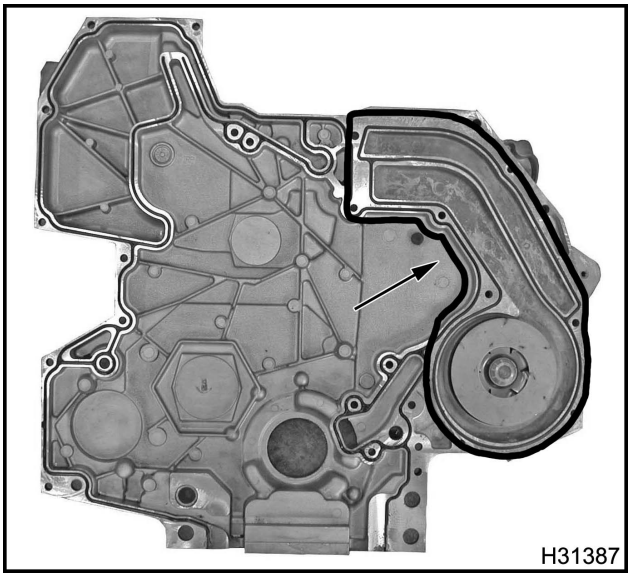

Figure 126 Front cover coolant leak location

1. Remove front cover and inspect gaskets and sealing surfaces following the procedure in the *Engine Service Manual*. Check front cover and crankcase with straight edge and feeler gauge. Repair or replace as required.
2. Test the cooling system again after any repair to validate the repair.

Cylinder Head Leak Test

1. Remove the valve cover following the procedure in the *Engine Service Manual*.

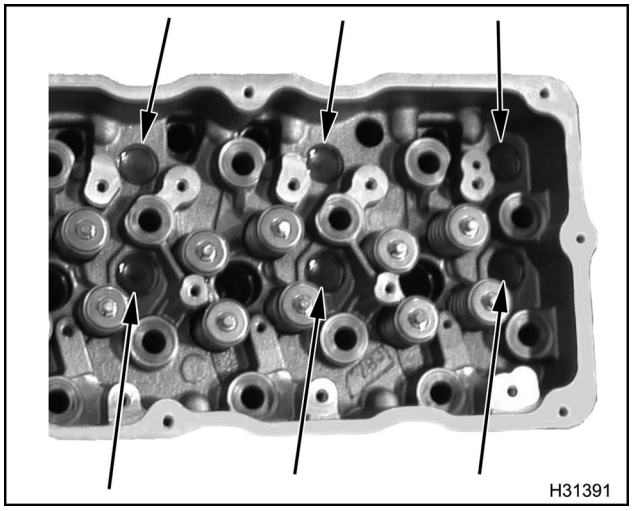

Figure 127 Cylinder head (top) cup plugs

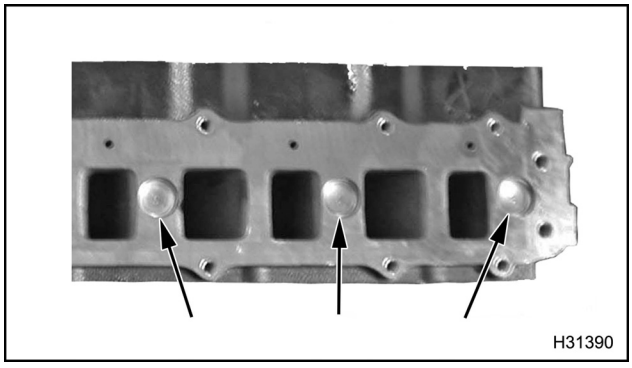

Figure 128 Cylinder head (intake side) cup plugs

2. Pressurize the cooling system to 96 kPa (14 psi)
3. Inspect the entire cylinder head for cracks or leaks at the cup plugs.
   - If a leak is noticed, repair or replace.
   - If no leaks are noticed, do step 4.
4. Drain coolant from system.
5. Remove cylinder head from engine following the procedures in the *Engine Service Manual*.
6. Inspect and pressure test the cylinder head following the procedures in the *Engine Service Manual*.
   - Inspect cylinder head gasket for damage at sealing points that may have caused a leak. Verify crankcase and cylinder head surface flatness using a straightedge and feeler gauge. Replace the head gasket. Repair or replace the cylinder head if necessary.
   - Inspect the cylinder head for cracks in the coolant passages. Repair or replace.
7. If cylinder head is in good condition, remove cylinder sleeve crevice seals following the procedures in the *Engine Service Manual*.
   - Inspect the engine block for cracks in the coolant passages. Repair or replace.
   - Inspect for damaged cylinder liners and seals. Repair or replace.
8. Test the cooling system again after any repair to validate the repair.

ECM Reset / IDM Reset (intermittent engine stumble)

Symptom

An Electronic Control Module (ECM) reset occurs when the ECM momentarily reboots or is turned OFF and ON while the engine is operating. Symptoms of this include the following:

- Wait to start lamp cycles ON while engine running
- Engine stumbles and may die
- Loss of accelerator pedal authority
- Miles driven are not logged if ECM reset occurs during current key cycle

If a reset occurs, the engine will momentarily stumble and the ECM will go through a normal KEY ON cycle. This includes the following:

- Illuminate the WAIT TO START lamp
- Validate the accelerator pedal position

If the pedal is not at idle position when the reset occurs, a DTC is set and engine speed goes to low idle. The ECM will not allow accelerator pedal authority until the Accelerator Pedal Sensor (APS) is released.

An Injector Drive Module (IDM) reset will occur if power is lost to the circuits for IDM Logic or IDM Main Power while the engine is operating. If power is lost, the engine will miss and recover or stall. The APS will not be affected by this fault.

Cause

Momentary loss of power to the ECM or IDM may be caused by the following:

- Failed fuses
- Intermittent open circuit
- Failed battery power feed harness
- Poor ground connection
- Failed power relay
- Shorted or open harness

Procedure

1. Using the EST, check for DTCs for both the engine and chassis modules.
   - If DTC 626 (unexpected reset fault) or 534 (IDM relay voltage low) are present as active or inactive codes, continue with next step.
   - If any other engine DTCs are active, perform appropriate diagnostics and repairs before continuing with these procedures.
   - If any chassis DTCs are active when checking the Electronic System Controller (ESC), perform appropriate diagnostics and repairs before continuing.

NOTE: See Section 7 in this manual, the *Chassis Electrical Circuit Diagram Manual and Electrical System Troubleshooting Guide* for the model and year of the vehicle when performing the following steps.

2. Check all ECM and IDM related fuses.
3. Check all Battery, V_{IGN} and ground connections for the ECM and IDM.
4. Monitor ECM powers and grounds with breakout box under operator complaint conditions.
5. Monitor IDM powers and grounds with 12-pin Breakout Harness under operator complaint conditions.
6. If root cause has not been identified in previous steps, continue diagnosis by performing the remaining steps on the Performance Diagnostics form or Section 6 of this manual.

Excessive Fuel Consumption

Symptom

Occasionally, it may be noticed that more fuel is required to perform the same task as before.

Cause

Operator effect

- Inaccurate record keeping or tank filling
- Winter blend or No. 1 fuel

Application effect

- Heavy loading Gross Vehicle Weight (GVW)
- Low rear axle ratio
- Large frontal area
- Accessory usage (Power Takeoff, etc.)
- Additional equipment drawing fuel from vehicle fuel tanks
- Extended idle applications
- Tire size, tire condition, air pressure

Chassis effect

- Brake drag
- Cooling fan clutch locked ON
- Transmission slippage/shifting
- Fuel tank plumbing or venting
- Intake or exhaust restriction

Engine effect

- Incorrect or failed thermostat
- Failed Variable Geometry Turbocharger (VGT) operation
- Oil aeration
- Fuel system leaks
- Base engine performance loss

Procedure

1. Review operator records and fueling procedures. Measurement errors are common. Fuel consumption taken only from one tank of use is susceptible to significant error because of filling procedures and vehicle application differences during operation. Accurate fuel consumption must be measured over time with a record of what the vehicle was doing during the measurement period.
2. Loss of fuel economy is normal if winter blend fuel or No. 1 diesel fuel is being used.
3. Review vehicle specifications to determine if fuel consumption is normal for type of application and use of vehicle. (Compare consumption with similar vehicles in the same application and Truck Computer Analysis of Performance and Economy (TCAPE) report.
4. Do all tests on Performance Diagnostic form or in Section 6 of this manual. These tests will verify the operating condition of the following engine and chassis systems:
   - Intake system
   - Exhaust system
   - Fuel delivery and filtration
   - High-pressure oil system
   - Injector operation
   - VGT operation
   - Oil aeration
   - Base engine condition
   - Electronic control system condition

   If all tests are passed, the engine is operating normally.

Fuel in Coolant

Symptom

Coolant contaminated with diesel fuel will have a diesel fuel odor.

Cause

- Leaking or cracked injector sleeve with injector O-ring failure
- Cracked or porous head casting in fuel rail cross-drillings.

Tools

- Regulated compressed air
- Fuel Test Fitting
- Fuel/Oil Pressure Test Coupler
- Cylinder head test plate
- Water supply housing pressure adapter
- Thermostat opening pressure adapter (cylinder head)

Procedure

1. Verify coolant contamination.
   - Check for diesel fuel odor in coolant.
   - Coolant may be discolored if diesel fuel is present.

   CAUTION: Be sure to place a rag or suitable container under the fuel pressure test valve when bleeding the fuel rail. Dispose of fuel in a correct container clearly marked DIESEL FUEL according to local regulations.

   NOTE: Engine fuel can be a threat to the environment. Never dispose of engine fuel by putting it in the trash, pouring on the ground, in the sewers, in streams, or bodies of water.
2. Plug in the cylinder block heater to warm coolant.

