DIAGNOSTIC/TROUBLESHOOTING MANUAL

EGES-395

November 2008

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Foreword

Navistar, Inc. is committed to continuous research and development to improve products and introduce technological advances. Procedures, specifications, and parts defined in published technical service literature may be altered.

NOTE: Photo illustrations identify specific parts or assemblies that support text and procedures; other areas in a photo illustration may not be exact.

This manual includes necessary information and specifications for technicians to maintain International® diesel engines. See vehicle manuals and Technical Service Information (TSI) bulletins for additional information.

International® MaxxForce™ 5 Series Service Literature

Number*	Description
1171940R2	International® MaxxForce™ 5 *Operation and Maintenance Manual*
EGES-390	International® MaxxForce™ 5 *Engine Service Manual*
EGES-395	International® MaxxForce™ 5 *Diagnostics Manual*
EGED-410	International® MaxxForce™ 5 Electronic Control Systems Form
EGED-400	International® MaxxForce™ 5 Diagnostic Form

* - Publication with the latest revision will be furnished.

NOTE: A dash (-) and a numeral after the form number indicate revision level.

Technical Service Literature is revised periodically and mailed automatically to “Revision Service” subscribers. If a technical publication is ordered, the latest revision will be supplied.

NOTE: To order technical service literature, contact your International® dealer.

Service Diagnosis

Service diagnosis is an investigative procedure to find and fix engine problems.

Prerequisites for Effective Diagnosis

- Availability of gauges and diagnostic test equipment
- Availability of current information for engine application and engine systems
- Knowledge of principles of operation for engine application and engine systems
- Knowledge to understand and do procedures in diagnostic and service publications

Technical Service Literature required for Effective Diagnosis

- International® MaxxForce™ 5 *Engine Service Manual*
- International® MaxxForce™ 5 *Engine Diagnostics Manual*
- International® MaxxForce™ 5 Diagnostic Form
- International® MaxxForce™ 5 Electronic Control Systems Form
- Service Bulletins

Safety Information

This manual provides general and specific service procedures essential for reliable engine operation and your safety. Since many variations in procedures, tools, and service parts are involved, advice for all possible safety conditions and hazards cannot be stated.

Disregard for warnings, cautions, and instructions can lead to injury, death, or damage to the engine or vehicle.

Read safety instructions before doing any service and test procedures for the engine or vehicle. See related application manuals for more information.

SAFETY TERMINOLOGY

Three terms are used to stress your safety and safe operation of the engine: Warning, Caution, and Note

Warning: Signals conditions, hazards, and unsafe practices that can cause injury or death

Caution: Signals conditions and practices that can cause damage to the engine or vehicle

Note: Signals a key point or procedure that must be followed for correct, efficient engine operation.

SAFETY INSTRUCTIONS

Vehicle

- Shift vehicle to park or neutral, set parking brake, and block wheels before doing any diagnostic or service procedures on the engine or vehicle.

Work area

- Keep work area clean, dry, and organized.
- Keep tools and parts off the floor.
- Make sure work area is ventilated and well lit.
- Make sure a First Aid Kit is available.

Safety equipment

- Use correct lifting devices.
- Use safety blocks and stands.

Protective measures

- Wear protective glasses and safety shoes (do not work in bare feet, sandals, or sneakers.)
- Wear appropriate hearing protection
- Wear correct work clothing.
- Do not wear rings, watches, or other jewelry.
- Restrain long hair.

Fire prevention

- Make sure charged fire extinguishers are in the work area.

NOTE: Check classification of each fire extinguisher to ensure the following fire types can be extinguished.

- Type A - Wood, paper, textiles, and rubbish
- Type B - Flammable liquids
- Type C - Electrical equipment

Batteries

Batteries produce highly flammable gas during and after charging.

- Always disconnect the main negative battery cable first.
- Always connect the main negative battery cable last.
- Avoid leaning over batteries.
- Protect your eyes.
- Do not expose batteries to flames or sparks.
- Do not smoke in workplace.

Compressed air

- Use an OSHA approved blow gun rated at 207 kPa (30 psi).
- Limit shop air pressure to 207 kPa (30 psi).
- Wear safety glasses or goggles.
- Wear hearing protection.
- Use shielding to protect others in the work area.
- Do not direct compressed air at body or clothing.

Tools

- Make sure all tools are in good condition.
- Make sure all standard electrical tools are grounded.
- Check for frayed power cords before using power tools.

Fluids under pressure

- Use extreme caution when working on systems under pressure.
- Follow approved procedures only.

Fuel

- Do not over fill fuel tank. Over fill creates a fire hazard.
- Do not smoke in the work area.
- Do not refuel the tank when the engine is running.

Removal of tools, parts, and equipment

- Reinstall all safety guards, shields, and covers after servicing engine.
- Make sure all tools, parts, and service equipment are removed from the engine and vehicle after all work is done.

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Engine Identification

Engine Serial Number

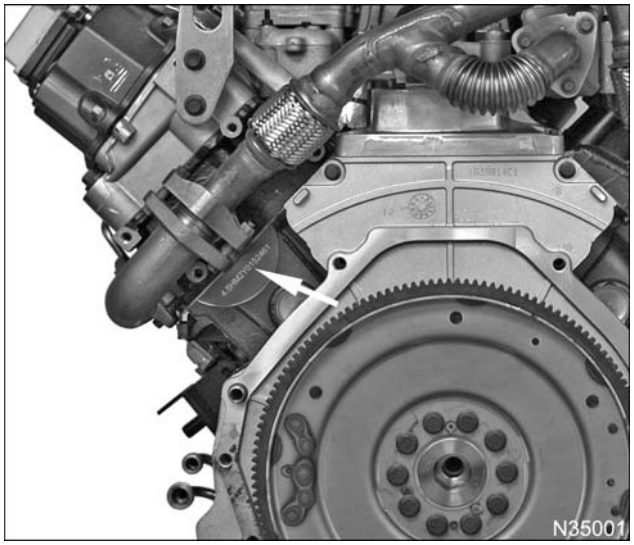

Figure 1 Engine serial number

The engine serial number is stamped on the crankcase pad, on the rear left side below the cylinder head.

Engine Serial Number Example

4.6HM2YXXXXXXX

4.6 – International® MaxxForce™ 5
H – Diesel, turbocharged, air intercooled and electronically controlled
M2 – Motor truck or **U2** power unit and OEM (Sold to original equipment manufacturer)
Y – United States, Huntsville
7 digit suffix – Sequence number

Emission Labels

Environmental Protection Agency (EPA) Engine Emission Label issued for International® MaxxForce™ 5 diesel engines.

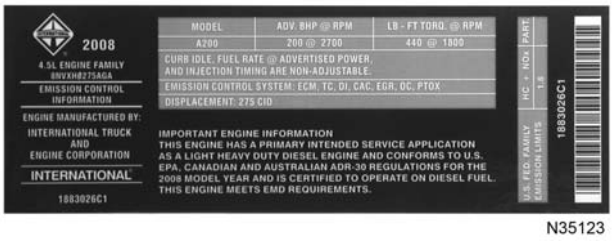

Figure 2 Example of U.S. Environmental Protection Agency (EPA) emission label (50 state)

The EPA exhaust emission label is on top of the crankcase breather, on the left valve cover. The label includes the following:

- Advertised brake horsepower ratings
- Engine model code
- Service applications
- Emission family and control systems
- Year engine was certified to meet EPA emission standards

Engine Accessories

The following engine accessories may have manufacturers' labels or identification plates:

- Air conditioning compressor
- Alternator
- Cooling fan clutch
- Dual turbocharger assembly
- Power steering pump
- Starter motor

Labels or identification plates include information and specifications helpful to vehicle operators and technicians.

Component Locations

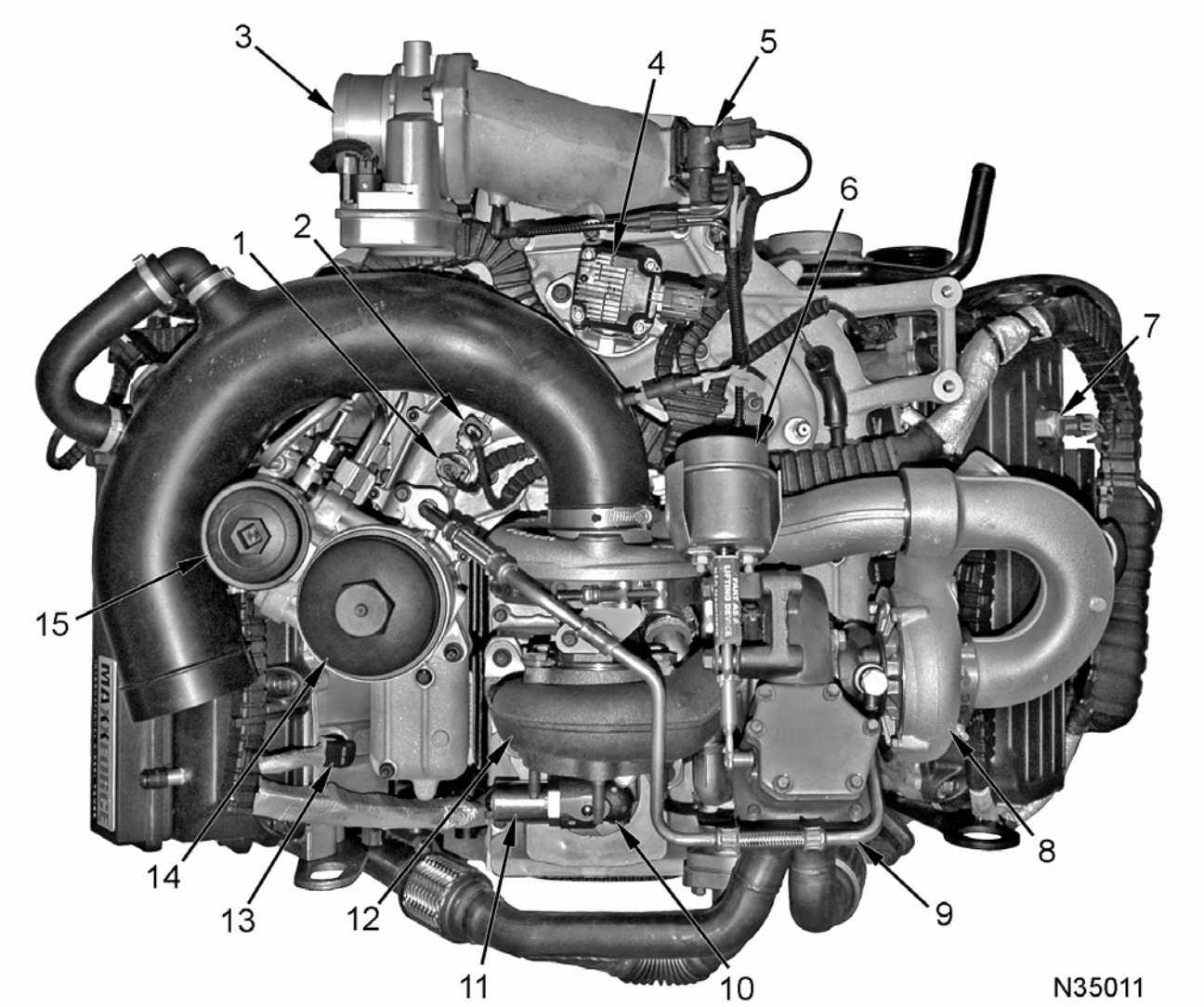

Figure 3 Top

1. Engine Oil Pressure (EOP) switch
2. Engine Oil Temperature (EOT) sensor
3. Intake Throttle Valve (ITV) assembly
4. Exhaust Gas Recirculation (EGR) valve
5. Boost Control Solenoid (BCS)
6. Turbocharger pneumatic actuator
7. Injection Control Pressure (ICP) sensor
8. Turbocharger high-pressure compressor
9. Turbocharger oil supply tube assembly
10. High-pressure oil pump assembly
11. Injection Pressure Regulator (IPR) valve
12. Turbocharger low-pressure turbine
13. Injector connection (6)
14. Oil filter housing assembly
15. Secondary fuel filter assembly

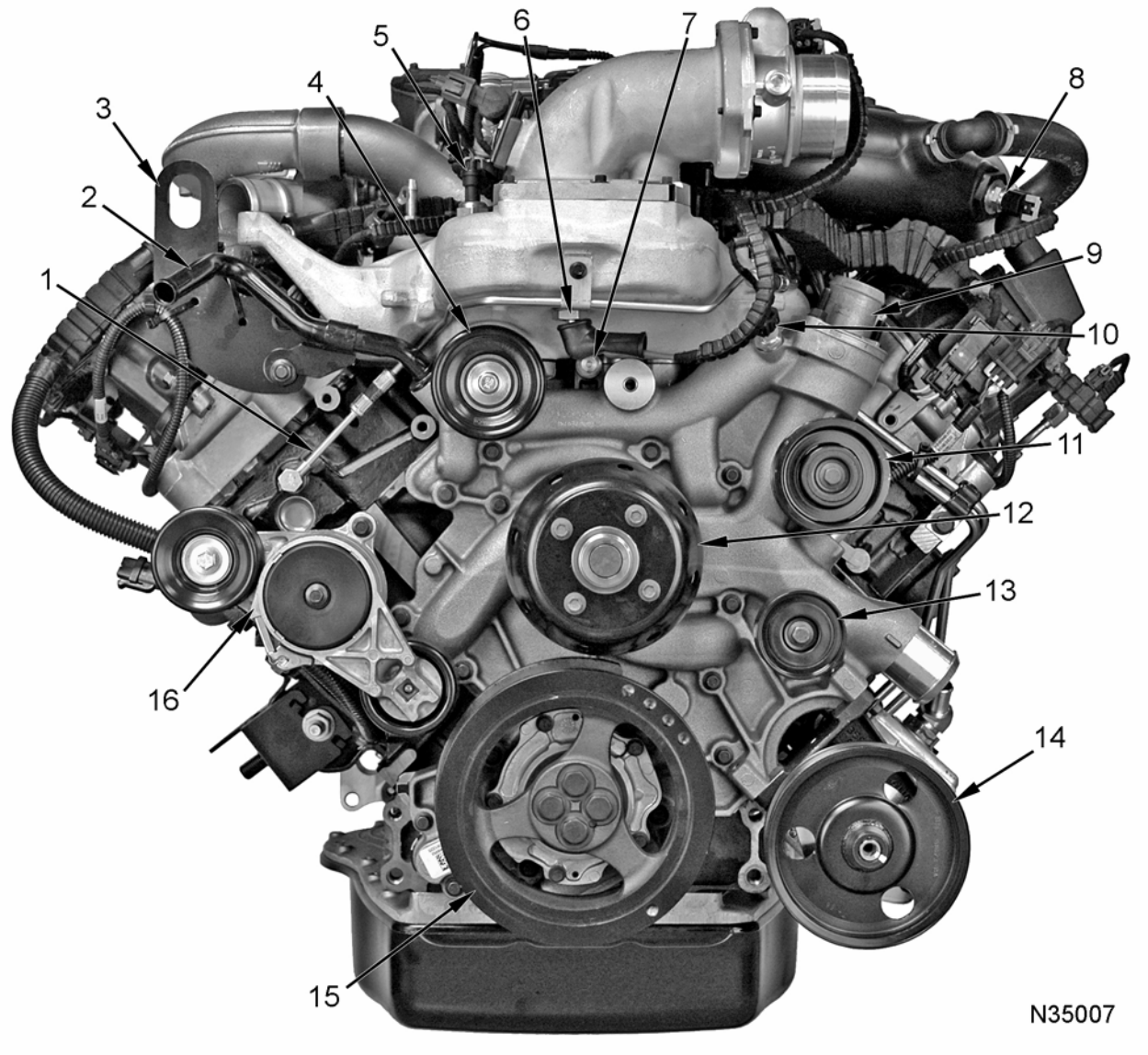

Figure 4 Front

1. Fuel filter to right cylinder head tube
2. Heater feed tube assembly
3. Lifting eye
4. Flat idler pulley
5. Manifold Absolute Pressure (MAP) sensor
6. Inlet Air Heater (IAH) element
7. Diagnostic port (oil cooler)
8. Intake Air Temperature (IAT) sensor
9. Thermostat assembly
10. Engine Coolant Temperature (ECT) sensor
11. 8-groove idler pulley
12. Water pump / fan drive pulley
13. Smooth idler pulley
14. Power steering pulley
15. Vibration damper
16. Belt tensioner assembly