WARNING: To avoid serious personal injury, possible death and damage to the engine:

- **Always allow the engine to cool for 15 minutes.**
- **Wrap a thick cloth around the cap.**
- **Loosen cap slowly a quarter to half turn.**
- **Pause for a moment to avoid water or steam scalding.**
- **Continue to turn the cap and remove.**
- **Never add cold coolant to a hot engine. This can result in a cracked cylinder head or crankcase.**
- **Never use water as a coolant substitute.**

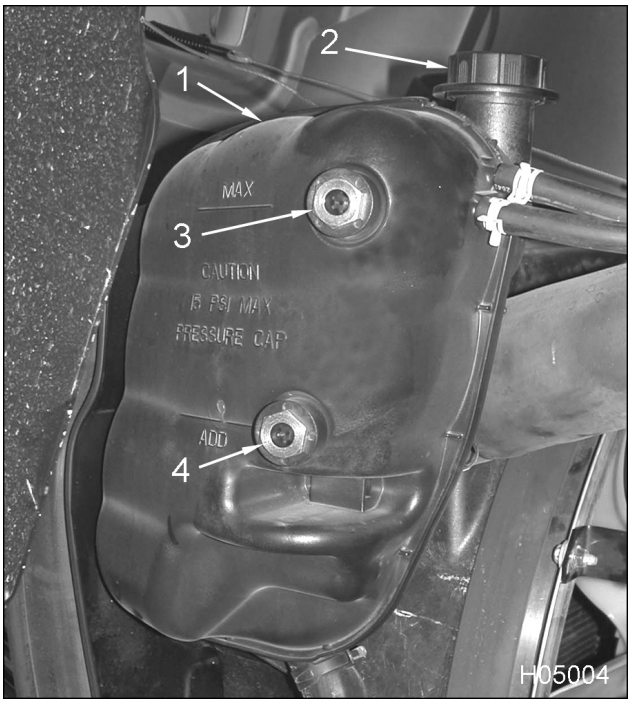

Figure 129 Deaeration tank fill position

1. Deaeration tank cap
2. Deaeration tank
3. MAXIMUM coolant level mark
4. ADD coolant level mark

3. Remove cap from deaeration tank and fill with coolant to a level above the deaeration inlet line to tank.

Figure 130 Shrader valve assembly

1. Valve
2. Center stem

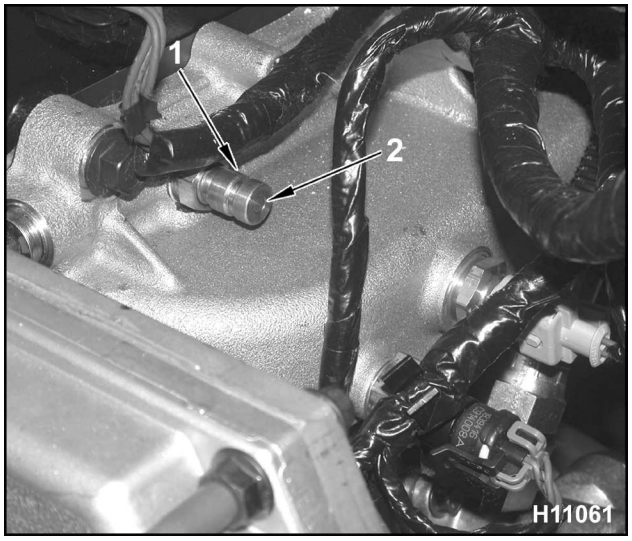

Figure 131 Diagnostic coupling

1. Valve
2. Center section

NOTE: Engines are equipped with a fuel pressure test valve in the form of either a Shrader valve or a diagnostic coupling.

4. Pressurize fuel rail with air from the fuel pressure test valve on the intake manifold to 550 kPa to 690 kPa (80 psi to 100 psi) using the fuel line test adapter. Observe deaeration tank for air bubbles.
   - If air bubbles appear in deaeration tank, do step 5.
   - If air bubbles do not appear in deaeration tank, do step 6.

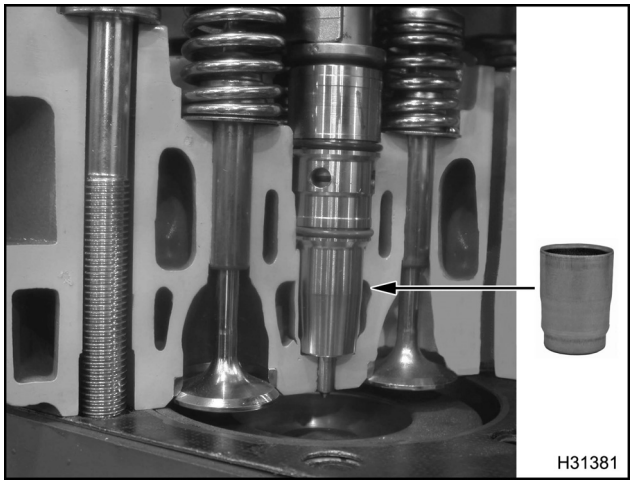

Figure 132 Injector cut-away with injector sleeve

5. Remove all injectors and inspect O-rings and injector sleeves for damage.
   - If any injector O-ring or injector sleeve appears damaged, clean the injector and replace O-rings or injector sleeves. Test the system again. Do step 4.
   - If injector O-rings or injector cups are not damaged, do step 6.
6. Remove, inspect, and pressurize the cylinder head following the procedure in the *Engine Service Manual*.

Coolant Leak to Exhaust

Symptom

- Coolant residue at exhaust manifold flanges
- Observation of coolant loss without engine overheating
- Excessive white smoke from exhaust pipe on start up (hot or cold)
- Coolant smell in exhaust
- Coolant leaking from muffler
- Severe case – engine hydraulic lock

Cause

- Failed EGR cooler
- Injector cup and gasket leak
- Intake side of cylinder head cup plugs leaking
- Porosity in cylinder head casting

Tools

- Regulated compressed air
- Water supply housing pressure adapter
- Radiator pressure testing kit and plastic surge cap adapter
- EGR cooler pressure test plates (2)

Procedure

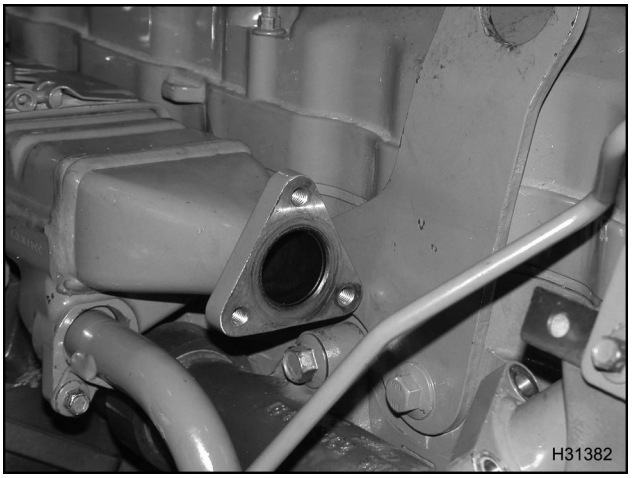

Figure 133 EGR cooler without cross-over tube

1. Remove EGR crossover tube assembly following the procedure in the *Engine Service Manual*.
2. Check for presence of coolant in EGR cooler and tube.
3. Plug in the cylinder block heater to warm coolant.
4. Install radiator pressure tester with the appropriate adapter.

   WARNING: To avoid serious personal injury, possible death and damage to the engine:

   - **Always allow the engine to cool for 15 minutes.**
   - **Wrap a thick cloth around the cap.**
   - **Loosen cap slowly a quarter to half turn.**
   - **Pause for a moment to avoid water or steam scalding.**
   - **Continue to turn the cap and remove.**
   - **Never add cold coolant to a hot engine. This can result in a cracked cylinder head or crankcase.**
   - **Never use water as a coolant substitute.**
5. Pressurize cooling system to 96 kPa (14 psi).
6. Check EGR cooler for the presence of coolant.
   - If coolant is present, replace EGR cooler following the procedure in the *Engine Service Manual*.
   - If no leak is found, do step 7.

     If pressure is dropping rapidly, coolant may be leaking from the EGR cooler into the exhaust manifold or tail pipe.
7. Drain coolant from the system.
8. Remove EGR cooler following the procedure in the *Engine Service Manual*.

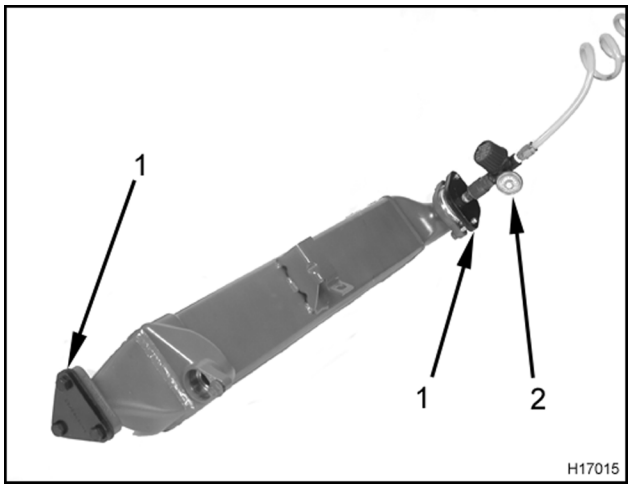

Figure 134 EGR cooler pressure test

1. EGR cooler pressure test plates (2)
2. Air pressure regulator

9. Bolt EGR cooler pressure test plates to each end of the cooler assembly.
10. Use regulated air pressure and apply no more than 207 kPa (30 psi) to the EGR cooler assembly.
11. Submerge the EGR cooler assembly into a tank of water. Watch for air bubbles leaving the cooler.
    - If a leak is noticed, replace the EGR cooler.
    - If a leak is not noticed, install the EGR cooler.
12. Fill cooling system.
13. Pressurize cooling system to 96 kPa (14 psi).
14. Inspect cylinder head (removing components as required) for cracks, porosity, and leaking cup plugs.

Coolant Over-Temperature

Symptom

When the coolant temperature is above 107 °C (224 °F), DTC 325 will be set and the control system will command less fueling. A power loss may also occur.

When the coolant temperature is above 109 °C (228 °F), the red ENGINE lamp will be illuminated and DTC 321 will be set.

When the coolant temperature is above 112 °C (234 °F), the red ENGINE lamp will flash, an audible alarm will sound, and DTC 322 will be set. If the vehicle has the warning protection feature enabled, the engine will shutdown after 30 seconds.

Cause

- Low engine coolant level
- External coolant leaks
- Internal or external radiator blockage
- Broken/worn accessory drive belt
- Accessory belt tensioner failure
- Coolant thermostat stuck (closed)
- Slipping cooling fan drive clutch
- Water pump failure
- Cooling fan blade assembly wrong/damaged
- Inoperative electric cooling fan
- Instrument panel gauge error
- Engine Coolant Temperature (ECT) sensor biased
- Incorrect radiator
- Missing coolant thermostat
- Internal coolant leak
- Chassis effects, transmission, after-market equipment

Tools

- Radiator pressure test kit and adapter
- Regulated compressed air
- EST with MasterDiagnostics® software
- EZ-Tech® interface cable
- Digital Multimeter (DMM) with thermocouple

Coolant System Inspection

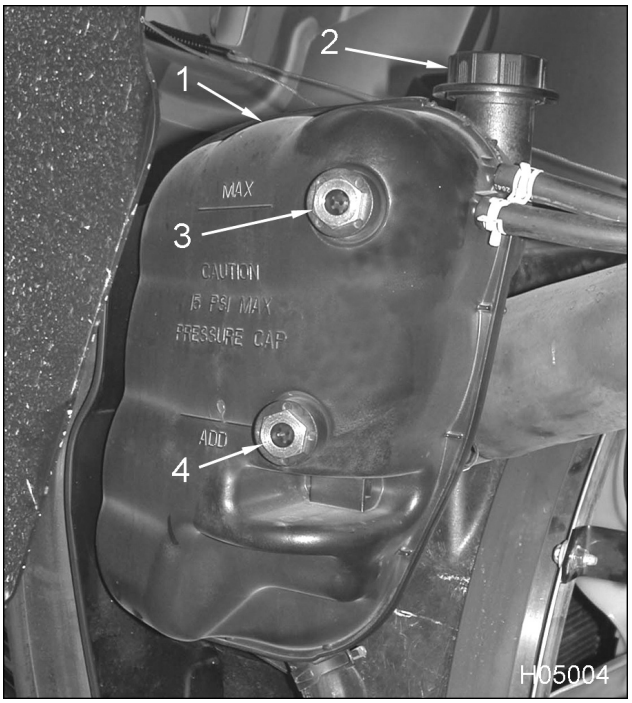

Figure 135 Deaeration tank components

1. Deaeration tank cap
2. Deaeration tank
3. MAXIMUM coolant level mark
4. ADD coolant level mark

1. Check coolant deaeration tank for contamination and correct fill level.
   - If coolant level is low, do step 2.
   - If coolant level is correct, do step 6.
   - If coolant is contaminated with oil, go to “Lube Oil in Coolant” (page 122).
2. Inspect for coolant leaks. Check for external leaks from coolant hoses, radiator, heater core, engine, or cylinder head cup plugs. Check for coolant in oil.
   - If any external leaks are found, repair and fill cooling system. Test again for over-temperature condition.

- If oil is contaminated with coolant, go to “Coolant in Lube Oil” (page 109) in this section.
- If no leaks are found, do step 3.

WARNING: To avoid serious personal injury, possible death and damage to the engine:

- **Always allow the engine to cool for 15 minutes.**
- **Wrap a thick cloth around the cap.**
- **Loosen cap slowly a quarter to half turn.**
- **Pause for a moment to avoid water or steam scalding.**
- **Continue to turn the cap and remove.**
- **Never add cold coolant to a hot engine. This can result in a cracked cylinder head or crankcase.**
- **Never use water as a coolant substitute.**

3. Fill cooling system to the maximum coolant level mark.

Figure 136 Coolant crossover pipe drain valve

4. Start the engine.
5. Purge all air out of system by opening the coolant crossover pipe drain valve. Close the port when coolant appears.

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, use extreme caution when purging air out of the cooling system.

6. Test again for over-temperature condition
   - If the engine is not running over-temperature, do step 7.
   - If the engine continues overheating, do step 9.
7. Install radiator pressure tester with the appropriate adapter.
8. Pressurize the cooling system to 96 kPa (14 psi)
   - If coolant is leaking externally, identify the leak and repair.
   - If coolant is not leaking externally, but the pressure is dropping, see “Coolant Leak to Exhaust” (page 117) and “Coolant in Lube Oil” (page 109) in this section.
9. Inspect the condition of the following items: cooling fan blade, shroud, accessory drive belt, accessory drive belt tensioner, cooling fan drive clutch, operation of electric or air fan, and radiator.

   CAUTION: To avoid radiator damage, when using high pressure washer, be careful not to damage radiator fins with wand.
   - If vehicle is new or recently repaired, verify the correct part number for any component related to the cooling system.
   - If the radiator cooling fins are blocked due to a build-up of dirt or debris, use a power washer to clean blockage from radiator fins or any debris on the cooling fan and fan drive clutch.
   - If no problems are identified, go to “Temperature Electrical System Test” (page 120) in this section.

Temperature Sensor Validation Test

1. Install EST and check for active and inactive DTCs related to engine coolant over-temp conditions.
   - If any DTCs remain relating to coolant over-temp condition, correct DTC before continuing.

- If no DTCs exist, do step 2.

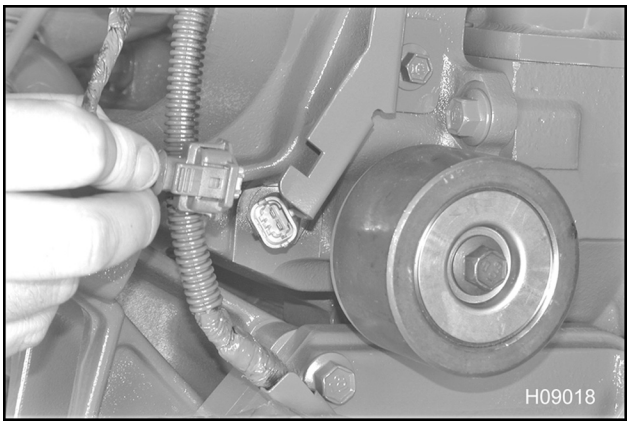

Figure 137 ECT sensor location

2. Using the EST, compare Engine Coolant Temperature (ECT), Engine Oil Temperature (EOT), and Manifold Air Temperature (MAT) with Key On Engine Off. All of the sensors should read within 2° C (5° F) of each other.

   NOTE: This is only accurate if done after a cold soak of at least 8 hours on the engine.

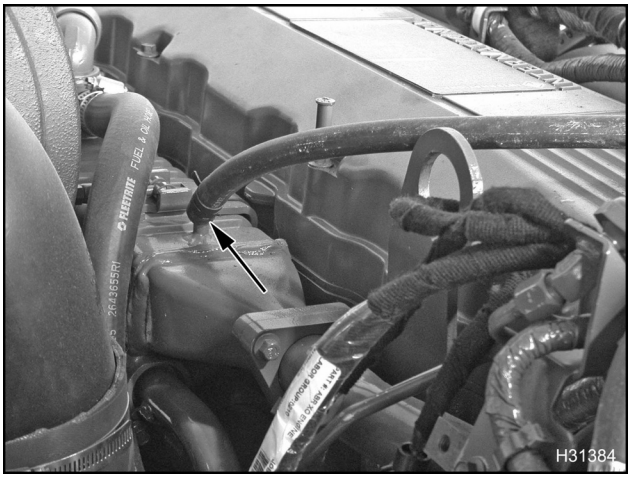

Figure 138 EGR coolant outlet port

3. Install a manual gauge or DMM with a thermocouple in the EGR cooler inlet port, operate the engine, and use the EST to monitor ECT.
4. Run engine up to an operating temperature of at least 70° C (158° F). While monitoring ECT using the EST, instrument panel coolant temperature gauge and the mechanical or electrical gauge. Attempt to duplicate the operator's concern of coolant over-temp.
   - If instrument panel coolant temperature gauge reads a different temperature than the EST and test gauge, refer to the *Electrical System Troubleshooting Guide* for the appropriate model and year of vehicle.
   - If test gauge and EST read values with a difference greater than +/- 3° C (+/- 5° F), do Electronic Control Systems Diagnostics for ECT circuit found in Section 7 of this manual.
   - If the gauge is reading correctly and the engine is running over-temperature, go to "Cooling System Operating Pressure Test" (page 121) in this section.

Cooling System Operating Pressure Test

1. Install the radiator pressure tester on the deaeration tank and run engine at elevated idle. Monitor the pressure in the system using the tester gauge to see if pressure rises above normal value of deaeration tank cap.
   - If pressure is higher than the pressure rating of the cooling system cap, go to "Combustion Leaks to Coolant" (page 102) in this section.
   - If pressure gauge reading is below pressure rating of system, replace the thermostat.

Lube Oil in Coolant

Symptom

Coolant contaminated with lube oil will have oil in the deaeration tank.