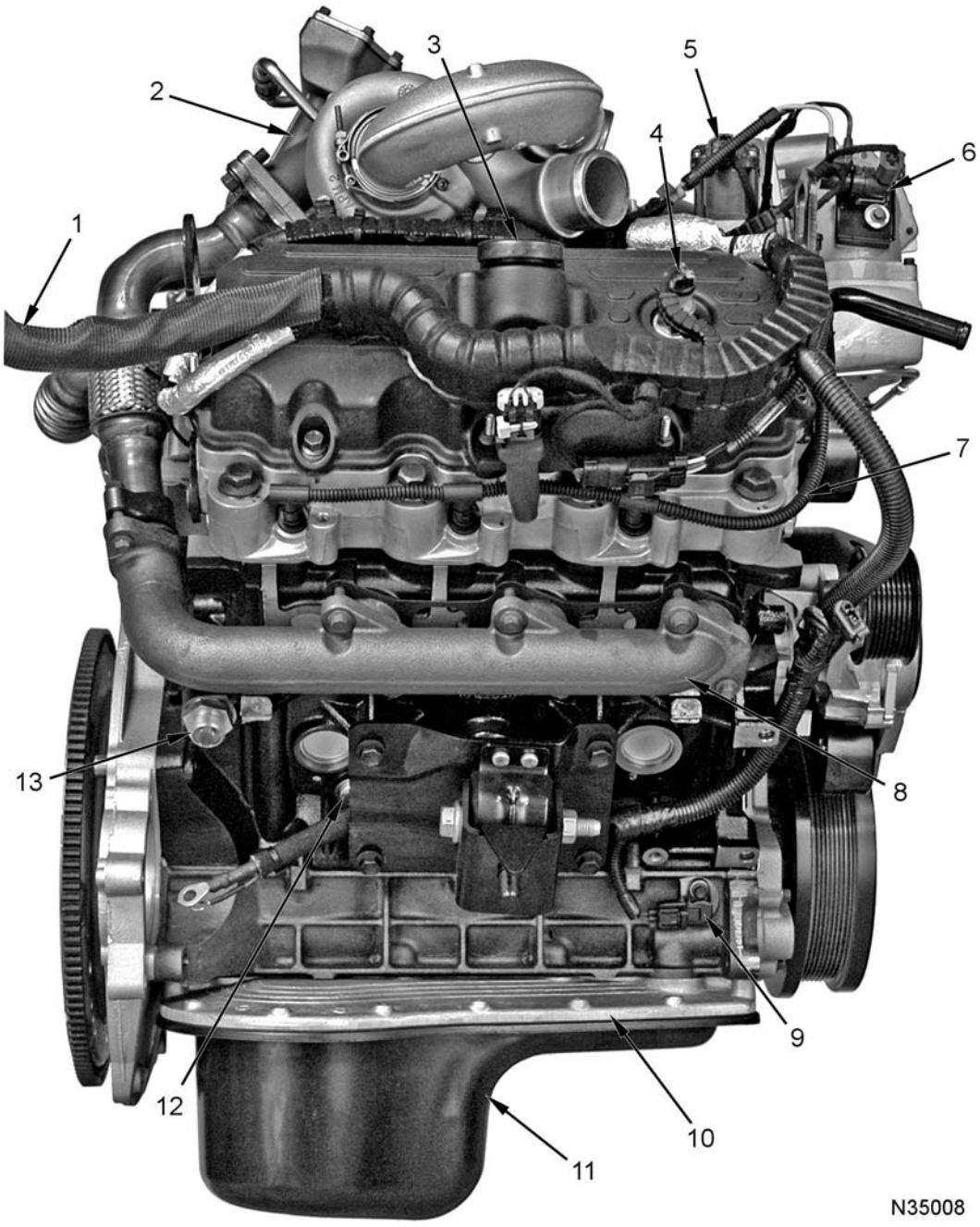

Figure 5 Right

1. Sensor wiring harnesses to chassis mounted ECM, IAH and glow plug relays
2. Dual turbocharger assembly
3. Oil fill cap
4. Injection Control Pressure (ICP) sensor
5. Exhaust Gas Recirculation (EGR) valve
6. Boost Control Solenoid (BCS)
7. Glow plug harness assembly (right)
8. Exhaust manifold (right)
9. Crankshaft Position (CKP) sensor
10. Upper oil pan
11. Lower oil pan
12. Crankcase coolant drain plug (right)
13. Coolant heater

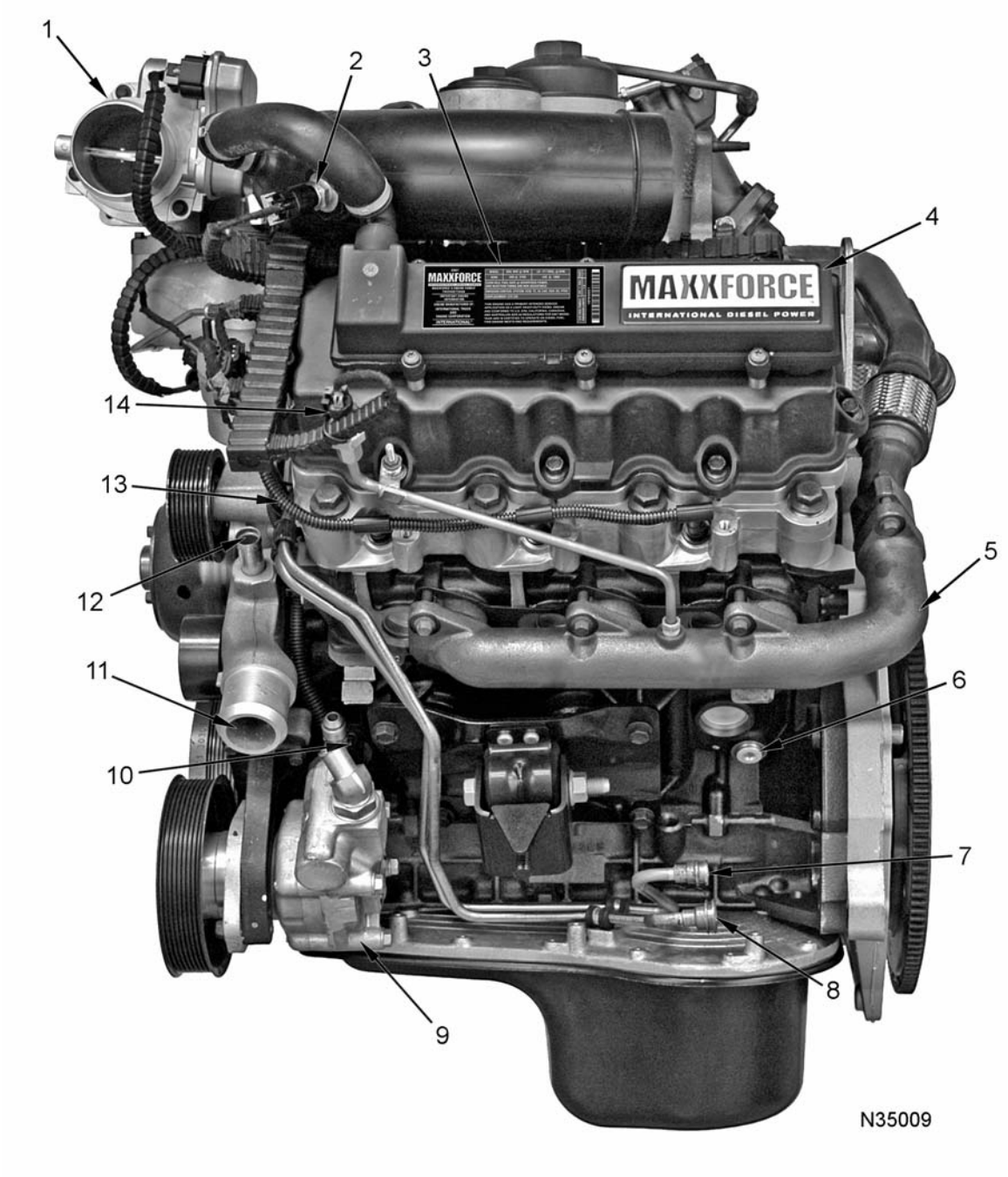

Figure 6 Left

1. Intake Throttle Valve (ITV) assembly
2. Intake Air Temperature (IAT) sensor
3. Exhaust emission label
4. Crankcase breather assembly
5. Exhaust manifold (left)
6. Crankcase coolant drain plug (left)
7. Fuel return to HFCM
8. Fuel supply to filter tube
9. Power steering pump
10. Camshaft Position (CMP) sensor
11. Coolant inlet
12. Heater return port
13. Glow plug harness assembly (left)
14. Exhaust Back Pressure (EBP) sensor

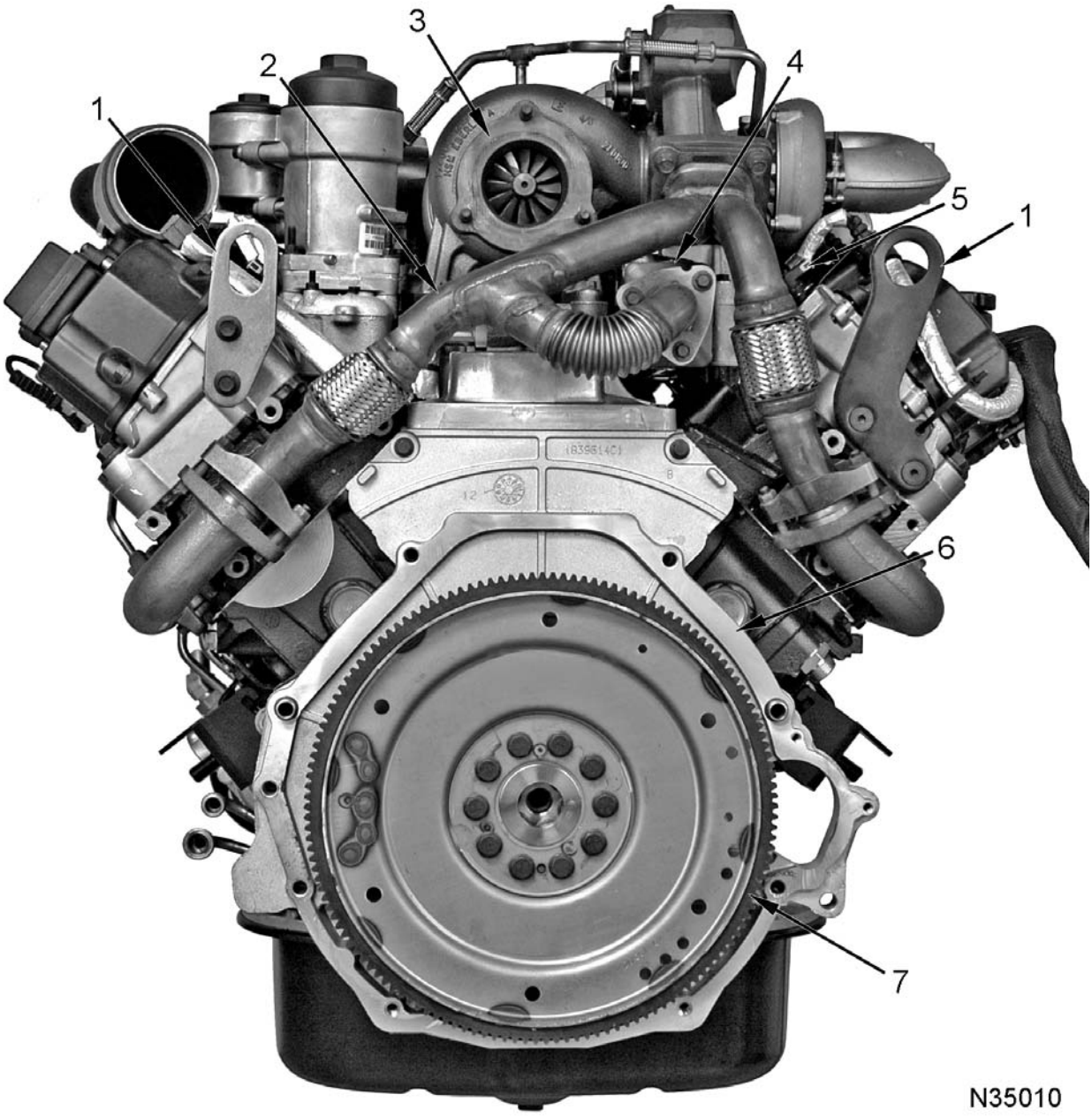

Figure 7 Rear

1. Lifting eye
2. Exhaust tube assembly
3. Turbocharger/exhaust outlet
4. Exhaust Gas Recirculation (EGR) cooler
5. Injector connector (6)
6. Rear cover
7. Flywheel assembly

Engine Description, Specifications, and Features

Table 1 International® MaxxForce™ 5 Description and Specifications

Engine configuration	4 stroke V6 diesel, 4 valves/cylinder
Displacement	4.5 liters (275 in^3)
Bore	95 mm (3.74 in.)
Stroke	105 mm (4.134 in.)
Compression ratio	18.0:1
Aspiration	Dual turbocharged and Charge Air Cooled (CAC)
Advertised brake horsepower @ rpm	See EPA exhaust emission label
Peak torque @ rpm	See EPA exhaust emission label
Engine rotation (facing flywheel)	Counterclockwise
Combustion system	Direct injection turbocharged
Fuel system	International® electro-hydraulic generation 2 injection
Cooling system capacity (engine only)	11 liters (12 quarts US)
Lube system capacity (including filter)	13 liters (14 quarts US)
Lube system capacity (overhaul only, with filter)	14 liters (15 quarts US)
Firing order	1-2-5-6-3-4

Engine Features

Table 2 International® MaxxForce™ 5 Standard and Optional Features

Standard Features	**Optional Features**
Four valves per cylinder	Coolant heater wiring harness
Primary balancer shaft assembly	
Dual timing sensors	**Chassis Mounted Features**
Two-piece crankcase	Horizontal Fuel Conditioning Module (HFCM)
One-piece aluminum alloy pistons	Diamond Logic® Engine Control
Fracture cap joint connecting rods	Inlet air heater relay
International® electro-hydraulic generation 2 injection system	Glow plug relay
Dual turbocharger assembly	Charge Air Cooler (CAC)
Secondary fuel filter	

Engine Description

Cylinder Heads

Each cylinder head has four valves per cylinder for improved air flow. The overhead valve train includes hydraulic roller tappets, push rods, rocker arms, and valve bridges to operate the four valves. Each fuel injector is centrally located between the four valves, directly over the piston combustion bowl, for improved performance and reduced emissions.

Crankcase Assembly

The crankcase assembly consists of an upper crankcase and a lower crankcase. The upper crankcase assembly includes the cylinders, main bearing saddles, and cast or machined coolant passages. The lower crankcase, a structural plate that mates to the upper crankcase, has machined main bearing saddles for improved load retention and alignment.

Aluminum alloy pistons are mated to fractured cap joint connecting rods. Piston pins, secured with retaining rings, are free floating for lateral movement in the connecting rod and piston.

The crankshaft is supported by four main bearings with fore and aft thrust controlled at the upper half of number 3 main bearing. Two connecting rods, attached to each crankshaft rod journal, are offset to minimize vibration.

The camshaft is supported by four bushings pressed into the crankcase. The camshaft is crankshaft driven and thrust is controlled by a plate mounted behind the number four cam journal.

A closed crankcase breather system separates crankcase vapors and oil. Vapors are vented through a hose to the air inlet duct, while oil drains back to the crankcase.

Fuel System

The Horizontal Fuel Conditioning Module (HFCM) includes an electric fuel pump, primary fuel filter, Diesel Thermo Recirculation Module (DTRM), fuel heater, water drain plug, and a Water In Fuel (WIF) sensor. An amber Water In Fuel lamp is illuminated when a predetermined quantity of water has accumulated.

- The HFCM is mounted on the inside of the frame rail (operator's side) for CityStar™ vehicles.
- The HFCM is mounted near the transmission and frame rail (passenger side) for stripped chassis vehicles.

A secondary fuel filter assembly (engine mounted) includes outlets for fuel lines to each cylinder head fuel rail, a fuel pressure regulator, an Engine Fuel Pressure (EFP) switch, and an air bleed orifice to discharge air if the vehicle runs out of fuel.

The International® electrohydraulic generation 2 injection system includes a high-pressure oil pump, cast iron oil rail assemblies, and fuel injectors.

An Electronic Control Module (ECM) processes signals from the Crankshaft Position (CKP), Camshaft Position (CMP), exhaust aftertreatment, and other sensors. The ECM sends voltage pulses to opening and closing coils of each injector to control injection timing, quantity, and duration.

Lubrication System

The engine lubrication system is pressure regulated, full flow cooled, and full flow filtered. A crankshaft driven gerotor lube oil pump delivers oil through an oil filter element and oil cooler to engine components and an oil reservoir for the high-pressure oil system. An oil pressure regulator, in the front cover, maintains the desired system pressure.

Air Management System

A dual stage turbocharger provides boost pressure for a variety of engine speeds and load conditions. An electronic Boost Control Solenoid (BCS) and a pneumatic actuator helps control the turbocharger.

A Charge Air Cooler (CAC), an air-to-air heat exchanger, cools and increases the air density from the turbocharger. Cooled dense air flows to the intake manifold. An intake throttle valve restricts air flow to help heat exhaust gas during aftertreatment regeneration.

An Exhaust Gas Recirculation (EGR) system includes an EGR cooler and EGR valve. Some exhaust from the exhaust tube assembly flows through the EGR cooler into a passage in the intake manifold and to the EGR valve. When the EGR valve opens, cooled exhaust gases enter the intake manifold.

The Inlet Air Heater relay and glow plug relay work together to improve cold weather engine performance and starting. An Intake Air Heater (IAH) element, installed in the intake manifold under the inlet air elbow, is controlled by an inlet air heater relay (chassis mounted). Six glow plugs are controlled by a glow plug relay (chassis mounted).

The Aftertreatment System processes engine exhaust to meet EPA emissions requirements.

- The Diesel Oxidation Catalyst (DOC) helps burn oxygen and hydrocarbons in the exhaust.
- A Diesel Particulate Filter (DPF) captures and burns particulates in the exhaust.

Optional Features

Although a 1250 watt coolant heater is standard equipment, an optional 120 volt cable is available for operation. The coolant heater raises coolant temperature around the cylinders to improve cold engine starts.