Cause

- Oil cooler

Tools

- Oil cooler pressure test plate
- Air pressure regulator

Procedure

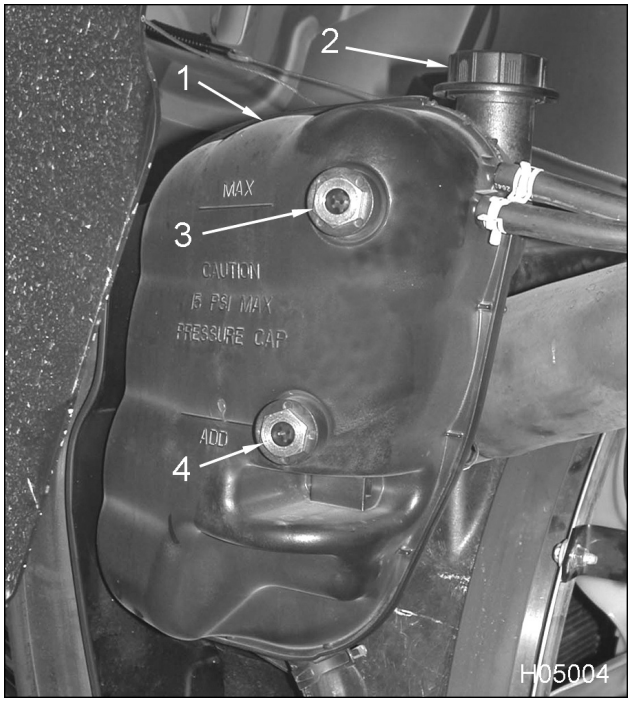

Figure 139 Deaeration tank fill position

1. Deaeration tank cap
2. Deaeration tank
3. MAXIMUM coolant level mark
4. ADD coolant level mark

WARNING: To avoid serious personal injury, possible death and damage to the engine:

- **Always allow the engine to cool for 15 minutes.**
- **Wrap a thick cloth around the cap.**
- **Loosen cap slowly a quarter to half turn.**
- **Pause for a moment to avoid water or steam scalding.**
- **Continue to turn the cap and remove.**
- **Never add cold coolant to a hot engine. This can result in a cracked cylinder head or crankcase.**
- **Never use water as a coolant substitute.**

1. Verify if coolant is contaminated by inspecting deaeration tank for presence of oil.
2. Place a coolant drain pan under the oil system module.

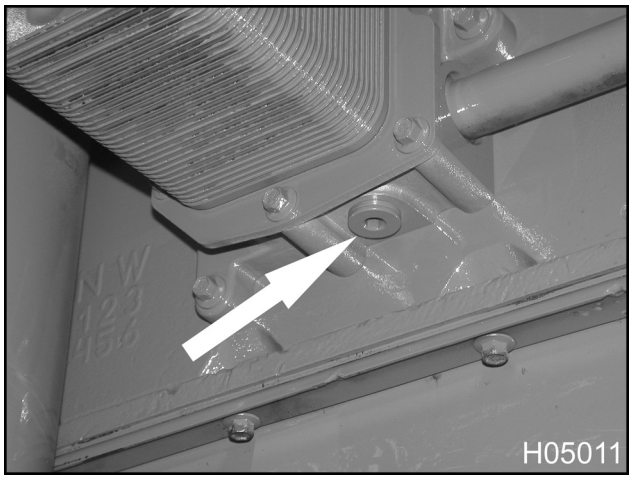

Figure 140 Coolant drain plug

3. Remove the coolant drain plug located at the bottom of the oil system module. Drain coolant

   NOTE: Replace O-ring with a new O-ring when installing the coolant drain plug.

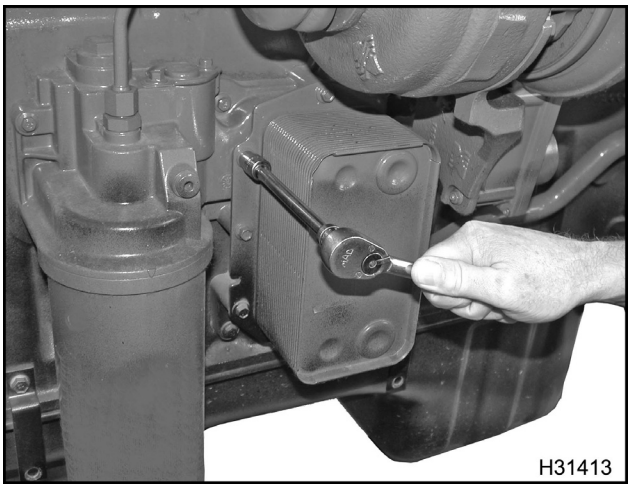

Figure 141 Removing oil cooler

4. Remove the eight bolts (M8 x 20) securing the oil cooler to the oil cooler housing. Separate the oil cooler from the oil cooler housing.

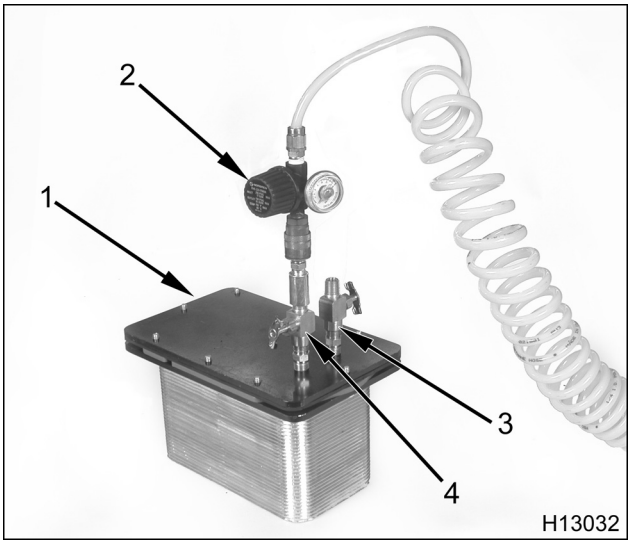

Figure 142 Checking the oil cooler for internal leakage

1. Test plate set
2. Air pressure regulator
3. Coolant port (open)
4. Oil port

5. Pressure test the oil cooler following the procedure in the *Engine Service Manual*. If a leak is noticed, replace the oil cooler.

Fuel in Lube Oil

Symptom

Oil contaminated with diesel fuel will cause the oil level in engine to increase.

Cause

- Leaking fuel injector or injector O-ring (A leaking injector sleeve or injector tip could cause contaminated engine oil, but would most likely be identified as a performance problem.)
- Cracked or porous cylinder head casting in fuel rail area cross-drillings

Tools

- 2 oz of fuel dye
- UV Leak Detection Kit (black light)
- Fuel pressure gauge kit
- Fuel pressure test adapter
- Fuel/Oil Pressure Test Coupler
- 1 to 5 gallon bucket
- Inspection mirror

Procedure

NOTE: The black light requires warm-up time. Turn on the black light

1. Verify oil contamination.

   NOTE: Other issues that may contribute to fuel dilution beside fuel injectors, include the following:

   - Hard starting
   - Running rich (strong fuel odor)
   - Valve related issue

   If the engine is mechanically sound and the oil has been changed, diagnose for fuel in the oil with dye.

2. Remove the fuel filter housing cap.

   NOTE: If the fuel filter housing cap is out of the system for an extended time, the O-ring will swell and needs to be replaced.

3. Add 2 oz fuel dye to the fuel filter housing.

   NOTE: Use only recommended dye, manufactured by Balkamp, Inc., available at local NAPA Auto Parts stores, part number 765-2661.

4. Install the fuel filter housing cap.

CAUTION: Be sure to place a rag or suitable container under the fuel pressure test valve when bleeding the fuel rail. Dispose of fuel in a correct container clearly marked DIESEL FUEL according to local regulations.

NOTE: Engine fuel can be a threat to the environment. Never dispose of engine fuel by putting it in the trash, pouring on the ground, in the sewers, in streams, or bodies of water.

Figure 143 Shrader valve assembly

1. Valve
2. Center stem

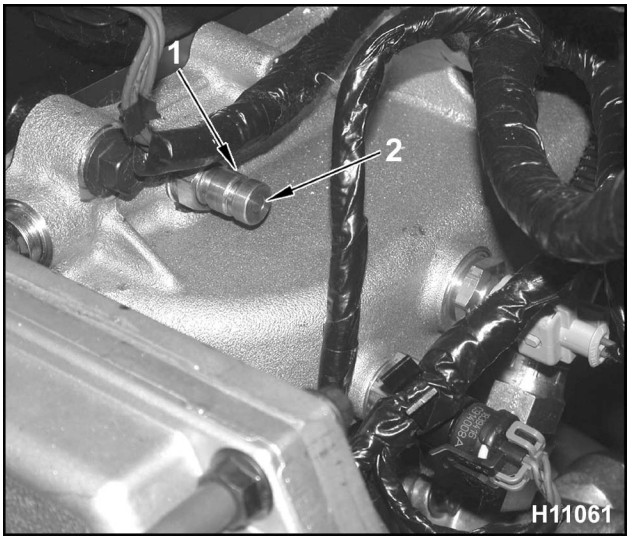

Figure 144 Diagnostic coupling

1. Valve
2. Center section

NOTE: Engines are equipped with a fuel pressure test valve in the form of either a Shrader valve or a diagnostic coupling.

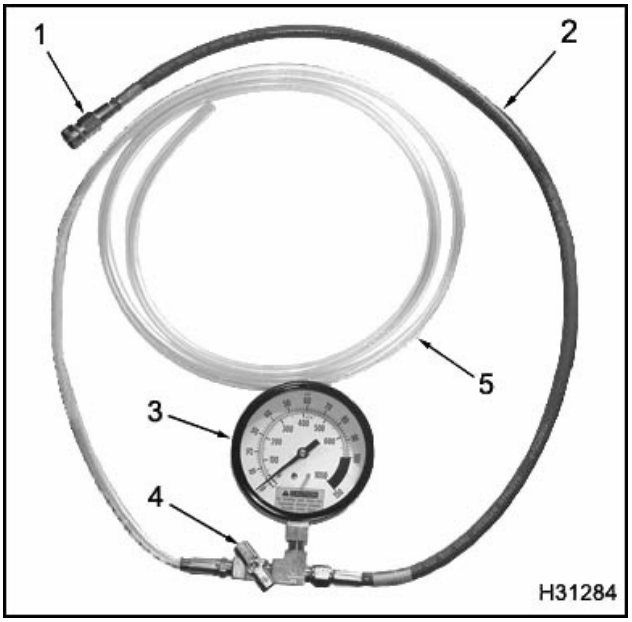

Figure 145 Fuel Pressure Gauge

1. Quick disconnect check valve
2. Fuel test line
3. Fuel Pressure Gauge
4. Inline shut-off valve
5. Clear test line

Figure 146 Fuel Pressure Test Adapter

NOTE: If the engine is equipped with a Shrader valve, use the Fuel Pressure Test Adapter.

Figure 147 Fuel/Oil Pressure Test Coupler

NOTE: If the engine is equipped with a diagnostic coupling, adapt the Fuel/Oil Pressure Test Coupler to the Fuel Pressure Gauge.