Engine Systems Interaction Diagram

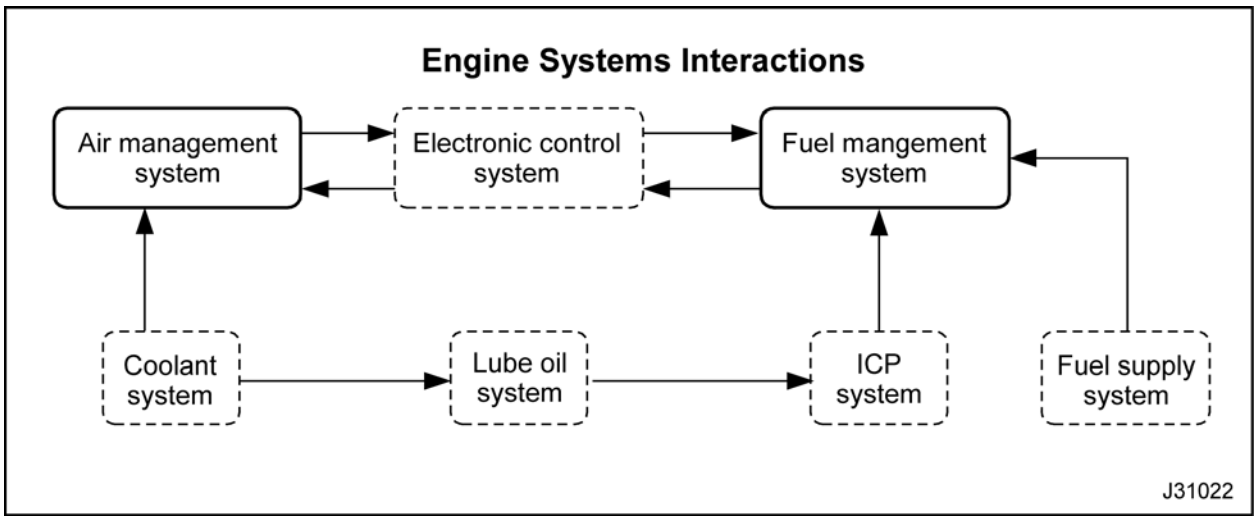

Figure 8 Engine systems interactions

The primary engine performance systems are air management and fuel management which share some subsystems or have a subsystem that contributes to their operation.

- The electronic control system controls the air management system and fuel management system.
- The Coolant System provides heat transfer for crankcase and cylinder walls, cylinder head, EGR gases, and lubrication oil.
- The lube oil system provides lubrication and heat transfer for engine components.
- The Injection Control Pressure (ICP) system uses engine oil to actuate the fuel injectors.
- The fuel supply system pressurizes fuel to the fuel injectors.

Air Management System

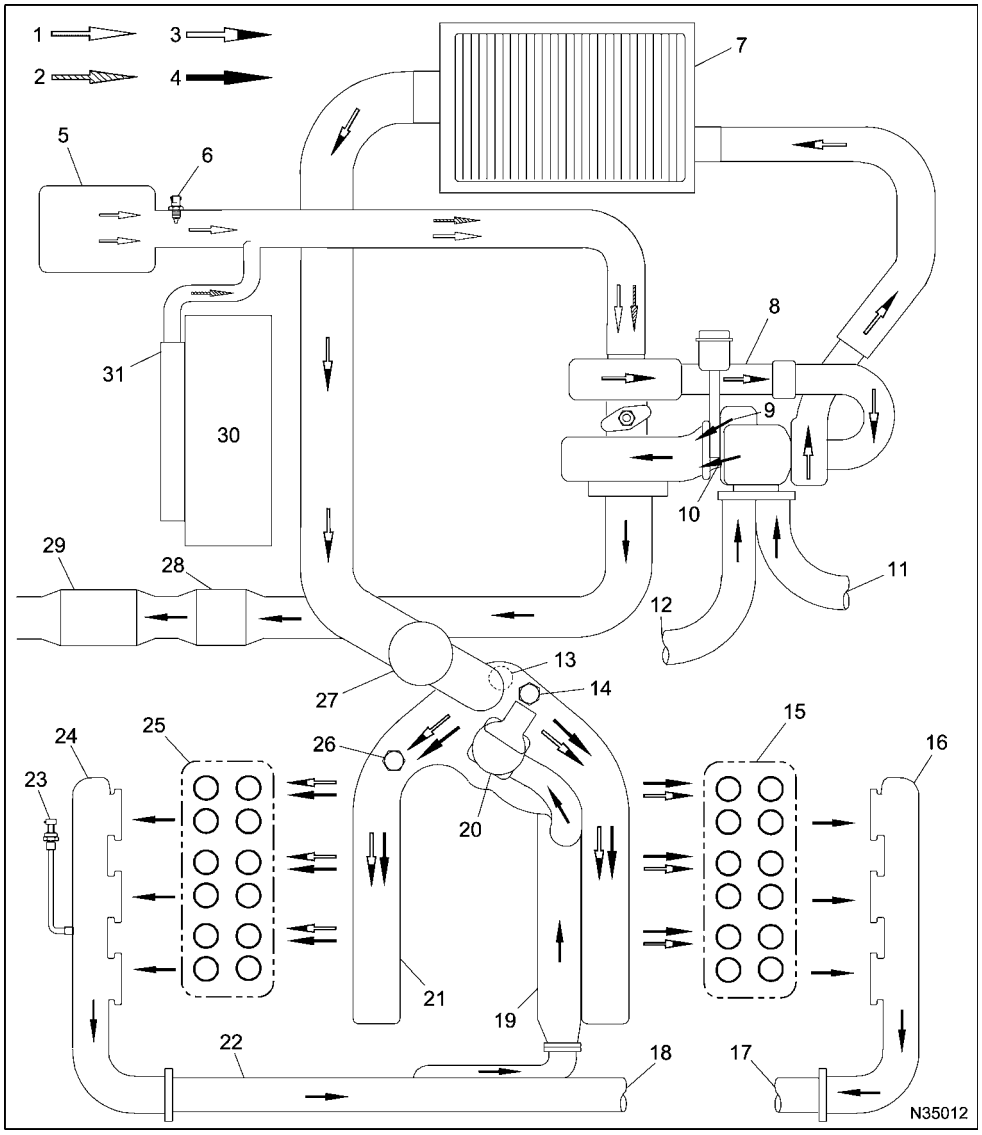

Figure 9 Air management system components and flow

1. Air flow
2. Crankcase gas flow
3. Compressed air and crankcase gas flow
4. Exhaust gas flow
5. Air filter
6. Intake Air Temperature (IAT) sensor
7. Charge Air Cooler (CAC)
8. Dual turbocharger
9. Exhaust flow (bypass closed)
10. Exhaust flow (bypass open)
11. Exhaust in from right cylinders
12. Exhaust in from left cylinders
13. Intake Air Heater (IAH)
14. Manifold Absolute Pressure (MAP) sensor
15. Right cylinder head
16. Right exhaust manifold
17. Exhaust out from right cylinders
18. Exhaust out from left cylinders
19. Exhaust Gas Recirculation (EGR) cooler
20. EGR valve
21. Intake manifold
22. Exhaust tube assembly
23. Exhaust Back Pressure (EBP) sensor
24. Left exhaust manifold
25. Left cylinder head
26. Manifold Air Temperature (MAT) sensor
27. Intake throttle assembly
28. Diesel Oxidation Catalyst (DOC)
29. Diesel Particulate Filter (DPF)
30. Left valve cover
31. Crankcase breather

Air, Exhaust, and Crankcase Gas Flow

Ambient air is initially drawn through the air filter assembly past the IAT sensor and into the air inlet duct.

A crankcase breather and hose are used to draw crankcase gasses from the engine.

Air continues to flow through the low-pressure turbocharger compressor (larger turbo), where it is compressed and discharged to the high-pressure turbocharger compressor (smaller turbo). The high-pressure compressor compresses discharge air to a higher pressure and temperature before it enters the CAC.

As compressed air (hot) flows through the CAC, ambient air flows across the CAC and heat is exchanged to the atmosphere.

During cold weather starts, an Inlet Air Heater warms incoming air. The Electronic Control Module (ECM) controls the Inlet Air Heater (IAH) relay. The IAH relay controls the operation of the IAH element depending on ambient temperature and atmospheric pressure.

Air flows through the intake manifold, past the intake valves and into the cylinders. After combustion, hot exhaust gases are forced through the exhaust manifolds and into the exhaust piping.

Most of the hot exhaust gas flows into the turbocharger high-pressure turbine (smaller turbo), spinning the high-pressure turbine wheel. Exhaust continues to flow onto the low-pressure turbine (larger turbo), spinning the low-pressure turbine wheel before exiting the turbocharger to the exhaust system.

A portion of the hot exhaust gas is routed through the EGR cooler and EGR valve where it is metered into the intake manifold to blend with filtered incoming air. This helps reduce combustion temperatures and Oxides of Nitrogen (NO_x).

Exhaust flows through the exhaust piping, aftertreatment, and out the exhaust pipe.

Exhaust Gas Recirculation (EGR) System

The EGR system reduces Nitrogen Oxide (NO_x) emissions. NO_x gas forms when nitrogen and oxygen react during high combustion temperatures. Mixing exhaust with inlet air reduces combustion temperature and NO_x gas formation.

Some exhaust from the exhaust tube assembly flows through the EGR cooler, intake manifold EGR passage, and to the EGR valve. The Electronic Control Module (ECM) commands the EGR valve to open, when needed, allowing cooled exhaust gases to enter the intake manifold to mix with intake air.

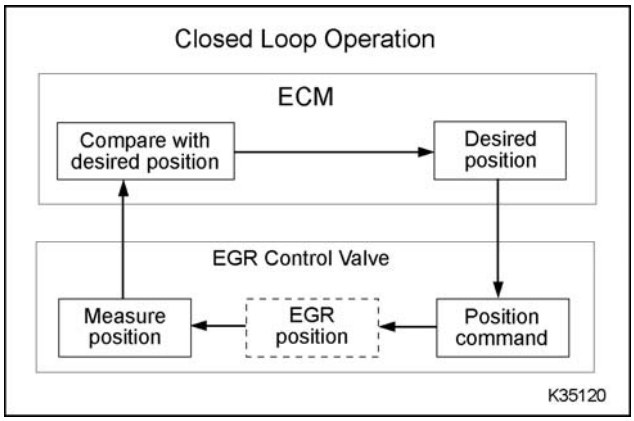

Figure 10 EGR closed loop operation

The ECM commands EGR valve position based on engine speed, Exhaust Back Pressure (EBP), Manifold Air Temperature (MAP), and Manifold Air Pressure (MAT) sensor input. The EGR valve provides feedback to the ECM on current valve position.

Figure 11 EGR valve

The EGR valve assembly consists of three major components; a dual poppet valve, a DC motor, and an Integrated Circuit (IC). The IC has three Hall effect position sensors to monitor valve movement. The EGR valve uses a DC motor to control the position of the valve assembly. The valve assembly has two valve heads on a common shaft.

The EGR valve is installed in the front of the intake manifold.

Dual Stage Turbocharger Assembly

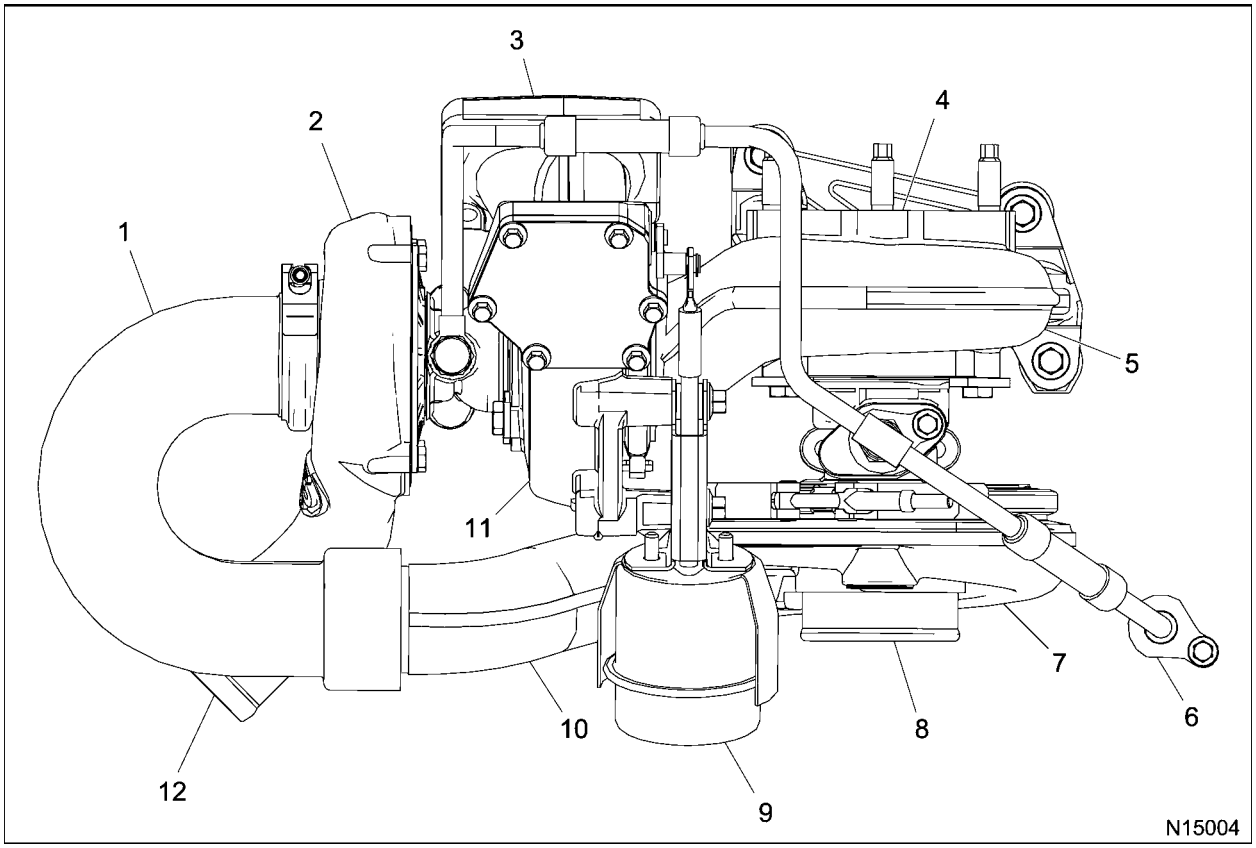

Figure 12 Dual stage turbocharger

1. Crossover tube
2. High-pressure compressor
3. Exhaust inlet
4. Exhaust outlet
5. Low-pressure turbine
6. Oil supply tube
7. Low-pressure compressor
8. Air inlet
9. Pneumatic actuator
10. Low-pressure compressor outlet
11. High-pressure turbine
12. High-pressure compressor discharge

The dual stage turbocharger responds to engine loads. During heavy loads, an increased flow of exhaust gasses turn the turbine wheels faster. Turbine wheel speed controls compressor boost pressure. As engine rpm and load decrease, less fuel and air enter the cylinders. Exhaust temperature and pressure decrease; lower exhaust energy decreases turbine and compressor speed which lowers the pressure and temperature of compressed air.

During light loads, all exhaust flows through the high-pressure turbine and low-pressure turbine. When boost pressure reaches a predetermined value, the pneumatic actuator opens the bypass valve, allowing some exhaust to bypass the high-pressure turbine and flow directly to the low-pressure turbine; maximum boost pressure is limited. The dual stages of the turbocharger contribute to lower exhaust emissions.

Aftertreatment (AFT) System

The AFT System processes engine exhaust to meet emissions requirements. The aftertreatment system consists of the Diesel Oxidation Catalyst (DOC), Diesel Particulate Filter (DPF), three Exhaust Gas Temperature (EGT) sensors, and a Exhaust Gas Differential Pressure (EGDP) sensor. The Electronic Control Module (ECM) monitors aftertreatment and engine sensors to control AFT regeneration cycles. During a regeneration cycle the exhaust is heated to clear soot accumulation.

AFT Control System

The control system performs the following functions:

- Monitors exhaust gases, the aftertreatment system, and controls engine operating parameters for emission processing and failure recognition
- Cancels regeneration in the event of catalyst or sensor failure
- Monitors Diesel Particulate Filter (DPF) soot accumulation level and adapts engine operating characteristics to compensate for increased back pressure
- Controls engine operating parameters to make regeneration automatic.
- Maintains vehicle and engine performance during regeneration

Diesel Oxidation Catalyst (DOC)

The DOC does the following:

- Oxidizes hydrocarbons and carbon monoxide (CO)
- Provides heat for exhaust system warm-up
- Aids in system temperature management for the DPF
- Oxidizes NO into NO_2 for passive DPF regeneration

Diesel Particulate Filter (DPF)

The DPF does the following:

- Captures and temporarily stores carbon-based particulates in a filter
- Allows for oxidation (regeneration) of stored particulates once loading gets to a particular level (pressure drop)
- Stores noncombustible ash

Sensors

Sensors produce an electronic signal based on temperature or pressure and are used by the ECM to monitor aftertreatment function and control regeneration.

AFT Conditions and Responses

The operator is alerted audibly or with instrument panel indicators of AFT system status. Automatic or manual regeneration is required when levels of soot exceed acceptable limits. For additional information see applicable vehicle *Operator's Manual* and vehicle visor placard.

Fuel Supply System

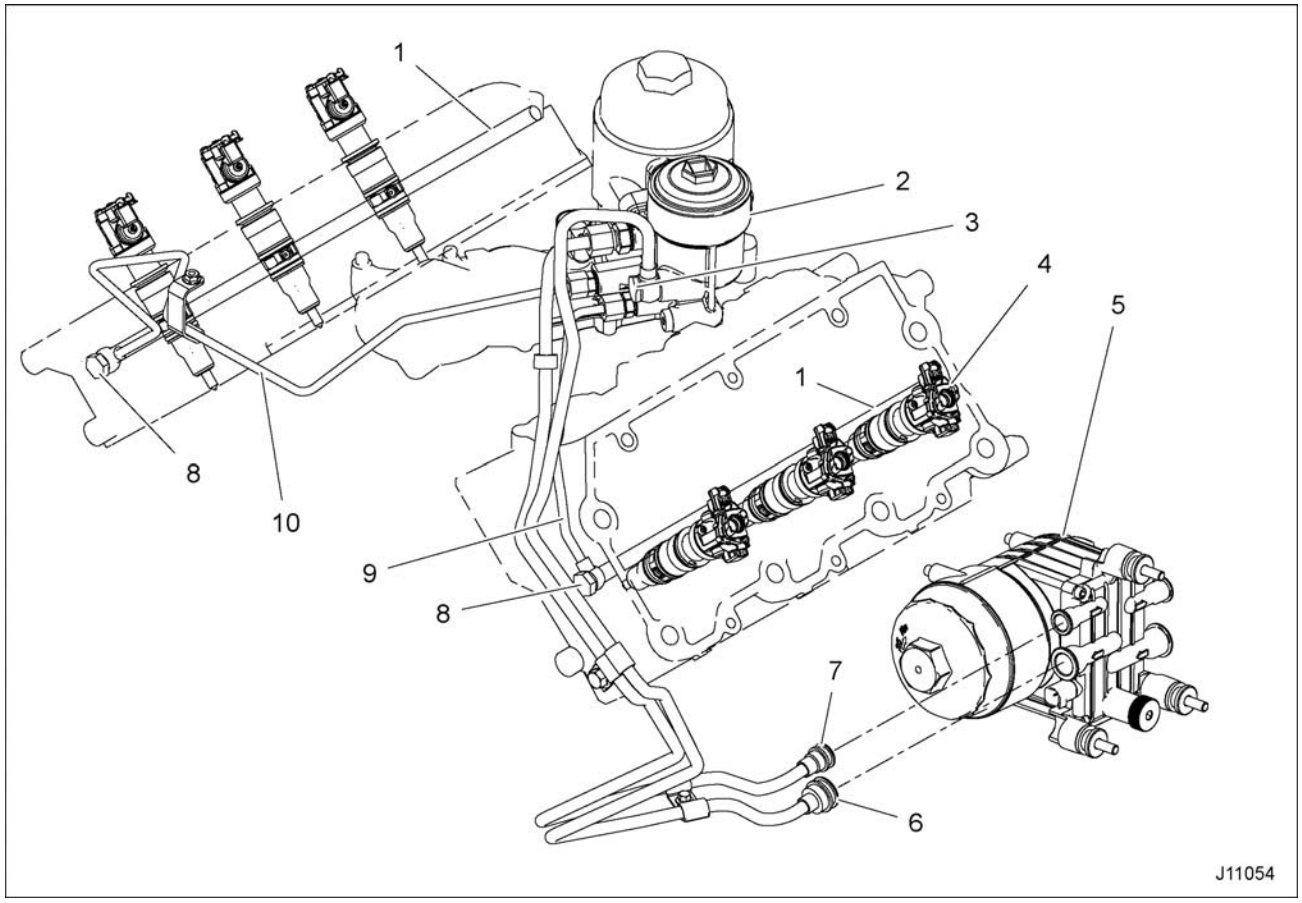

Figure 13 Fuel supply system

1. Drilled passage to fuel injectors (2)
2. Secondary fuel filter assembly
3. Banjo bolt (fuel supply)
4. Fuel injector (6)
5. Horizontal Fuel Conditioning Module (HFCM) (chassis mounted)
6. Fuel line (supply from HFCM)
7. Fuel line (return to HFCM)
8. Banjo bolt with check valve (2)
9. Fuel line (supply left cylinder head)
10. Fuel line (supply right cylinder head)

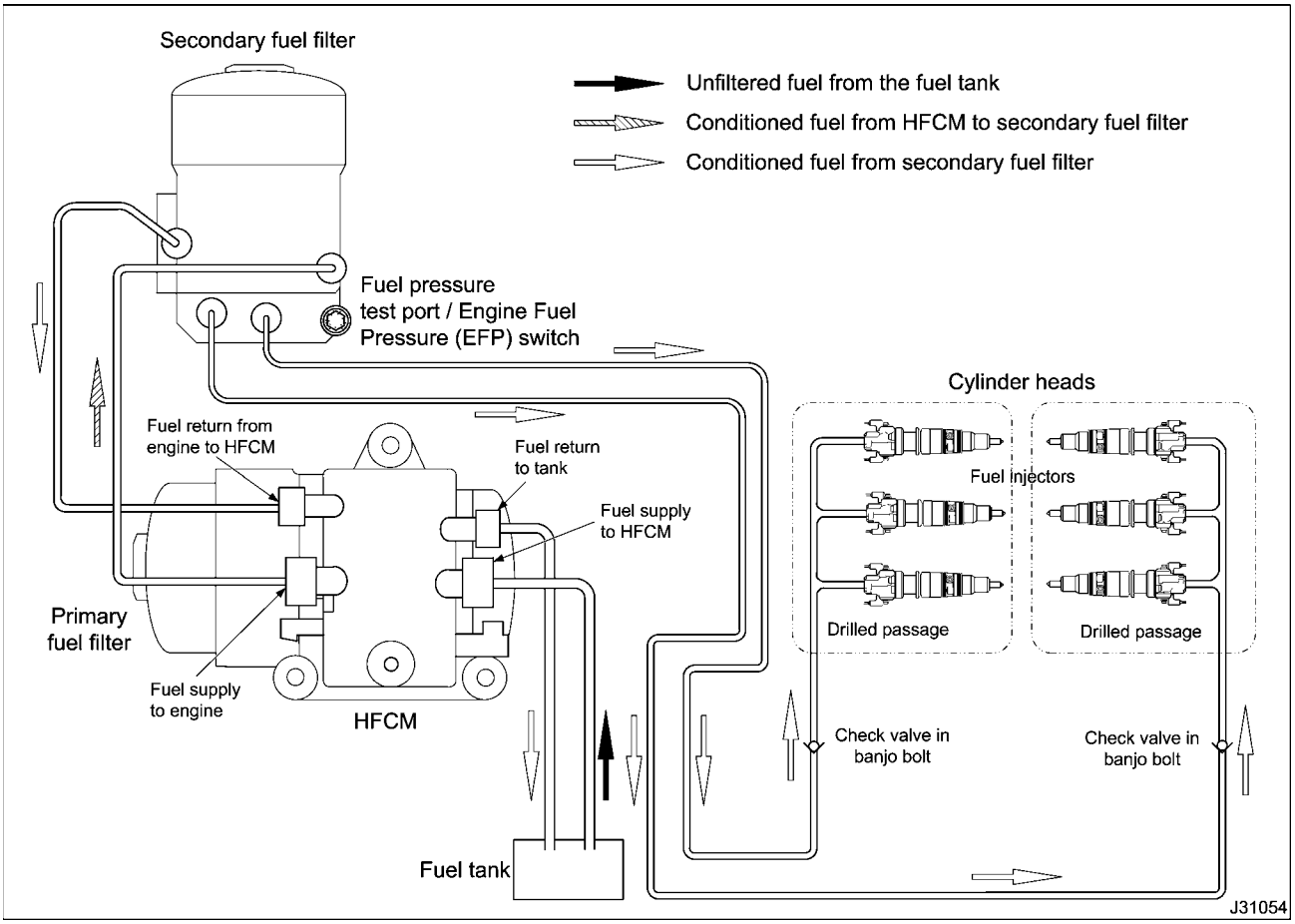

Figure 14 Fuel supply system flow

Fuel Flow

The fuel pump in the HFCM draws fuel through a fuel line from the fuel tank. The HFCM heats, filters, and pressurizes fuel. Conditioned fuel flows from the HFCM through the supply line to the secondary fuel filter assembly.

The secondary fuel filter assembly conditions, maintains system pressure, and deaerates fuel. Fuel flows through each fuel line and a banjo bolt connecting the fuel line to the cylinder head. Fuel flows through drilled passages in each cylinder head to the fuel injectors. When the fuel injectors are activated, fuel flows into three inlets in each injector. Fuel does not return to the fuel supply system from the injectors or cylinder heads; this is a deadhead fuel system.

Horizontal Fuel Conditioning Module (HFCM)

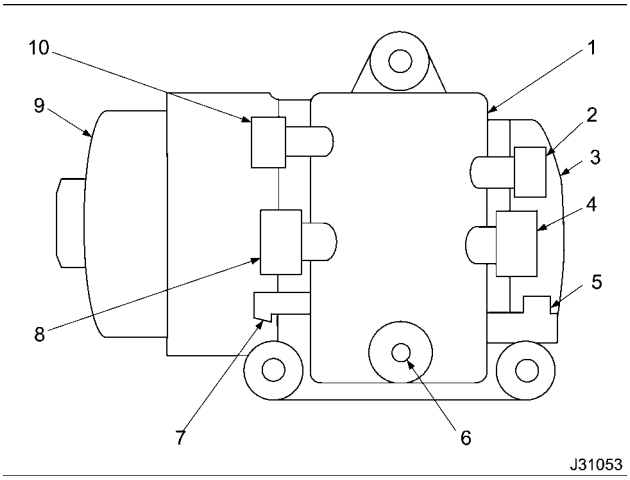

Figure 15 HFCM

1. Cover plate assembly
2. Fuel return to tank
3. Electric fuel pump
4. Fuel supply to HFCM
5. Water In Fuel (WIF) sensor connector
6. Water drain plug
7. Fuel heater connector
8. Fuel supply to engine
9. Primary filter cap
10. Fuel return from secondary filter

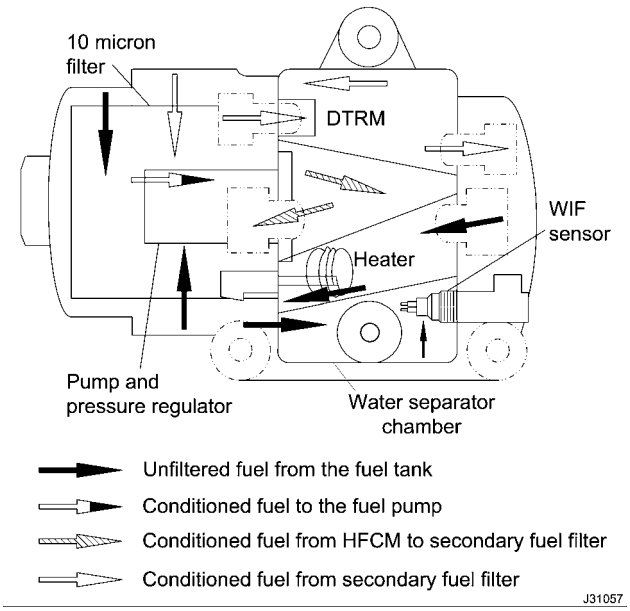

Figure 16 HFCM - fuel flow

The HFCM fuel pump draws fuel from the fuel tank, across an electric fuel heater and through a 10 micron fuel filter. The electric fuel heater is activated when incoming fuel temperature is below 10 °C (50 °F) and is deactivated when incoming fuel temperature reaches 27 °C (80 °F). A 10 micron fuel filter/water separator separates particles and water from incoming fuel before reaching the pump. The conditioned fuel is then pumped to the secondary fuel filter assembly. The outlet fuel pressure is controlled by a pressure relief valve located within the fuel pump. When water separated from the incoming fuel accumulates in the water sump the Water In Fuel (WIF) sensor sends a signal to the Electronic Control Module (ECM) and illuminates the amber WATER IN FUEL lamp.

During cold temperature operation, the Diesel Thermo Recirculation Module (DTRM) installed in the HFCM, redirects warm fuel returned from the secondary fuel filter assembly back into the unfiltered side of the HFCM filter. When incoming fuel temperature is below 30 °C (85° F), a portion of the return fuel is redirected into the HFCM to increase supply fuel temperature. When incoming fuel temperature reaches 38 °C (100 °F) the DTRM diverts all returned fuel back to the tank.

Secondary Fuel Filter Assembly

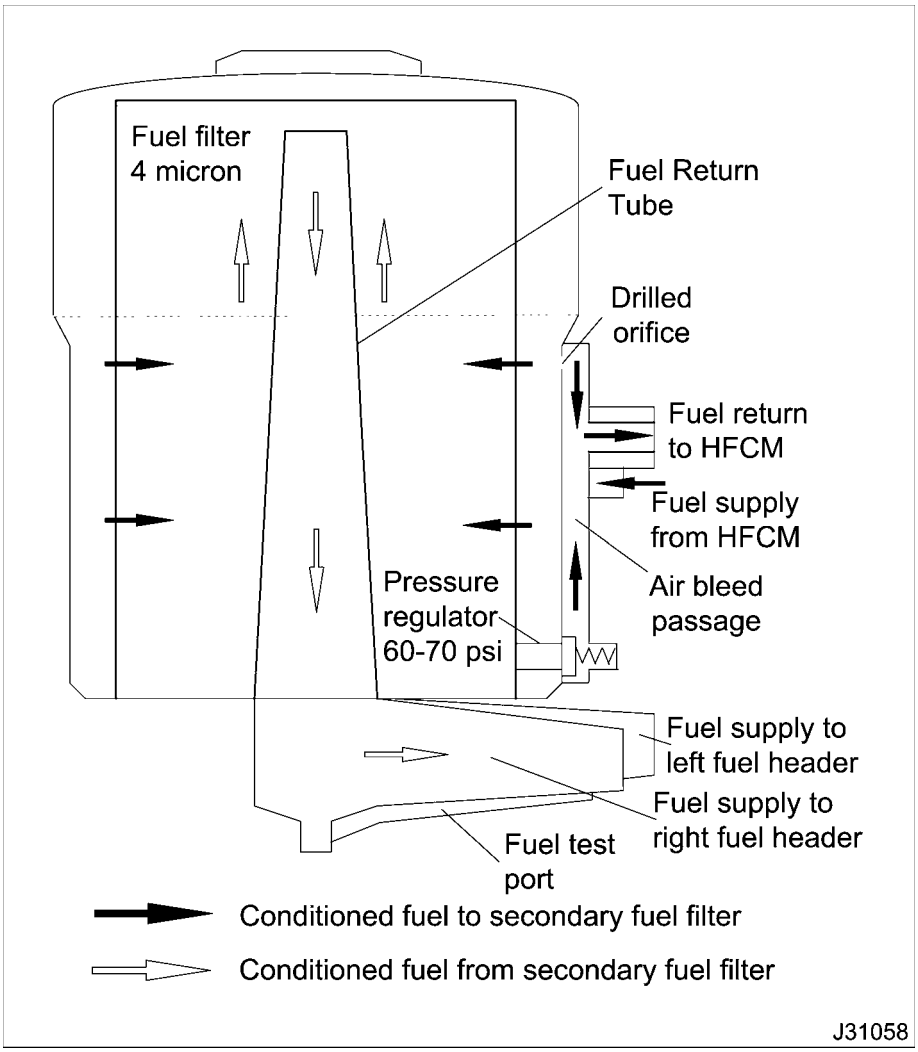

Figure 17 Secondary fuel filter assembly - fuel flow

Conditioned fuel flows through a fuel return tube to the two fuel supply ports to the cylinder heads and the fuel test port.

An orifice is drilled through the side of the secondary fuel filter housing, to the return fuel passage on the side of the secondary fuel filter. Air trapped in the housing is returned through the return fuel passage.

During idle and low engine loads most fuel is cycled between the fuel filter housing and HFCM. When engine load increases, engine fuel consumption increases; fuel flows through the filter with little or no cycling.

A banjo bolt, with check valve, connects each fuel line to each cylinder head. The check valve prevents fuel return to the secondary fuel filter and keeps the drilled passages full. Fuel flows through drilled passages to the fuel injectors in each cylinder head. When the fuel injectors are activated, fuel flows into three inlets in each injector. Fuel does not return to the fuel supply system from the injectors; this is a deadhead fuel system.

A four micron filter element in the secondary fuel filter housing filters particles in the fuel.

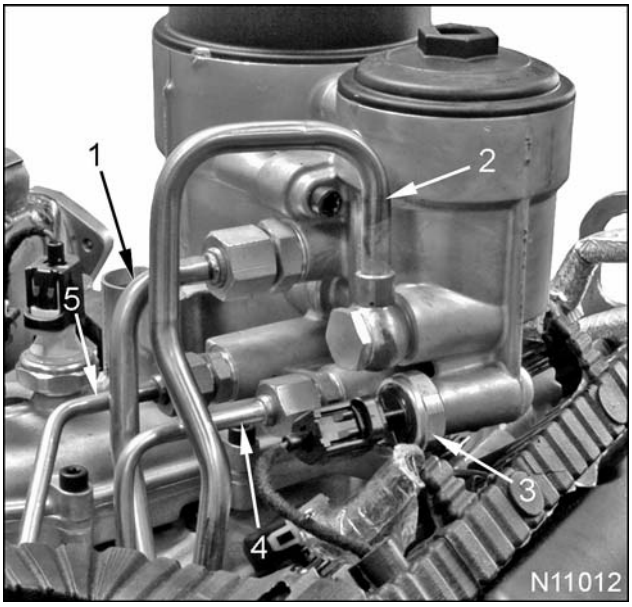

Figure 18 Fuel lines connected to the secondary fuel filter housing

1. Fuel return to fuel pump
2. Fuel supply from fuel pump
3. Engine Fuel Pressure (EFP) switch
4. Conditioned fuel to left cylinder head
5. Conditioned fuel to right cylinder head

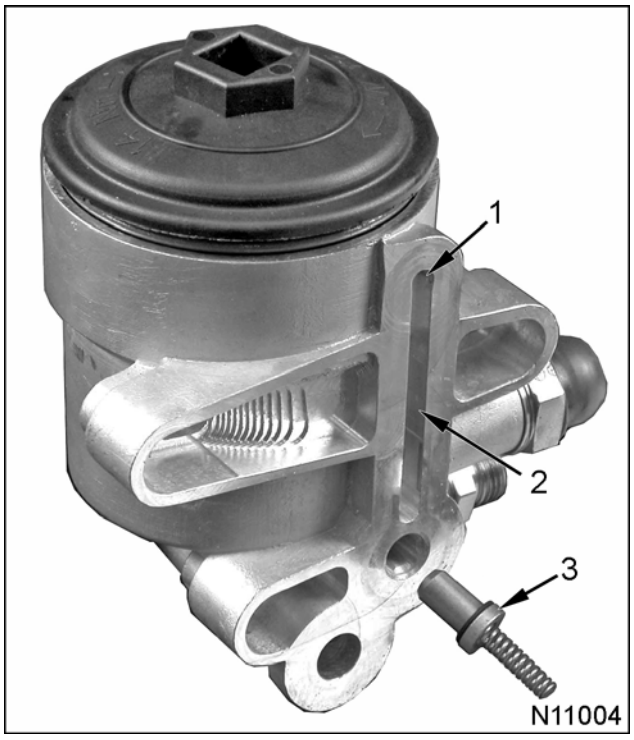

Figure 19 Secondary fuel filter housing and fuel pressure regulator

1. Orifice
2. Return fuel passage
3. Poppet valve (fuel pressure regulator)

The fuel pressure regulator is a spring loaded poppet valve used to regulate and relieve excessive fuel pressure. Fuel passing through the pressure regulator returns to the HFCM.