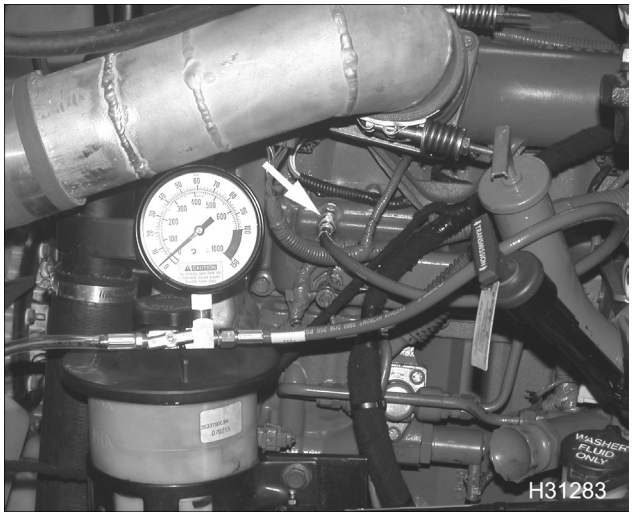

Figure 148 Fuel Pressure Gauge to fuel pressure test adapter

5. Connect a fuel pressure gauge with shut-off valve and clear 3/8” diameter hose to test valve.
6. Route the clear hose into a drain pan.
7. Open the gauge setup shut-off valve
8. Shine the black light at the fuel pressure gauge clear line. The dyed fuel will have a yellow-green fluorescent glow.
9. Using the priming pump, purge the fuel until the dyed fuel begins to flow from the pressure gauge clear hose.
10. Close the shut-off valve.
11. Remove the valve cover following the procedure in the *Engine Service Manual*.
12. Start and run the engine at low idle for 3 to 5 minutes.

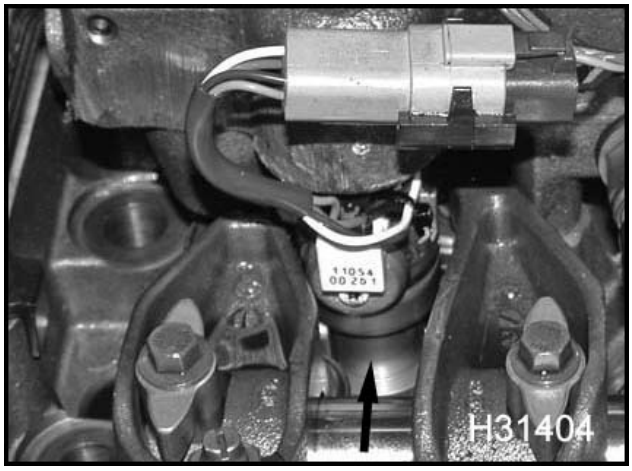

Figure 149 High-pressure oil rail with injector

13. While the engine is running, use the black light to inspect for yellow-green streams of dye running between the valve spring seats at each injector. A small mirror can aid in hard to reach areas.

    Inspection should take no longer than 5 minutes. Because disbursement of dye in the fuel, the amount of dye seen does not indicate severity of failure, only that a failure exists.

    NOTE: If no dye or leak is found after running engine, verify there is fuel dilution issue by oil analysis or observing an oil level increase.

    - If a leak is found, turn off the engine. Do steps 14 through 17.
    - If a leak is not found, turn off the engine. Continue with step 18.
14. Remove the high-pressure oil rail following the procedure in the *Engine Service Manual*.
15. Inspect remaining injectors for leaks. Failed injectors will have a solid yellow-green color around the intensifier body area (weep hole).
16. Relieve the pressure in the fuel system to avoid further contamination of oil.

17. Replace leaking fuel injector following the procedure in the *Engine Service Manual*.

    NOTE: If a set (six) of injectors must be replaced, contact International® Technical Services to start a case file.

18. Remove the high-pressure oil rail following the procedure in the *Engine Service Manual*.

19. Use the black light to inspect between each injector and hold-down clamp. Do not remove the injectors.

    - If a leak is found, do steps 20 and 21.
    - If no leak is found, do steps 22 through 24.

20. Relieve the pressure in the fuel system to avoid further contamination of oil.

21. Replace leaking fuel injector following the procedure in the *Engine Service Manual*.

    NOTE: If a set of injectors (six) must be replaced, contact International® Technical Services to start a case file.

22. Relieve the pressure in the fuel system to avoid further contamination of oil.

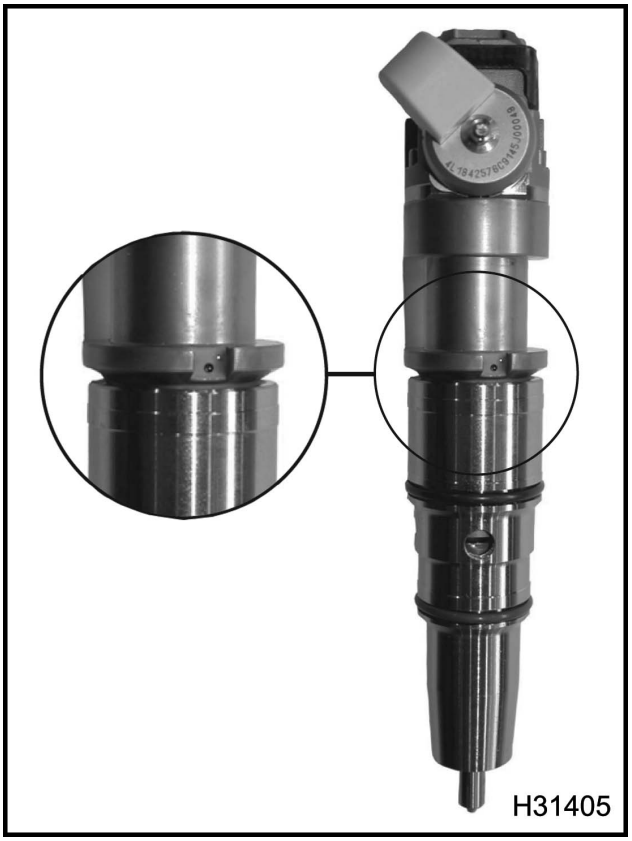

Figure 150 Fuel injector weep hole

23. Remove each injector (one at a time) following the procedure in the *Engine Service Manual*. Hold each fuel injector over their respective injector opening for several seconds to allow fuel to drain from injector. Inspect each injector.

24. Replace leaking fuel injector following the procedure in the *Engine Service Manual*.

    NOTE: If a set of injectors (six) must be replaced, contact International® Technical Services to start a case file.

Low Oil Pressure

Symptom

Low oil pressure can cause any or all of the following:

- Red ENGINE lamp
- DTC 313 – Engine oil pressure below warning level
- DTC 314 – Engine oil pressure below critical level
- Engine knock
- Engine hard start or no start condition
- Engine loss of power
- DTC 335 – ICP unable to build pressure during cranking
- DTC 333 – Injection control pressure above/below desired level

Cause

- Instrument panel gauge error
- Low oil level: oil leak, oil consumption or incorrect servicing
- High oil level: incorrect servicing, fuel in oil or coolant in oil
- Incorrect oil viscosity
- Incorrect EOP sensor
- Stuck oil pressure regulator
- Scored/damaged oil pump
- EOP sensor biased
- Broken, missing or loose piston cooling tube(s)
- Missing, damaged or worn bearing inserts or camshaft bushings
- Aeration (cracked pickup tube or pickup tube gasket)

Tools

- EST with MasterDiagnostics® software
- EZ-Tech® interface cable
- Gauge bar tool
- Air Regulator
- Shut-off valve

Oil Inspection

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.

1. Park vehicle on level ground.
2. Check oil level with oil level gauge.

   NOTE: Never check the oil level when the engine is running or immediately after the engine is shut down; the reading will be inaccurate. Allow 15 minute drain down time, before checking oil level.

   NOTE: If the oil level is too low, the fuel injectors will not work correctly. If the oil level is above the operating range, the engine has been incorrectly serviced, fuel is in the oil, or coolant is in the oil.

   - Engine oil level will vary depending on temperature of engine
   - If oil level is low, fill to the correct level and retest.
   - If oil level is at the correct level and not contaminated, do step 4.
3. Inspect oil for thickening and odor.

   NOTE: When the crankcase lube oil is contaminated with coolant, the oil will have a dark-gray or black sludgy appearance. The crankcase may also be overfilled.

   - If oil is contaminated, go to "Fuel in Lube Oil" (page 124) or "Coolant in Lube Oil" (page 109) test procedures located in this section.
   - If oil level is at the correct level and not contaminated, do step 4.
4. Measure pressure at low and high idle. The engine must be at operating temperature.

   - If oil pressure does not read within the specification listed in Appendix A in this Manual, go to "Oil Pressure Regulator Inspection" (page 129) in this section.
   - If oil pressure reads within specification listed in Appendix A in this Manual, compare mechanical gauge readings with instrument panel gauge and Engine Oil Pressure (EOP) value on the Electronic Service Tool (EST).

- If mechanical gauge and EST read values with a difference greater than +/- 14 kPa (+/-2 psi), perform Electronic Control Systems Diagnostics for the EOP circuit as described in Section 7 in this Manual.
- If instrument panel engine oil pressure gauge reads a different value than the EST and mechanical gauge refer to the *Electrical System Troubleshooting Guide* for the model and year of vehicle.