Fuel Management System

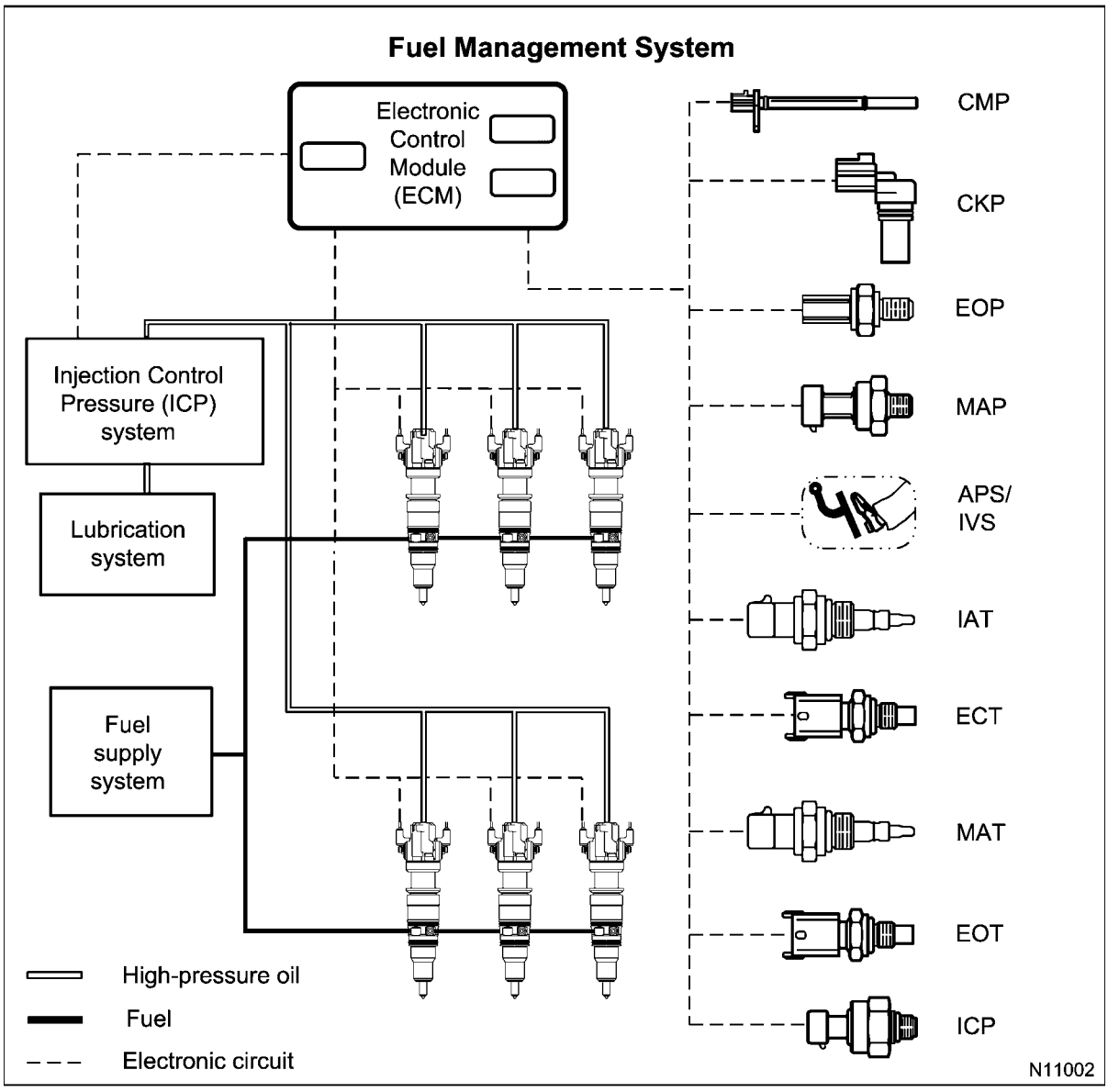

Figure 20 Fuel management system components and sub-systems

The fuel system uses high-pressure oil to increase fuel pressure inside the injectors for high-pressure fuel injection.

The ECM uses sensor input signals to determine timing and quantity of fuel for the injectors. The ECM uses CMP and CKP input signals to calculate engine speed and valve train position.

The ECM controls engine fueling by sending voltage pulses to the OPEN and CLOSE coils of the injectors. The ECM has a dual output DC to DC converter which supplies current for generating injection pulses. The DC to DC converter boosts ECM input working voltage to a high level voltage (max 50 V) and a low level voltage (max 24 V). The two voltages are used to achieve the peak and hold injector current waveform.

High-pressure Oil Flow

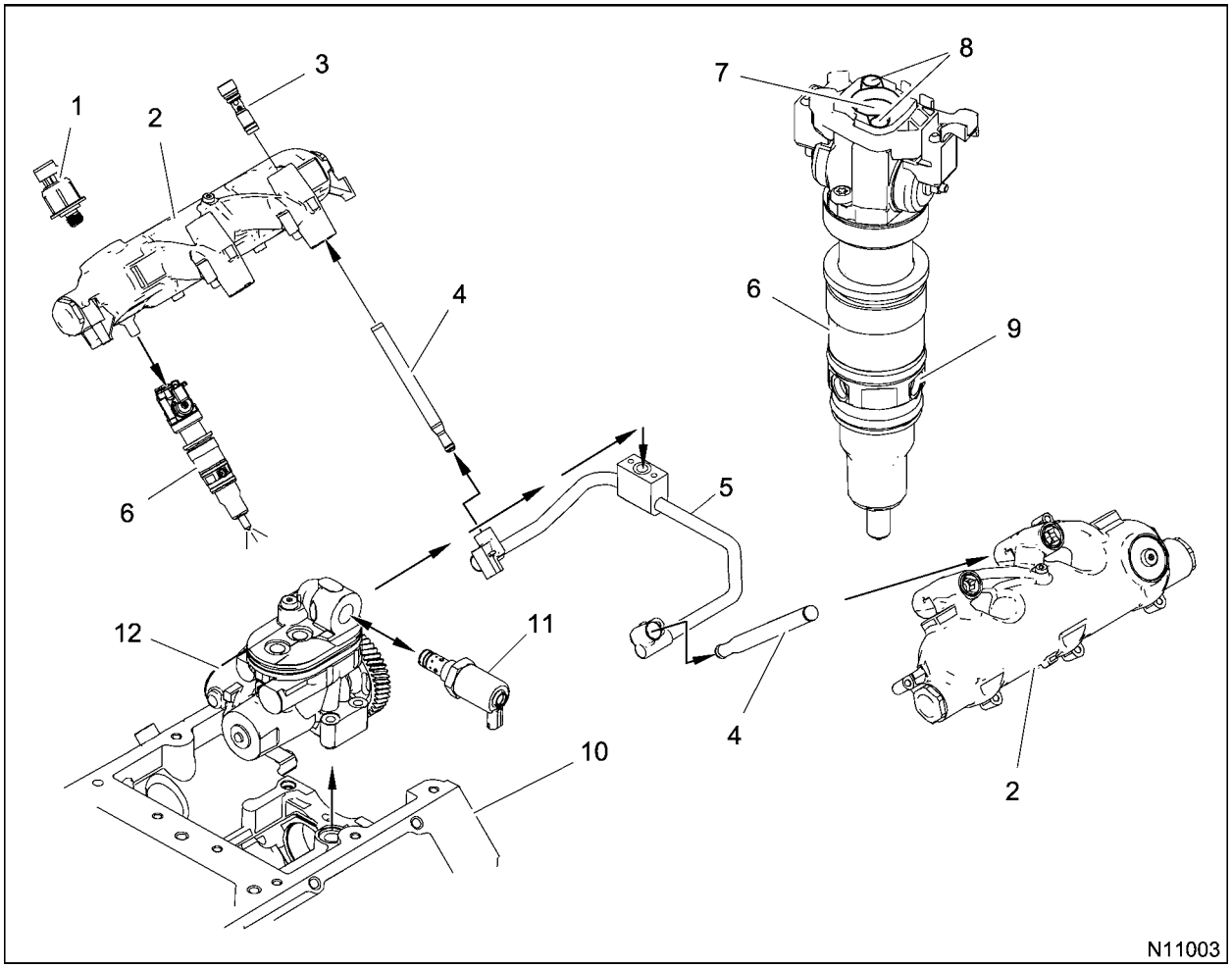

Figure 21 High-pressure oil flow and components

1. Injection Control Pressure (ICP) sensor
2. High-pressure oil rail assembly
3. Case-to-head tube plug (2)
4. Case-to-head tube assembly
5. Branch tube assembly
6. Fuel injector (6)
7. High-pressure oil inlet (injector)
8. Oil exhaust ports
9. Fuel inlet (4)
10. Crankcase
11. Injection Pressure Regulator (IPR) valve
12. High-pressure pump assembly

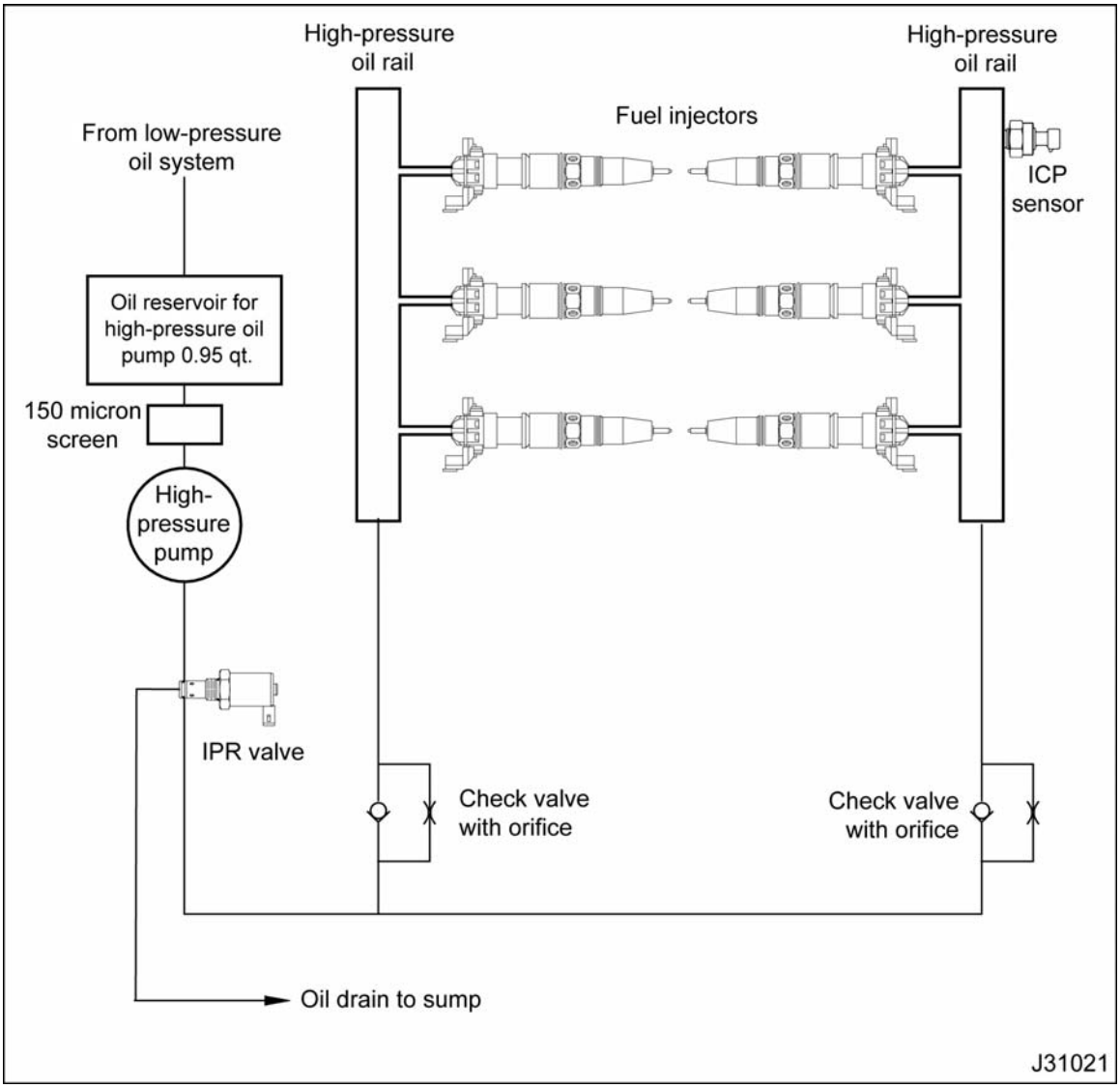

Figure 22 High-pressure oil flow schematic

The lubrication system constantly refills the high-pressure oil reservoir located in the top of the crankcase below the oil cooler.

A gear-driven, high-pressure oil pump is mounted on the top rear of the crankcase under the turbocharger. The high-pressure oil pump draws oil through a screen from the oil reservoir.

High-pressure oil flows from the high-pressure oil pump to the branch tube assembly, to both case-to-head tube assemblies and then to each high-pressure oil rail. High pressure oil from the high-pressure oil rails enters the fuel injector oil inlet ports in the top of each fuel injector.

High-pressure oil is used by the fuel injectors to pressurize and inject fuel in the cylinders. Injection begins when the OPEN coil for each fuel injector is energized. The CLOSE coils are energized to end injection. Injector exhaust oil exits through two outlet ports in the top of each injector and drains back to the oil pan.

Injection Control Pressure (ICP) System

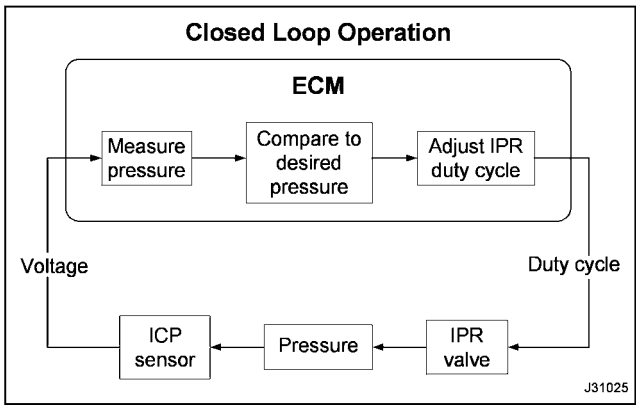

Figure 23 ICP closed loop system

The ICP system is a closed loop system that uses ICP sensor voltage to provide feedback to the Electronic Control Module (ECM). The ECM commands IPR valve duty cycle to open or close to maintain ICP pressure by dumping excess high-pressure oil back to the crankcase sump.

ICP System Control

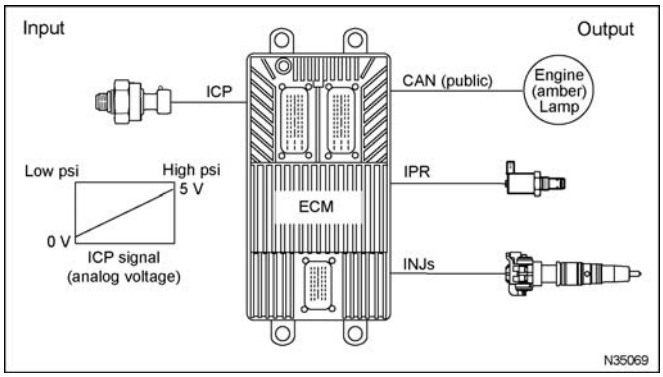

Figure 24 ICP system

The IPR solenoid receives pulse width modulated signals from the ECM to control IPR valve on and off time. The pulse is modulated to control ICP pressure in a range from 4.5 MPa (650 psi) up to 27 MPa (3,920 psi). Maximum pressure relief occurs at about 31 MPa (4,500 psi).

The IPR valve is installed in the body of the high-pressure oil pump.

As demand for ICP increases, the ECM increases the pulse - width modulation to the IPR solenoid. When ICP demand decreases, the ECM decreases the duty cycle to the solenoid, allowing more oil to flow from the drain orifice.

If the ICP signal is out of range the ECM sets one or more Diagnostic Trouble Code (DTC). The ECM ignores ICP signals that are out of range and the IPR valve will operate from programmed default values. This is called Open Loop operation.