Oil Pressure Regulator Inspection

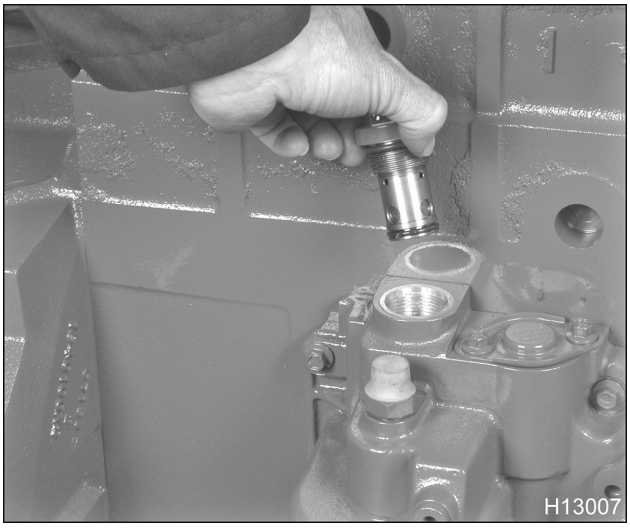

Figure 151 Oil pressure regulator

1. Remove and inspect oil pressure regulator as described in the *Engine Service Manual*.
   - The oil pressure regulator piston should move freely in its bore.
   - If oil pressure regulator is functional and passes inspection, install regulator following the procedure in the *Engine Service Manual*. Go to “Oil and Crankcase Inspection” (page 129) in this section.

Oil and Crankcase Inspection

1. Drain oil from engine. Inspect oil drain plug magnet, drained oil and oil filter for foreign debris.
   - An oil sample should be taken to determine level of engine wear metals and contaminants in the oil.

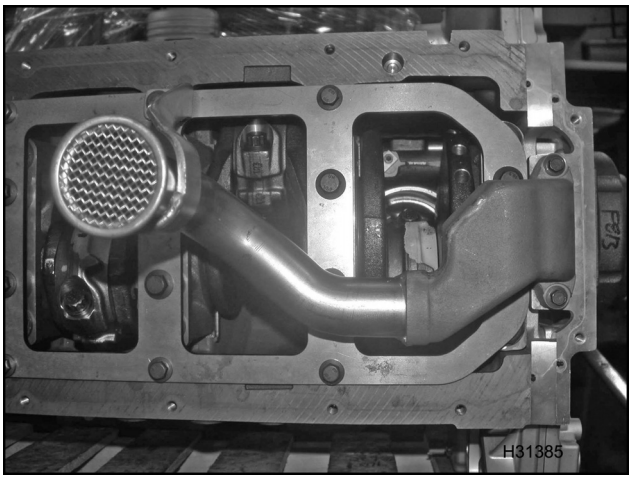

Figure 152 Bottom of engine

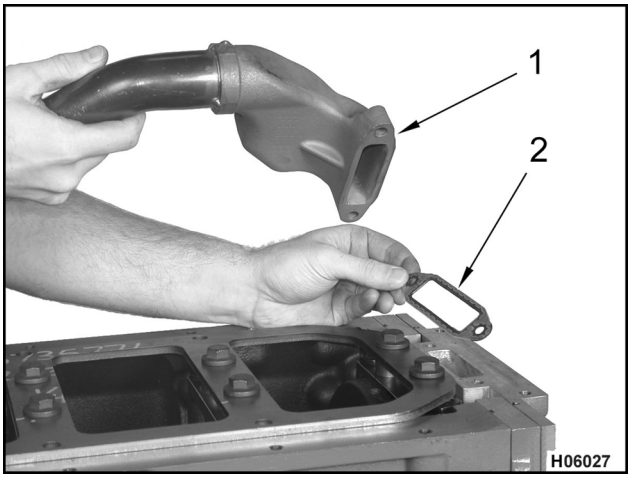

Figure 153 Oil pickup tube assembly and gasket

1. Oil pickup tube assembly
2. Gasket

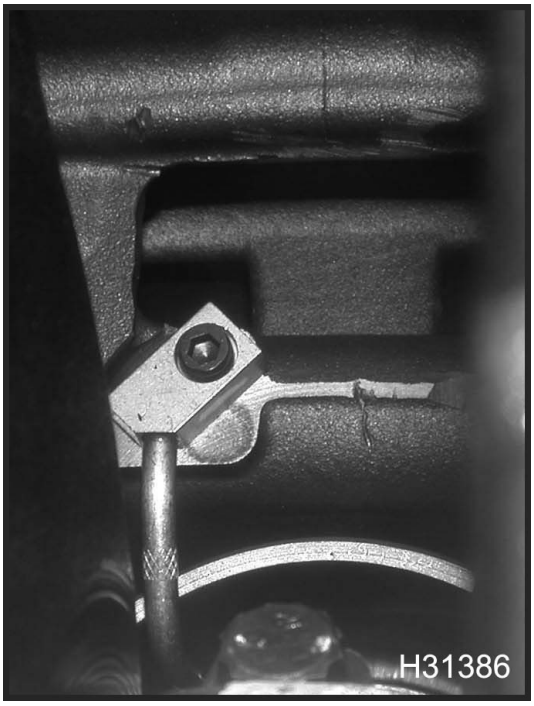

Figure 154 Piston cooling tube

2. Remove oil pan following the procedure in the *Engine Service Manual*.
3. Inspect for missing, loose, plugged or damaged oil pickup tube, pickup tube gasket, piston cooling tubes, bearing inserts, and cam bushings.
   - If unable to identify any damaged parts, Go to “Pressurized Oil System Leak Inspection” in this section.

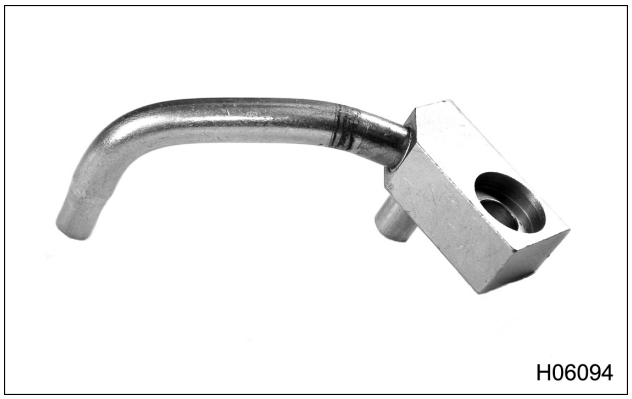

Figure 155 Old piston cooling tube

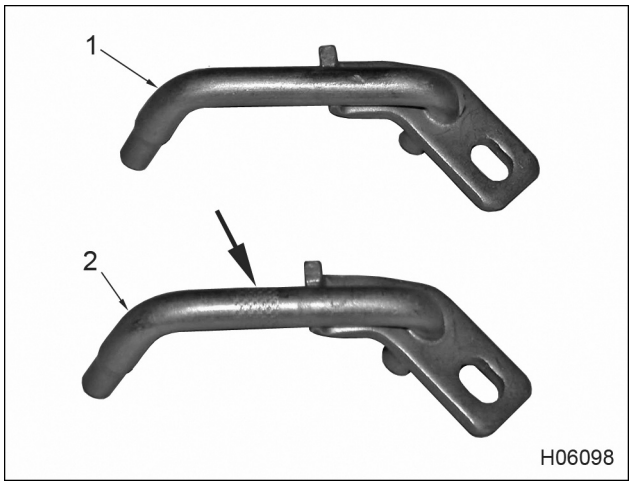

Figure 156 New piston cooling tubes

1. New piston cooling tube (unknurled) – DT 466 engines
2. New piston cooling tube (knurled) – DT 570 and HT 570 engines

NOTE: The piston cooling tube was redesigned. The new piston cooling tube is lighter and structurally stronger. The piston cooling tubes with knurling are used on the HT 570 and DT 570 engine. The piston cooling tubes without knurling are used on the DT 466 engine.

Oil Pump Inspection

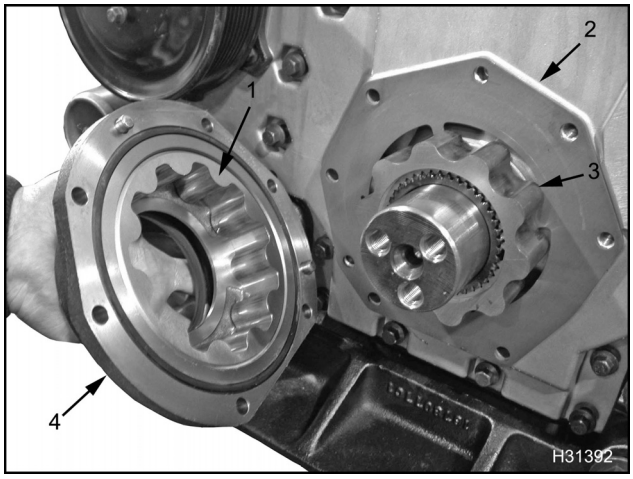

Figure 157 Oil pump housing cover

1. Outer gerotor
2. Oil pump housing plate
3. Inner gerotor
4. Oil pump housing

1. Remove and inspect the lube oil pump as described in the *Engine Service Manual*.
   - Inspect the lube oil pump housing and plate for gouging, deep scratches, or a discolored hot-scored appearance.
   - Inspect the gerotor gears for excessive wear or damage.
   - If no excessive damage is found, go to “Front Cover Inspection” (page 131) in this section.

Front Cover Inspection

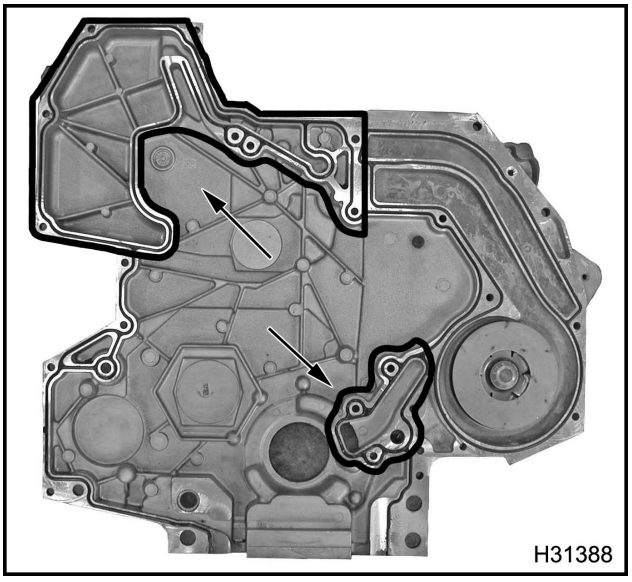

Figure 158 Front cover oil pressure leak locations

1. Remove the front cover assembly (front half) from the engine following the procedure in the *Engine Service Manual*. Inspect the front cover and front cover gasket for damage. Repair or replace and test.