Fuel Injector Assembly

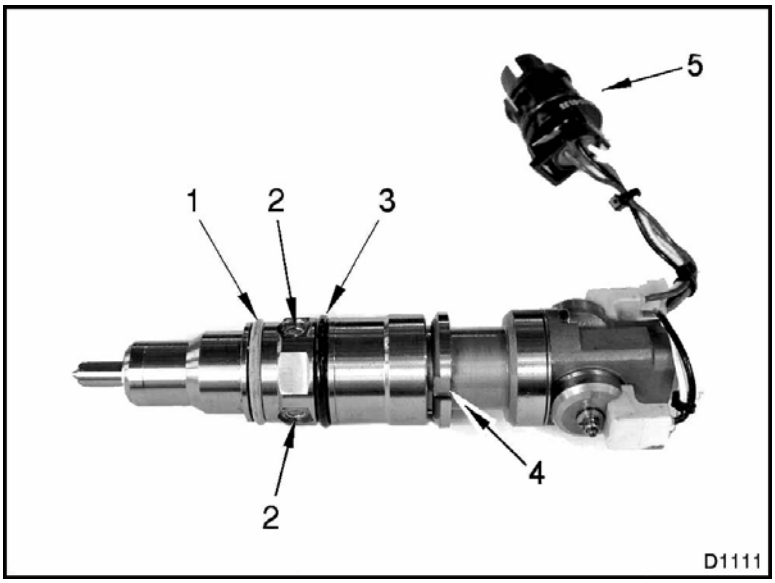

Figure 25 Fuel injector assembly

1. Lower O-ring
2. Fuel inlet screens (3)
3. Upper O-ring
4. Clamp alignment slot
5. Harness connector

Fuel Injector Features

Two 48 volt, 20 amp coils control a spool valve that directs oil flow in and out of the injector. The injector coils are turned on for approximately 800 µs (microseconds). Each injector has a single four pin connector that couples to the engine sensor wiring harness through the rocker arm carrier.

Injector Coils and Spool Valve

An OPEN coil and a CLOSE coil on the injector move the spool valve from side to side using magnetic force. The spool has two positions:

- Open; oil flows into the injector from the high-pressure oil manifold.
- Closed; oil exits the top of the fuel injector and drains back to the oil pan.

Intensifier Piston and Plunger

When the spool valve opens, high-pressure oil enters the injector and pushes down the intensifier piston and plunger. The intensifier piston is 7.1 times greater in area than the plunger so, fuel injection pressure is 7.1 times greater than Injection Control Pressure (ICP).

Plunger and Barrel

Fuel pressure builds at the base of the plunger in the barrel. When the intensifier piston pushes the plunger down, the plunger increases fuel pressure in the barrel 7.1 times greater than Injection Control Pressure (ICP). The plunger has a hardened coating to resist scuffing.

Injector Needle

The injector needle opens inward when fuel pressure overcomes Valve Opening Pressure (VOP) of 20 MPa (2,900 psi). Fuel is atomized at high-pressure through the nozzle tip.

Fuel Injector Operation

Injector operation has three stages:

- Fill
- Injection
- End of injection

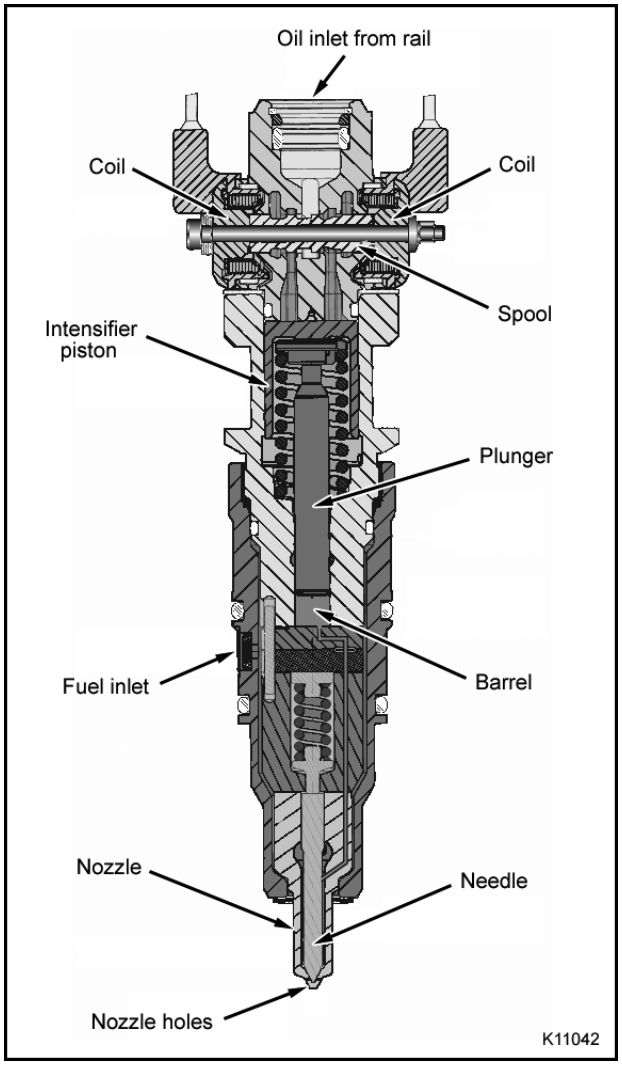

Figure 26 Fuel injector cross section

Fill

During Fill, both coils are de-energized and the spool valve is closed. High-pressure oil from the high-pressure oil manifold is stopped at the spool valve.

Low-pressure fuel fills the three ports and enters through the fuel inlet screens on its way to the chamber beneath the plunger. The needle control spring holds the needle onto its seat to prevent fuel from entering the combustion chamber.

Injection

1. A pulse-width controlled current energizes the OPEN coil. Magnetic acceleration moves the spool valve open. High-pressure oil flows past the spool valve and onto the top of the intensifier piston. Oil pressure overcomes the force of the intensifier piston spring and the intensifier starts to move down. An increase in fuel pressure under the plunger seats the fuel inlet check ball, and fuel pressure starts to build on the needle.
2. The pulse-width controlled current to the OPEN coil is shut off, but the spool valve remains open. High-pressure oil from high-pressure oil manifold continues to flow past the spool valve. The intensifier piston and plunger continue to move and fuel pressure increases in the barrel. When fuel pressure rises above Valve Opening Pressure (VOP), the needle lifts off its seat and injection begins.

End of Injection

1. When the Electronic Control Module (ECM) determines the correct injector on-time has been reached (the correct amount of fuel has been delivered), the ECM sends a pulse-width controlled current to the CLOSE coil of the injector. The current energizes the CLOSE coil and magnetic acceleration closes the spool valve. High-pressure oil is stopped against the spool valve.
2. The pulse-width controlled current to close the coil is shut off, but the spool valve remains closed. Oil above the intensifier piston flows past the spool valve through the exhaust ports. The intensifier piston and plunger return to their initial positions. Fuel pressure decreases until the needle control spring forces the needle back onto its seat.

Engine Lubrication System

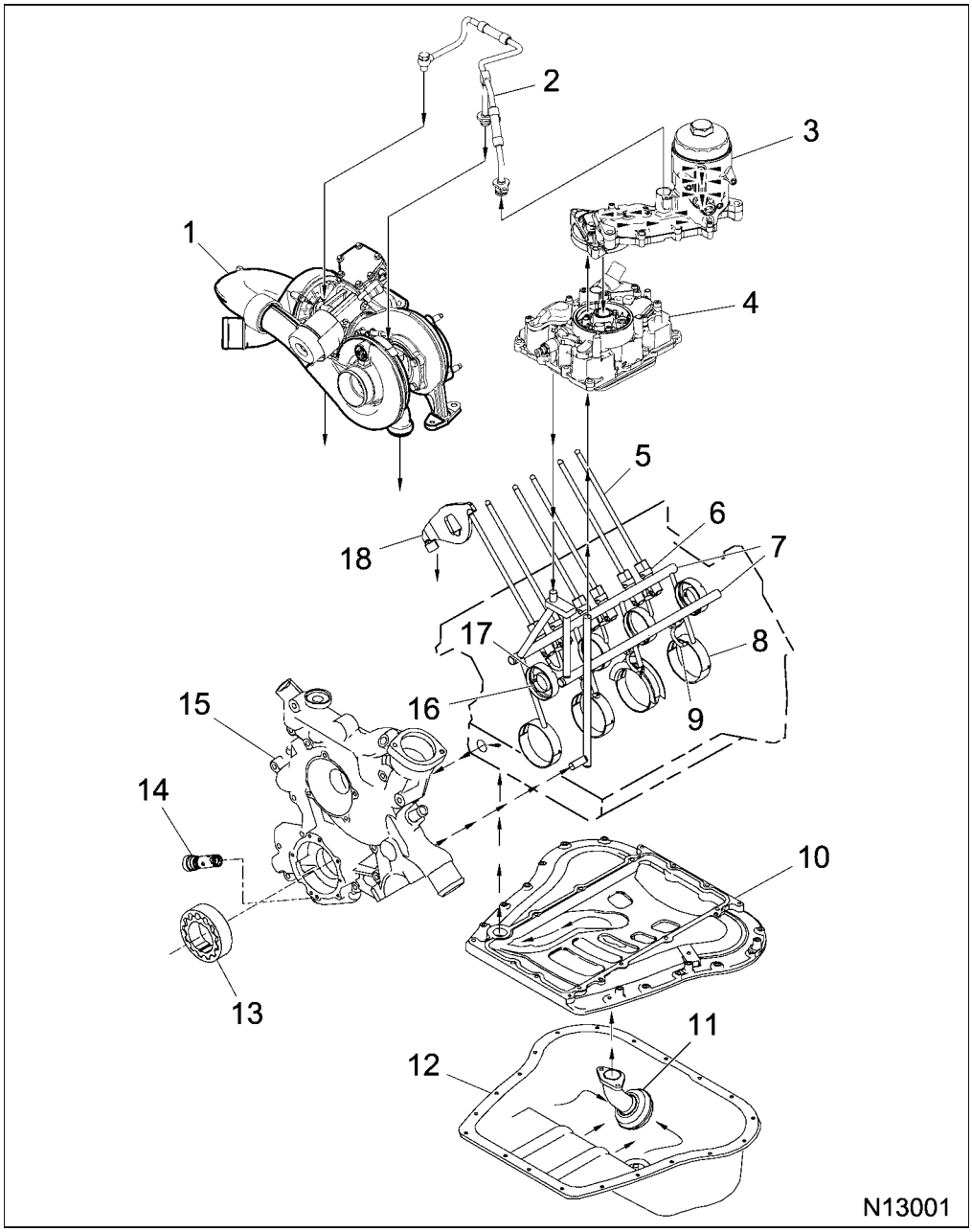

Figure 27 Lubrication system

1. Dual stage turbocharger assembly
2. Turbocharger oil supply line
3. Oil filter assembly
4. Oil cooler assembly
5. Push rod (12)
6. Hydraulic roller follower (12)
7. Oil galleries
8. Crankshaft main bearing (4)
9. Piston cooling tube (6)
10. Upper oil pan
11. Oil pickup tube
12. Oil pan
13. Rotor assembly (gerotor oil pump)
14. Oil pressure regulator
15. Front cover
16. Primary balancer shaft bushing (2) (inside camshaft)
17. Camshaft bushing (4)
18. Rocker arm assembly (12)

Oil Flow Diagram

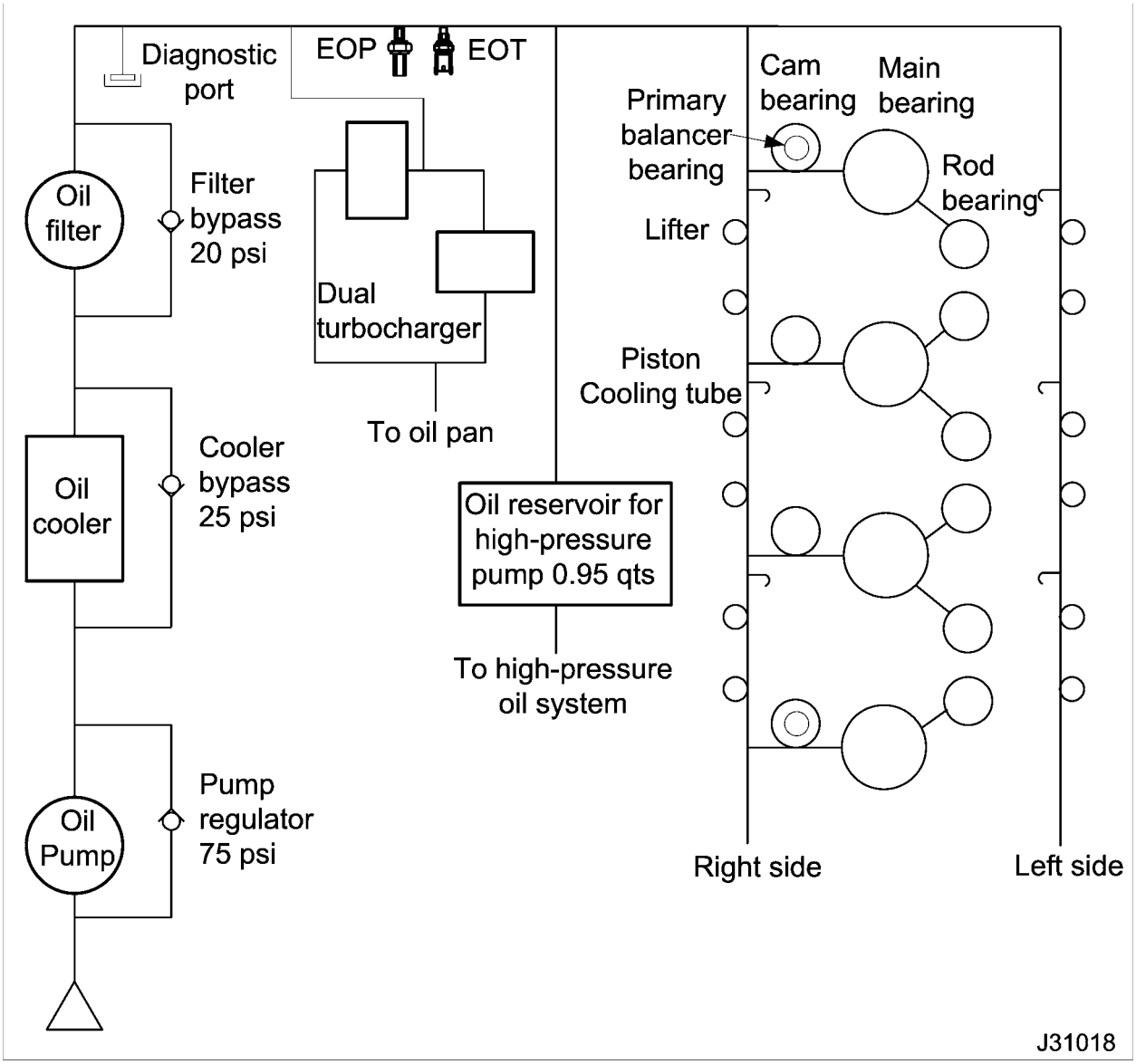

Figure 28 Lubrication system schematic

A gerotor oil pump draws oil from the oil pan through an oil pickup tube bolted to the upper oil pan. Oil flows through passages in the upper oil pan, lower crankcase, and front cover to the oil pump. The oil pump includes the front cover assembly, rotor assembly (inner and outer gears), and the gerotor housing cover. The crankshaft drives the inner rotor gear of the gerotor pump. Discharge oil flows through a passage in the front cover through the regulator valve to the gerotor pump suction.

The Electronic Control Module (ECM) monitors Engine Oil Pressure (EOP) switch and Engine Oil Temperature (EOT) sensor signals.

Oil Cooler and Filter Assemblies

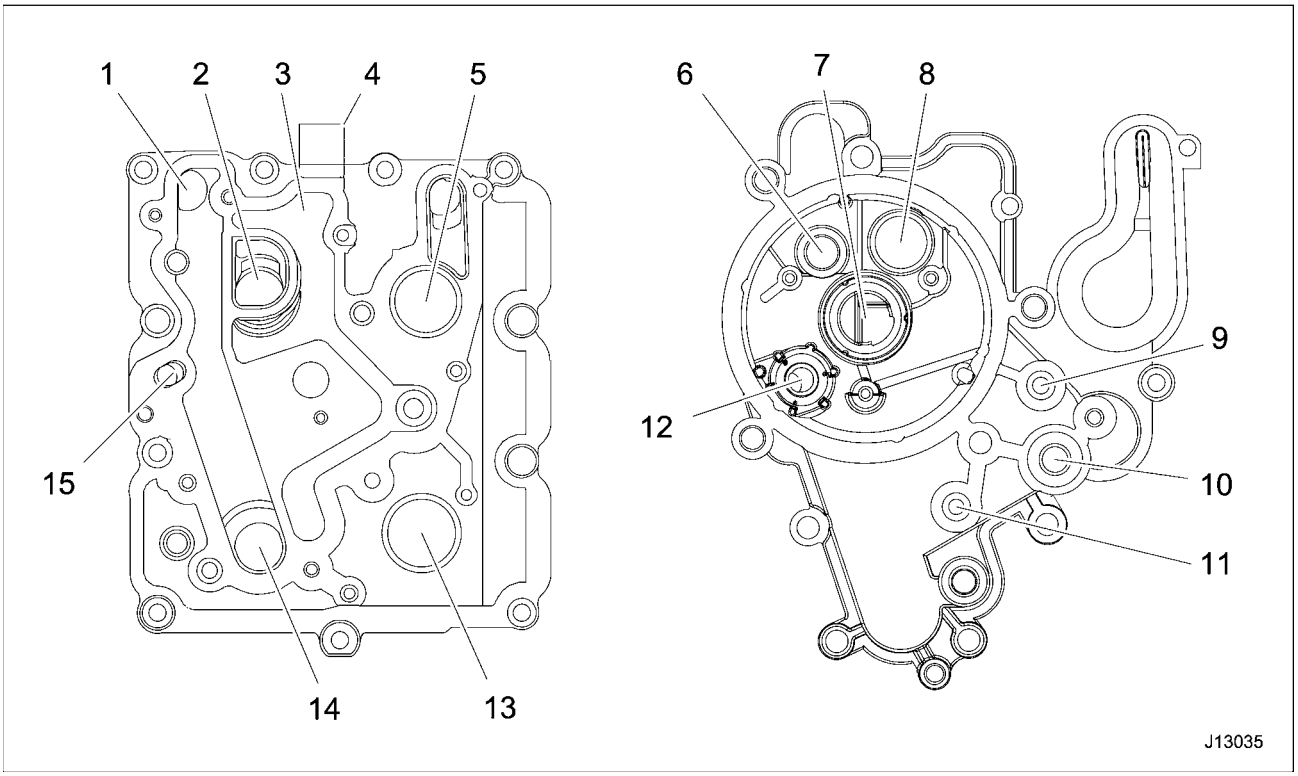

Figure 29 Oil cooler cover and oil filter base

1. Unfiltered oil flow from pump
2. Oil cooler outlet (oil)
3. Filtered oil to reservoir
4. Oil pressure test port fitting
5. Coolant inlet
6. Oil cooler bypass valve
7. Filtered oil to crankcase galleries
8. Unfiltered oil inlet
9. Oil temperature sensor port
10. Turbocharger oil supply port
11. Oil pressure sensor port
12. Oil filter drain to sump
13. Coolant outlet
14. Oil cooler inlet (oil)
15. Oil drain to sump

Pressurized oil from the oil pump flows through a passage in the front cover, through a passage in the upper crankcase, to the oil cooler cover. Passages in the oil cooler cover direct lube oil and coolant. Oil flows through plates in the oil cooler from back to front, is cooled, and flows back to the oil cooler cover.