Priming Fuel System

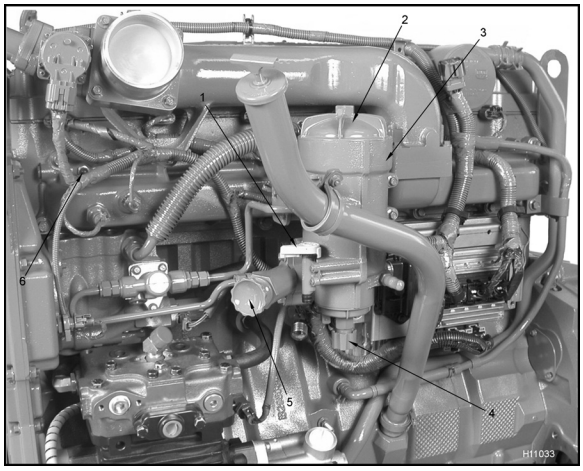

Figure 159 Fuel system components

1. Water drain valve
2. Fuel filter cover
3. Fuel filter header
4. Drain valve (fuel)
5. Fuel primer pump assembly
6. Fuel Pressure Test Valve

WARNING: To avoid personal injury, possible death or damage to the engine or vehicle, make sure the transmission is in neutral, 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 prime the fuel system.

WARNING: To avoid serious personal injury or possible death: do not allow engine fuel to stay on your skin. Clean your skin and nails with soap and water, or a good hand cleaner. Wash or properly throw away clothing or rags containing used engine fuel. Used engine fuel contains certain elements that may be unhealthy for skin.

CAUTION: Do not add fuel to the fuel filter header. This can add contaminates to the fuel.

Tools

- Fuel Pressure Gauge
- Fuel pressure test adapter
- Fuel Test Fitting
- Fuel/Oil Pressure Test Coupler
- 1 to 5 gallon bucket

If the engine runs out of fuel, do the following:

1. Set parking brake and place transmission control lever to NEUTRAL or PARK.
2. Verify that there is at least 15 liters to 19 liters (4 gallons to 5 gallons) of fuel in the tank.

NOTE: If your vehicle is equipped with dual fuel tanks, fill each tank with 15 liters to 19 liters (4 gallons to 5 gallons) of fuel.

3. Unlock the fuel primer pump assembly by turning the knob counter-clockwise.
4. Fill the fuel filter header and fuel rail by pumping the fuel primer pump.
5. Pump the system until enough pressure is built up. Typically, 20 to 30 pumps will build enough pressure. At this point, the pump plunger will become difficult to pump. Make sure the pump plunger is pushed in when finished. It is not necessary to lock the fuel primer knob at this time.
   - If the pump is working correctly and the pressure is built up, do step 11.
   - If the pump plunger does not pump on the first attempt, the fuel system may be full of compressed air. Do step 6.
   - If little pressure is felt after pushing the knob of the fuel primer pump several times, air must be bled from the fuel rail. Do step 8.

WARNING: To avoid serious personal injury or possible death, wear safety glasses with side shields when performing the following procedure.

CAUTION: Be sure to place a rag or suitable container under the fuel pressure test valve when bleeding the fuel rail. Dispose of fuel in a correct container clearly marked DIESEL FUEL according to local regulations.

NOTE: Engine fuel can be a threat to the environment. Never dispose of engine fuel by putting it in the trash, pouring on the ground, in the sewers, in streams, or bodies of water.

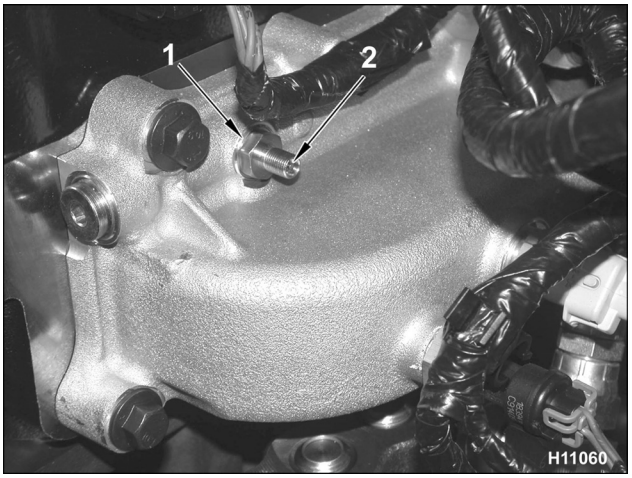

Figure 160 Shrader valve assembly

1. Valve
2. Center stem

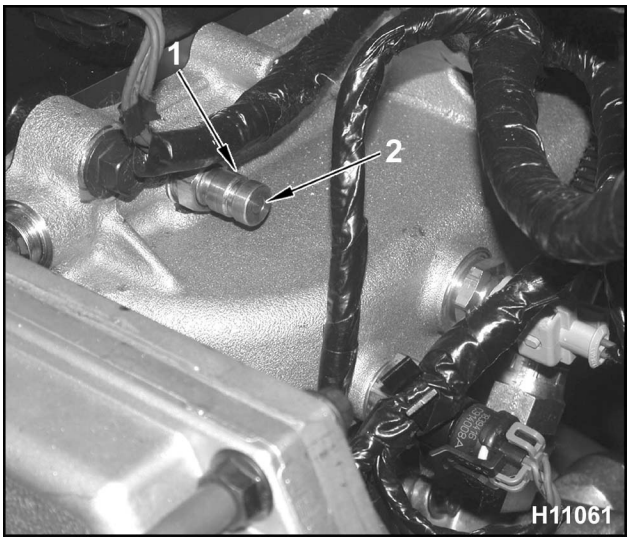

Figure 161 Diagnostic coupling

1. Valve
2. Center section

NOTE: Engines are equipped with a fuel pressure test valve in the form of either a Shrader valve or a diagnostic coupling.

6. Place either a shop rag or suitable container under the fuel pressure test valve.

NOTE: It is recommended to use the Fuel Pressure Test Adapter to avoid bending the needle in the Shrader valve. The Fuel Pressure Test Adapter is part of Fuel Pressure Test Kit ZTSE4657.

7. Depress the fuel pressure test valve center section.
   - If air is released, and you can now pump the primer hand pump, go to “Aerated Fuel” (page 104) in this section.
   - If unable to work the pump after releasing pressure from the fuel test valve, repair the fuel pump primer.

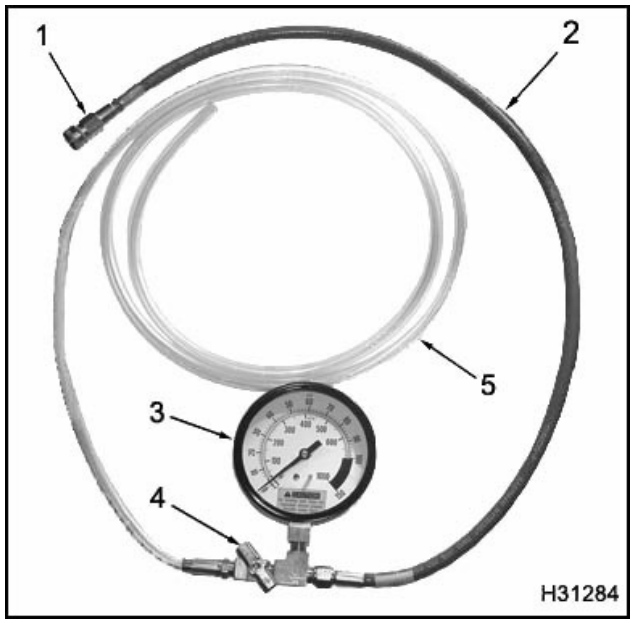

Figure 162 Fuel Pressure Gauge

1. Quick disconnect check valve
2. Fuel test line
3. Fuel Pressure Gauge
4. Inline shut-off valve
5. Clear test line

Figure 163 Fuel Pressure Test Adapter

NOTE: If the engine is equipped with a Shrader valve, use the Fuel Pressure Test Adapter.

Figure 164 Fuel/Oil Pressure Test Coupler

NOTE: If the engine is equipped with a diagnostic coupling, adapt the Fuel/Oil Pressure Test Coupler to the Fuel Pressure Gauge.

8. Install the Fuel Pressure Gauge with shut-off valve into the test port at the front of the intake manifold. Run the discharge hose into a bucket.
9. Open the shut-off valve. Pump the fuel primer pump knob until a steady stream of fuel flows out of the clear hose.
   - If fuel has air bubbles, go to “Aerated Fuel” (page 104) in this section.
   - If fuel flows without air bubbles, close shut-off valve. Do step 10.
10. Pump the fuel primer pump again to build pressure in the system. Lock down the knob.
11. Start the engine.
12. If the engine does not start in 20 seconds, repeat the priming procedure.
13. Once the engine starts, let it run for five to 10 seconds, then shut-off the engine. Turn the fuel primer pump knob clockwise to lock in place.
14. Remove fuel pressure test fitting (if used) and dispose of any fuel in correct container clearly marked DIESEL FUEL according to local regulations.

Rough Idle

Cause

- Engine oil (aerated, incorrect grade, low oil level, extended drain interval)
- Poor fuel quality
- Low fuel pressure
- Aerated fuel
- Electronic control system faults (ECM and IDM)
- Injection control pressure system problems
- Fuel injectors not working properly
- EGR valve stuck open
- Power cylinder problems
- Valve train problems
- Engine or flywheel balance problems
- Exhaust system to cab/chassis contact
- Loose/worn engine mounts

Procedure

1. Verify complaint. Confirm conditions when complaint is present.

   When does engine rough idle occur?

   - Hot – operating temperature
   - Cold
   - After high speed operation
   - Over entire engine speed range
   - Combination of the above conditions
   - Is there chassis vibration or any other conditions/observations present when engine idles rough.

2. Inspect exhaust system for contact with cab, frame or body of vehicle.

   Engine exhaust pipe contact with cab may transmit engine vibrations to cab, especially on acceleration or engine shifts. This condition may be incorrectly diagnosed as a rough idle complaint.