If the oil cooler is restricted, a bypass valve in the oil filter base opens, oil bypasses the oil cooler, and flows to the oil filter base.

Oil flows through the oil filter base to the oil filter element outside to inside, up the outside of the filter stand pipe, down the inside of the stand pipe, and back to the oil filter base. If the oil filter element is restricted, a bypass valve in the oil filter return line opens, oil bypasses the oil filter element, and flows to the oil filter base.

Both bypass valves ensure full engine oil flow, even if the filter or cooler is restricted.

The oil filter base directs filtered oil to the turbocharger oil supply tube, EOP switch, EOT sensor, diagnostic port, and the oil cooler cover. Lubricating oil from the dual turbocharger drains back to the oil pan through the high-pressure oil pump cover.

When the oil filter is removed, oil flows from a drain valve in the oil filter base back to the oil pan.

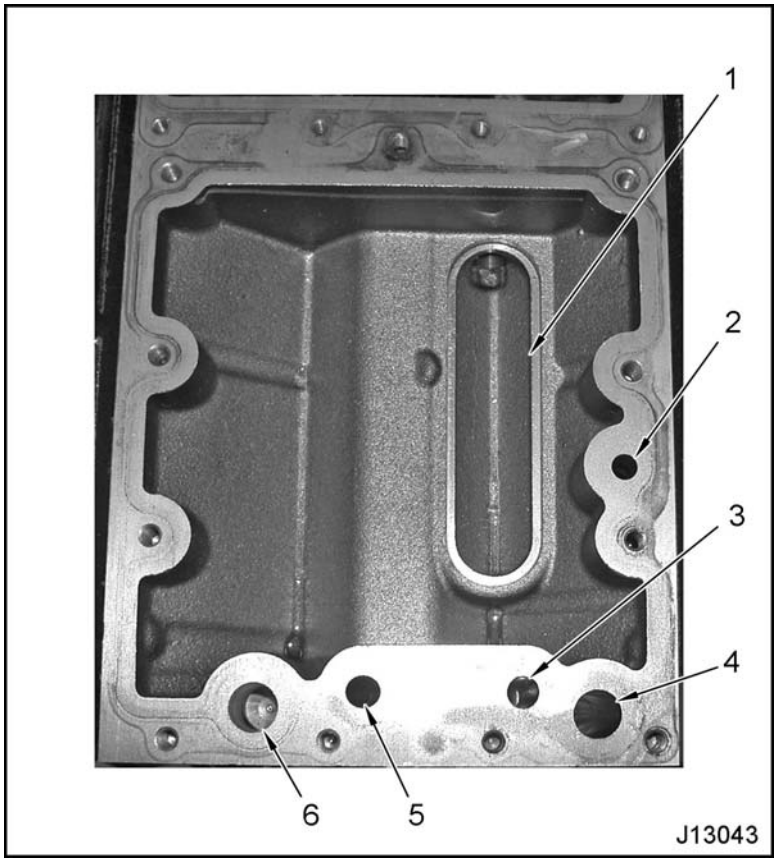

Figure 30 Oil reservoir in crankcase

1. Oil feed to high-pressure oil pump
2. Oil filter drain to pan
3. Oil feed to left side of main lube oil gallery
4. Oil feed to oil cooler cover
5. Oil feed to right side of main lube oil gallery
6. Coolant feed to oil cooler

The oil cooler cover and oil cooler base direct filtered oil in three ways:

- One passage supplies oil to the reservoir in the crankcase for the high-pressure oil pump and ICP system. A screen in the oil reservoir catches debris before oil goes to the high-pressure oil pump.
- One passage supplies filtered oil to the left side for the main lube oil gallery, push rod and rocker arms, piston cooling tubes, and lifters.
- One passage supplies filtered oil to the right side for the main lube oil gallery, push rods and rocker arms, piston cooling tubes, camshaft bushings, crankshaft main bearings, connecting rod bearings, primary balancer shaft bushings, and lifters.

Cooling System

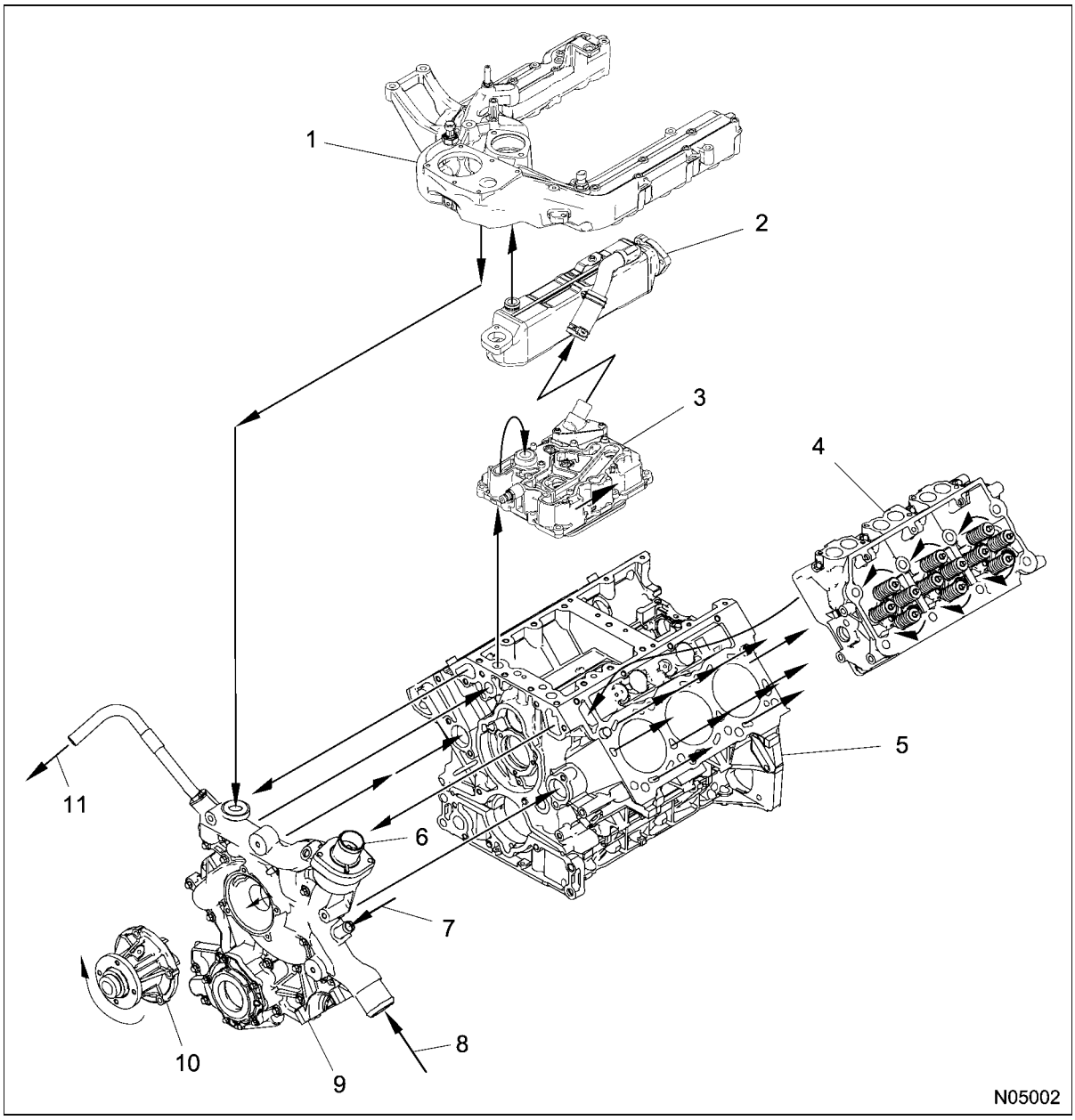

Figure 31 Cooling system components and flow

1. Intake manifold
2. EGR cooler assembly
3. Oil cooler
4. Cylinder head (2)
5. Crankcase
6. Thermostat assembly (coolant outlet to radiator)
7. Coolant return (from heater)
8. Coolant inlet (from radiator)
9. Front cover assembly
10. Water pump assembly
11. Coolant supply (to heater)

The cooling system circulates coolant to keep the engine within a designated temperature range. A centrifugal water pump (hub and impeller) is installed in the pump housing of the front cover.

Front Cover Coolant Flow

The water pump draws coolant from the radiator through the front cover coolant inlet. Coolant flows from the water pump through three passages in the front cover. Two passages (left and right) direct coolant into the crankcase coolant jackets (front to rear) to cool the cylinder walls and the cylinder heads. The third passage directs coolant through a passage in the crankcase to the oil cooler cover.

NOTE: If an oil cooler seal is damaged, weep holes in the oil filter base allow coolant to seep from the cooler cover.

Coolant returns through three front cover passages. Returned coolant is directed to the thermostat by the front cover. If the engine has reached operating temperature and the thermostat is open, coolant flows to the radiator to be cooled. If the thermostat is closed, coolant returns to the water pump through a bypass passage in the front cover.

Crankcase and Cylinder Head Coolant Flow

Coolant flows through passages in the front cover to the left and right sides of the crankcase. Coolant flows through the front of both sides of the crankcase, evenly distributing coolant around the cylinders, and exits the crankcase flowing up to the cylinder heads.

Coolant flows from the rear of the cylinder heads to the front, exits down a passage in the crankcase, and returns to the front cover.

For increased performance in cold weather, an optional power cord can be connected to the coolant heater installed in the crankcase.

Oil Cooler and EGR Cooler Coolant Flow

The front cover directs coolant to passages in the crankcase. Coolant flows from the crankcase to the front of the oil cooler cover. The oil cooler and the oil filter base direct coolant to the front of the oil cooler. Coolant flows through the oil cooler from the front to rear and exits through the EGR cooler supply tube.

Coolant flows from the rear of the EGR cooler to the front returning to the front cover though a passage in the intake manifold.

A deaeration port is on top of the intake manifold.

Thermostat Operation

The thermostat has two outlets. One directs coolant to the radiator when the engine is at operating temperature. The other directs coolant to the water pump until the engine reaches operating temperature. The thermostat begins to open at 89 °C (192 °F) and is fully open at 104 °C (219 °F).

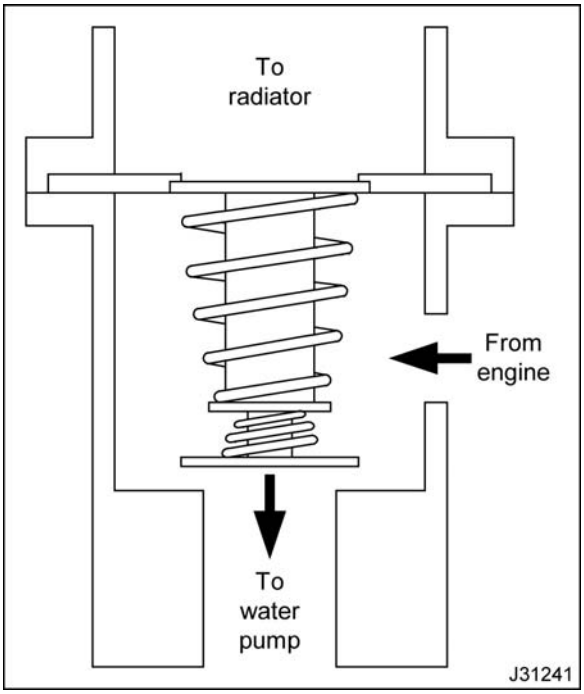

Figure 32 Coolant flow - thermostat closed

When engine coolant is below operating temperature the thermostat is closed, blocking flow to the radiator. Coolant is forced through a bypass port back to the water pump.

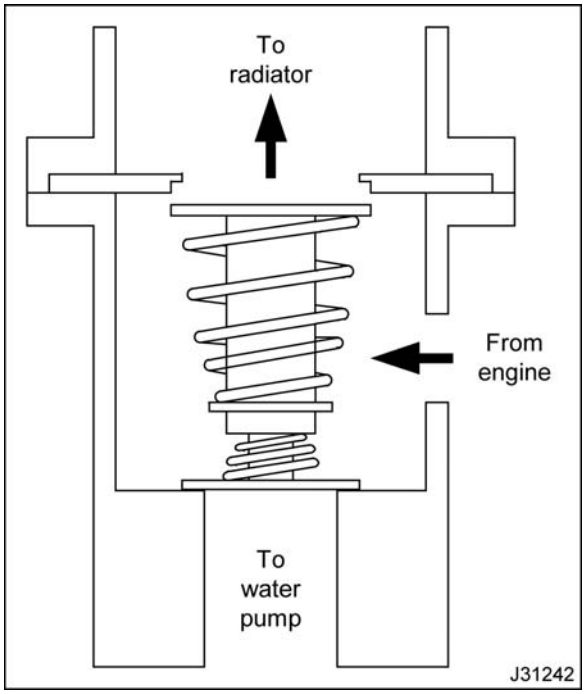

Figure 33 Coolant flow - thermostat open

As coolant temperature reaches opening temperature the thermostat starts to open allowing some coolant to flow to the radiator. When coolant temperature reaches operating temperature, the lower seat blocks the water pump port directing full coolant flow to the radiator.

Electronic Control System

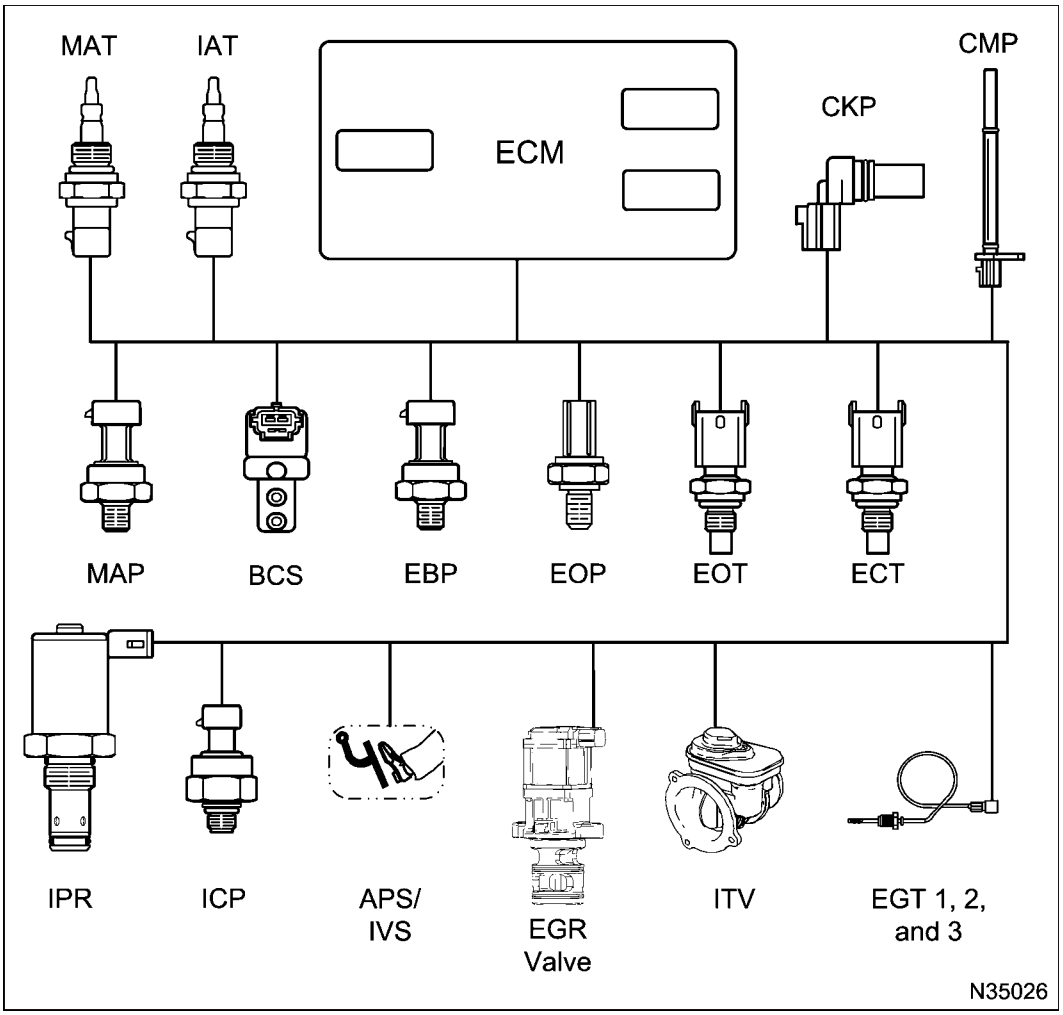

Figure 34 Electronic Control System components

Table 3 The Electronic Control System includes the following:

Electronic Control Module (ECM)	Engine Oil Temperature (EOT) sensor
Manifold Air Temperature (MAT) sensor	Engine Coolant Temperature (ECT) sensor
Intake Air Temperature (IAT) sensor	Injection Pressure Regulator (IPR) valve
Crankshaft Position (CKP) sensor	Injection Control Pressure (ICP) sensor
Camshaft Position (CMP) sensor	Accelerator Pedal Position Sensor and Idle Validation Switch (APS/IVS)
Manifold Absolute Pressure (MAP) sensor	Exhaust Gas Recirculation (EGR) valve
Boost Control Solenoid (BCS)	Intake Throttle Valve (ITV) assembly
Exhaust Back Pressure (EBP) sensor	Exhaust Gas Temperature (EGT) sensors
Engine Oil Pressure (EOP) switch	

Electronic Control System Operation and Function

The Electronic Control Module (ECM) monitors sensor input signals and controls engine performance with actuators and relays to ensure maximum performance while adhering to emissions standards. The ECM also has an internal barometric air pressure sensor which measures atmospheric pressure to compensate for changes in elevation.