Complete the following tests on the Performance Diagnostic form. See “Performance Diagnostics” – Section 6 (page 205) in this manual for specific details on each test.

3. Do Test 1 (Diagnostic Trouble Codes) on Performance Diagnostics form. Intermittent sensor, injector or wiring harness faults can affect engine idle conditions. The ECM may have detected and recorded these conditions.
4. Do Test 2 (KOEO Standard Test) on Performance Diagnostics form. This test will verify electrical operation of actuators.
5. Do Test 3 (KOEO Injector Test) on Performance Diagnostics form. This test will verify that the injectors are working electronically.
6. Do Test 4 (Engine Oil) on Performance Diagnostics form. Check engine oil level. Verify correct oil grade for ambient temperature. See *Engine Operation and Maintenance Manual*, Engine Lubrication Requirements section. Confirm oil meets correct API specification for your model and year of engine.
7. Do Test 5 (Fuel) on Performance Diagnostics form. Verify quality and quantity of diesel fuel. Poor quality fuel or low cetane rating can cause white smoking, engine misfire, and low power. See *Engine Operation and Maintenance Manual*, Fuel Requirements section for your model and year of engine to determine minimum necessary fuel grade and cetane rating.
8. Do Test 6 (Fuel Pressure and Aerated Fuel) on Performance Diagnostics form. Measure fuel pressure at fuel rail (intake manifold). Low fuel pressure, aerated fuel, and fuel inlet restriction will cause the engine to misfire and a loss of power.
9. Do Test 9 (KOER Standard Test) on Performance Diagnostics form. This test will verify the functionality of the injection control pressure system. The engine must be at operating temperature 70 °C (158 °F) to do this test.
10. Do Test 10 (Injection Control Pressure) on Performance Diagnostics form. This test will confirm if the injection control pressure system is functioning properly and verify injection control pressure stability.
11. Do Test 11 (Injector Disable) on Performance Diagnostics form. The primary function of this test is to show the contributions of the individual

power cylinders. The test will detect a weak cylinder which could be the result of an injector or base engine problem.

- Test 11 is used in conjunction with Test 12 (Relative Compression) to distinguish between an injector or mechanical problem.

12. Do Test 12 (Relative Compression) on Performance Diagnostics form. This will verify base engine compression.
    - Test 12 is used in conjunction with Test 11 (Injector Disable) to distinguish between an injector or mechanical problem.
13. Do Test 16 (Crankcase Pressure) on Performance Diagnostics form. This test will determine the condition of the power cylinders and base engine.
14. Inspect for engine and flywheel balance. Engine roughness at idle that gets worse with a no load acceleration may be caused by an out of balance condition.

    WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, support the vibration damper during mounting bolt removal. The damper can slide off the nose of the crankshaft very easily.

    - Following the procedure in the *Engine Service Manual* remove the vibration damper and inspect the elastomer layer for cracks and misalignment. If no problem is found, install vibration damper following the assembly procedure found in the *Engine Service Manual*. Verify that locating dowel on the end of the crankshaft pulley is aligned with locating hole in the balancer for proper installation.
    - Isolate the engine from transmission by removing the transmission, clutch and pressure plate or torque converter. Start the engine and evaluate for roughness. If the engine runs smooth, replace the torque converter or replace clutch and pressure plate.
    - Following the procedure in the *Engine Service Manual*, remove the flywheel and verify proper orientation. If orientation is correct, replace or rebalance flywheel. When removing/installing the flywheel, ensure that the locating dowel is in the right place and that the flywheel is located properly on the dowel.
    - For new engines only remove the oil pan following the procedure in the *Engine Service Manual*. Inspect the crankshaft counterweights to ensure balance holes exist.

Smoke

Two types of smoke conditions can occur, black and white. Dark-gray smoke is considered black smoke. Light-blue smoke is considered white smoke.

Refer to the following corresponding smoke condition for symptom, cause, and diagnostic procedure.

Black Smoke

Cause

- Air intake or exhaust restriction
- Turbocharger failure, turbocharger blade damage or turbocharger wheel stuck
- Loose or failed injector
- Altitude (black smoke on hard acceleration or snap acceleration may be more pronounced at higher elevations)
- Failed Manifold Absolute Pressure (MAP) sensor
- Failed Exhaust Back Pressure (EBP) sensor
- Failed Injection Control Pressure (ICP) sensor

Procedure

1. If engine has fuel knock or there is evidence of fuel in the exhaust, remove exhaust manifolds and inspect for fuel in the exhaust ports. (Suspect loose injectors, missing or damaged O-ring and gasket on bottom of injector).
2. Inspect air inlet system and exhaust system for possible sources of restriction.
3. Inspect turbocharger for oil leakage or failure of blades.
4. Do Test 7 (Intake Restriction) on Performance Diagnostics form or in Section 6 of this manual.
5. Do Test 8 (Exhaust Restriction) on Performance Diagnostics form or in Section 6 of this manual.

White Smoke

Cause

- Cold engine
- No Intake Air Heater (IAH) operation
- Poor quality fuel
- EGR stuck open on startup
- EGR cooler leaking coolant into exhaust
- Loose or failed injector
- Bent connecting rods
- Worn piston rings
- Low compression
- Coolant leaking into the intake manifold through the cylinder head cup plugs
- Coolant leaking into combustion chamber
- Aerated fuel

Procedure

1. In cold ambient temperatures, some white smoke is normal until the engine is up to operating temperature.
   - Ensure that engine is up to operating temperature 88 °C (190 °F) prior to verifying a white smoke complaint.
   - If the engine is unable to obtain operating temperature during a road test, verify thermostat opening temperature 88 °C (190 °F).
2. Do Test 15 (Inlet Air Heater System) on Hard Start and No Start Diagnostics form to verify inlet air heater operation.
3. Do Test 5 (Fuel) on Performance Diagnostics form. Verify quality and quantity of diesel fuel. Poor quality fuel or low cetane rating can cause white smoking, engine misfire and low power. See *Engine Operation and Maintenance Manual*, Fuel Requirements section for model and year of engine to determine minimum necessary fuel grade and cetane rating.
4. Do Test 6 (Fuel Pressure and Aerated Fuel) on Performance Diagnostics form to verify aerated fuel.
5. Do Test 11 (Injector Disable) and Test 12 (Relative Compression) on Performance Diagnostics form to identify failed injector or weak power cylinder.
6. Do Test 16 (Crankcase Pressure) to measure condition of power cylinders.

7. If there is coolant loss without engine overheating, check for coolant in exhaust.
   - If coolant is leaking from exhaust or can be smelled in the exhaust, go to “Coolant Leak to Exhaust” (page 117) in this section.
8. If engine has fuel knock or evidence of fuel in exhaust, remove exhaust manifolds and inspect for fuel in the exhaust ports. (Suspect loose injectors, missing or damaged O-ring and copper gasket on bottom of injector).
9. Inspect air induction system for evidence of water ingestion or evidence of unfiltered air entering the engine.
   - Water ingestion could have caused a hydraulic lock and bent connecting rods. If water ingestion is suspected, identify smoking cylinders by removing exhaust manifolds and running engine.
   - Unfiltered air entering the engine can cause excessive power cylinder wear and turbocharger compressor blade damage. If power cylinder wear is suspected, identify smoking cylinder(s) by removing exhaust manifolds and running engine.
   - If coolant is found in the intake manifold, check cylinder head cup plugs and intake manifold. Go to “Coolant Leak to Exhaust” (page 117) in this section.
10. If engine is overheating with coolant loss, and cylinder head gasket or injector sleeve is suspected for leaking, go to “Combustion Leaks to Coolant” (page 102) in this section.

Low Power (Turbocharger Assembly and Actuator)

Symptom

Excessive low power on take-off or intermittent low power from drive cycle to drive cycle

Cause

- Electrical power or ground issue
- Inoperative turbocharger assembly
- Failed turbocharger actuator

Tools

- Digital Multimeter (DMM)
- Turbo Breakout Harness
- 12-pin Breakout Harness

Procedure

1. Turn the ignition switch to OFF.
   a. Move turbocharger linkage through its full range of motion by hand. Linkage should move smoothly and not chatter or hesitate.
   b. Do a bounce test by moving turbocharger linkage all the way out towards frame rail and let it go. Linkage should move towards engine, bounce, and stay there.
      - If linkage moves smoothly, do step 2.
      - If linkage does not move smoothly, remove turbocharger actuator and move linkage through its full range of motion.
        — If linkage moves smoothly, replace turbocharger actuator.
        — If linkage does not move smoothly, replace turbocharger assembly.
2. Turn the ignition switch to ON. Watch turbocharger linkage during pre-cycle movement. Linkage should move all the way out towards frame rail, move all the way back in towards engine, and move back out about half way.

   Check pre-cycle three times with at least three seconds of key-off time between tests. Linkage should move through pre-cycle smoothly and not chatter, vibrate, hesitate or slow down during pre-cycle. Each pre-cycle should be completed in less than one second.

   NOTE: When pre-cycle is complete with key-on engine-off, the linkage should not move by hand.

   - If pre-cycle fails, do step 3.
   - If pre-cycle passes, the turbocharger or actuator may not be cause of low power.
     — Verify that all tests on Performance Diagnostic form do not indicate another cause.
     — If the low power complaint is intermittent, and all tests on Performance Diagnostic form do not indicate another cause, do step 3.
3. Connect turbocharger breakout harness between engine harness and actuator harness. Measure voltage between actuator power and ground terminals with key-on engine-off.
   - If pre-cycle fails, and voltage is 10 V or more, replace the actuator.
   - If low power complaint is intermittent, and voltage is 10 V or more, inspect turbocharger power and ground wires for corroded or loose connections.
     — If power and ground wires are properly connected, not corroded, and performance diagnostic tests do not indicate another cause of low power, replace the actuator.
   - If voltage is low, repair low voltage problem. See “VGT Actuator” in Section 7 (page 524).
     — Go to step 2 and test again.

   NOTE: The turbocharger actuator can be tested again with a known good power and ground supplied directly through turbocharger actuator breakout harness.