The ECM has four primary functions:

- Provides Reference Voltage (VREF)
- Conditions input signals
- Processes and stores control strategies
- Controls actuators

Reference Voltage (VREF)

The ECM supplies a 5 volt VREF signal to input sensors in the electronic control system. By comparing the 5 volt VREF signal sent to the sensors with their respective returned signals, the ECM determines pressures, positions, and other variables.

The ECM supplies two independent circuits for VREF:

- VREF A supplies 5 volts to engine sensors
- VREF B supplies 5 volts to vehicle sensors

Signal Conditioner

A signal conditioner in the ECM converts analog signals to digital signals, squares up sine wave signals, or amplifies low intensity signals.

Microprocessor

The ECM microprocessor stores operating instructions (control strategies) and value tables (calibration parameters). The ECM compares stored instructions and values with conditioned input values to determine the correct operating strategy for all engine operations.

Continuous calculations in the ECM occur at two different levels or speeds: Foreground and Background.

- Foreground calculations are faster than background calculations and are critical for engine operation. Engine speed control is an example.
- Background calculations are variables that change at slower rates. Engine temperature is an example.

Diagnostic strategies are also programmed into the ECM. Some strategies monitor inputs continuously and command the necessary outputs for correct performance of the engine. If inputs or conditions are not within expected values, the microprocessor sets a Diagnostic Trouble Code (DTC).

The ECM microprocessor includes Read Only Memory (ROM) and Random Access Memory (RAM).

ROM stores permanent information for calibration tables and operating strategies. Permanently stored information cannot be changed or lost by turning the ignition switch OFF or when ECM power is interrupted. ROM includes the following:

- Vehicle configuration, modes of operation, and options
- Engine Family Rating Code (EFRC)
- Engine warning and protection modes

RAM stores temporary information for current engine conditions. Temporary information in RAM is lost when the ignition switch is turned to OFF or when ECM power is interrupted. RAM information includes the following:

- Engine temperature
- Engine rpm
- Accelerator pedal position

Actuators

The ECM controls engine operation with the following:

- Intake Air Heater (IAH) relay
- Glow plug relay
- Fuel pump relay
- Injection Pressure Regulator (IPR) valve
- Boost Control Solenoid (BCS)
- Exhaust Gas Recirculation (EGR) valve
- Intake Throttle Valve (ITV) assembly

Actuators are controlled in the following ways:

- Switched on or off
- Pulse Width Modulation (PWM)
- Controller Area Network (CAN) digital signals
- Duty cycle (percent time on/off)

The ECM controls actuators by applying a low level signal (low side driver) or a high level signal (high side driver). When switched on, both drivers complete a ground or power circuit to an actuator.

Intake Air Heater (IAH) Relay

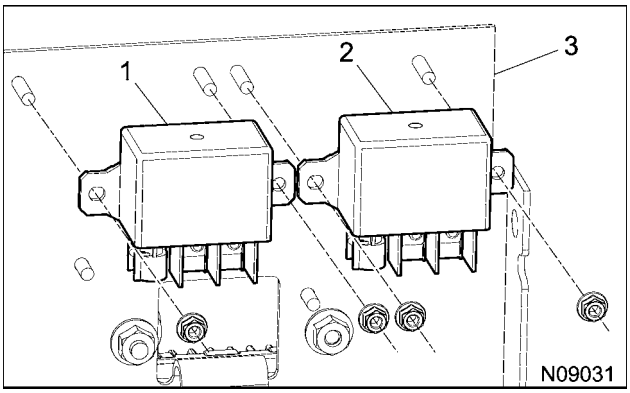

Figure 35 IAH and glow plug relays

1. Glow plug relay
2. IAH relay
3. ECM bracket

The IAH heats incoming air to aid cold starting and engine performance.

The ECM controls the IAH relay by switching on a voltage source. The relay delivers VREF to the Intake Air Heater for up to 30 seconds KOEO, depending on Engine Oil Temperature and altitude. Ground is supplied through pin-1 of the 16-pin connector to battery ground at all times. After the engine starts the IAH can stay on up to 30 minutes in cold conditions.

Glow Plug Relay

The glow plug system heats the engine cylinders to aid cold engine starting and to reduce exhaust emissions during warm-up.

The ECM controls the glow plug relay by switching on a voltage source. The relay delivers VREF to the glow plugs for up to 120 seconds, depending on engine coolant temperature and atmospheric pressure. Ground is supplied through pin-1 of the 16-pin connector to battery ground at all times.

Fuel Pump Relay

The fuel pump is installed inside the Horizontal Fuel Conditioning Module (HFCM). Power to the fuel pump is supplied through the fuel pump relay.

The ECM controls the fuel pump relay by switching on a voltage source.

Injection Pressure Regulator (IPR) Valve

The IPR valve releases excess high-pressure oil to regulate Injection Control Pressure (ICP).

The ECM controls the IPR valve with Pulse Width Modulation (PWM) signals in response to ICP sensor input.

Boost Control Solenoid (BCS)

The BCS assembly is a two position valve that controls intake manifold boost pressure to the turbocharger pneumatic actuator. The pneumatic actuator controls the turbocharger bypass valve and turbocharger boost pressure.

The ECM controls the BCS by setting its duty cycle to 100% or 0%.

Exhaust Gas Recirculation (EGR) Valve

The EGR valve controls the flow of cooled exhaust gases into the intake air stream to reduce NOx emissions by reducing combustion temperatures.

The EGR valve changes valve position in response to private Controller Area Network (CAN) digital signals from the ECM.

Intake Throttle Valve (ITV) Assembly

The ITV assembly restricts inlet air flow to control air/fuel ratio and increase exhaust temperature during aftertreatment regeneration. The ITV also restricts air flow for engine shutdowns due to Engine Warning and Protection System (EWPS) or Idle Shutdown Timer (IST) features, where the engine is shut-off without turning the key-off.

The ECM controls the ITV with Pulse Width Modulation (PWM) signals through H-bridge circuitry. The ITV contains an integral position sensor which monitors valve position and sends a position signal to the ECM.

Sensors and Switches

Thermistor Sensors

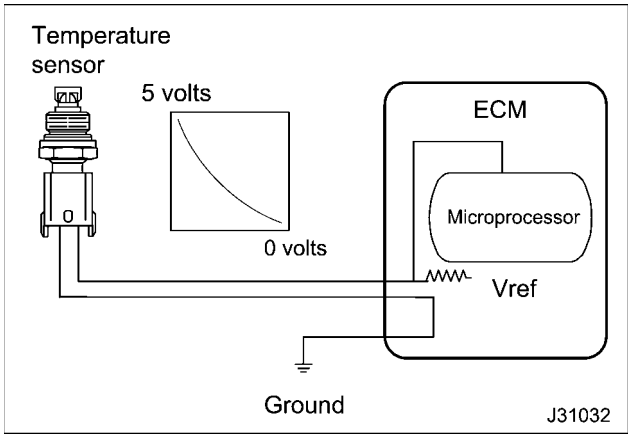

Figure 36 Thermistor

Thermistor sensors:

- Engine Oil Temperature (EOT)
- Engine Coolant Temperature (ECT)
- Manifold Air Temperature (MAT)
- Intake Air Temperature (IAT)
- Exhaust Gas Temperature (EGT)

Thermistor sensors change electrical resistance with changes in temperature. Resistance in the thermistor decreases as temperature increases, and increases as temperature decreases. Thermistors work with a resistor that limits current in the ECM to form a voltage signal matched with a temperature value.

The top half of the voltage divider is the current limiting resistor inside the ECM. Thermistor sensors have two electrical connectors, signal return and ground. The output of a thermistor sensor is a nonlinear analog signal.

Engine Oil Temperature (EOT) Sensor

The ECM monitors the EOT signal to control fuel quantity. The EOT signal allows the ECM to compensate for differences in oil viscosity as oil temperature changes. The EOT sensor is installed in the oil filter base.

Engine Coolant Temperature (ECT) Sensor

The ECM monitors the ECT signal and uses this information for the instrument panel temperature gauge, Coolant Temperature Compensation (CTC), Engine Warning Protection System (EWPS), Intake Air Heater (IAH) and glow plug operation. The ECM will use ECT sensor input as a backup, if EOT sensor values are out of range. The ECT sensor is installed in the left side of the front cover assembly.

Manifold Air Temperature (MAT) Sensor

The ECM monitors the MAT signal for EGR operation. The MAT sensor is installed in the left side of the intake manifold.

Intake Air Temperature (IAT) Sensor

The ECM monitors the IAT signal to control fuel timing and rate during cold starts. The IAT sensor is installed in the turbocharger air intake, between the inlet of the turbocharger and the air filter.

Exhaust Gas Temperature (EGT) Sensors

Three EGT sensors are used in the aftertreatment system.

The EGT1 sensor provides a signal to the ECM indicating Diesel Oxidation Catalyst (DOC) inlet temperature. The EGT1 sensor is the first temperature sensor installed past the turbocharger and just before the DOC.

The EGT2 sensor provides a feedback signal to the ECM indicating Diesel Particulate Filter (DPF) inlet temperature. The EGT2 sensor is the second temperature sensor installed past the turbocharger and just after the DOC.

The EGT3 sensor provides a feedback signal to the ECM indicating DPF outlet temperature. The EGT3 sensor is the third temperature sensor installed past the turbocharger and just after the DPF.

During catalyst regeneration, the ECM monitors all three EGT sensors and adjusts the Intake Throttle Valve (ITV) and Exhaust Gas Recirculation (EGR) valve as needed.

Variable Capacitance Sensors

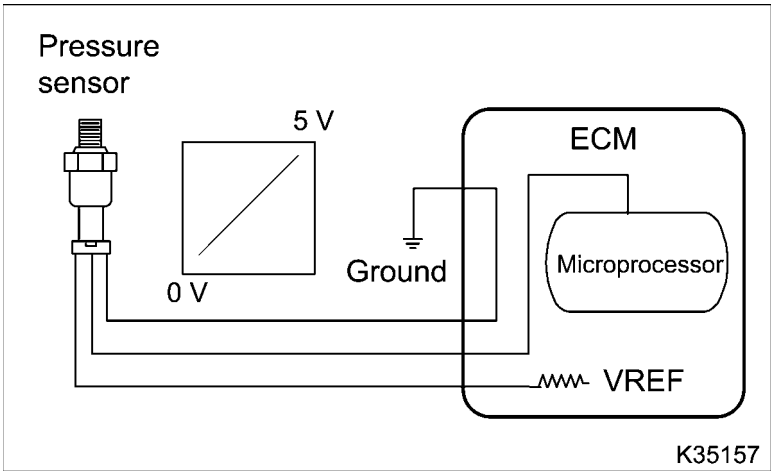

Figure 37 Variable capacitance sensor

Variable capacitance sensors:

- Exhaust Gas Differential Pressure (EGDP) sensor
- Exhaust Back Pressure (EBP) sensor
- Manifold Air Pressure (MAP) sensor

Variable capacitance sensors measure pressure. When pressure is applied to the sensor a ceramic material is forced closer to a thin metal disk which changes the capacitance of the sensor.

Variable capacitance sensors are connected to the ECM by three wires:

- VREF
- Signal
- Signal ground

The sensor receives the VREF and returns an analog signal voltage to the ECM. The ECM compares the voltage with pre-programmed values to determine pressure.

The operational range of a variable capacitance sensor is linked to the thickness of the ceramic disk. The thicker the ceramic disk the more pressure the sensor can measure.

Exhaust Gas Differential Pressure (EGDP) Sensor

The EGDP sensor provides a signal to the ECM indicating the pressure difference between the inlet and outlet of the Diesel Particulate Filter (DPF). During catalyst regeneration, the ECM monitors this sensor, three Exhaust Gas Temperature (EGT) sensors, the EGR System, and the Intake Throttle Valve (ITV).

The EGDP sensor is a differential pressure sensor with two tap-offs installed past the turbocharger. A tap-off is installed before and after the DPF.

Exhaust Back Pressure (EBP) Sensor

The ECM monitors exhaust back pressure to control turbocharger, EGR, and intake throttle systems. The EBP sensor is installed in a tube connected to the left exhaust manifold.

Manifold Air Pressure (MAP) Sensor

The ECM monitors the MAP signal to determine intake manifold pressure (boost). This information is used to control the turbocharger boost. The MAP sensor is installed in the intake manifold, left of the MAT sensor.

Micro Strain Gauge (MSG) Sensor

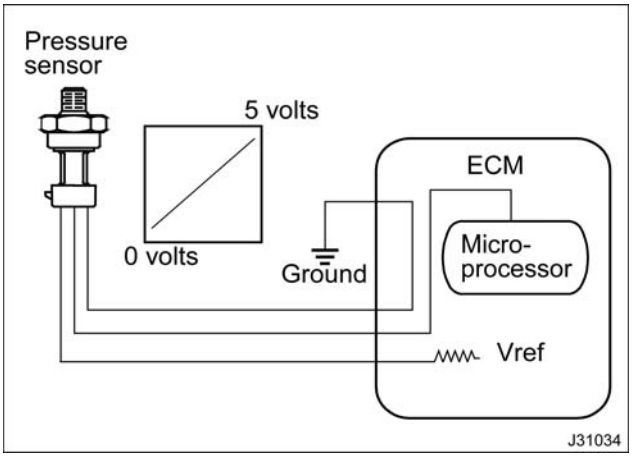

Figure 38 MSG sensor

Micro strain gauge sensor:

Injection Control Pressure (ICP)

A Micro Strain Gauge (MSG) sensor measures pressure. Pressure 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.

The Micro Strain Gauge (MSG) sensor is connected to the ECM by three wires:

- VREF
- Signal
- Signal ground

The sensor is powered by VREF received from the ECM and is grounded through the ECM to a common sensor ground.

Injection Control Pressure (ICP) Sensor

The ICP sensor measures injection control pressure. The ECM monitors the ICP signal for closed loop control of the Injection Pressure Regulator (IPR) valve. The ICP sensor is installed through the right side valve cover in the oil high-pressure oil rail.

Potentiometer

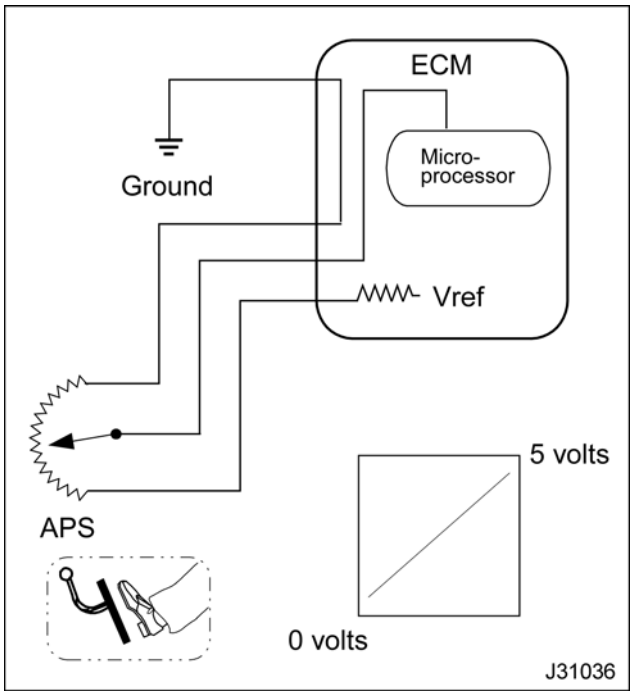

Figure 39 Potentiometer

Potentiometer:

APS

A potentiometer is a variable voltage divider that senses the position of a mechanical component. A reference voltage is applied to one end of the potentiometer. Mechanical rotary or linear motion moves the wiper along the resistance material, changing voltage at each point along the resistive material. Voltage is proportional to the amount of mechanical movement.

Accelerator Position Sensor (APS)

The APS provides the ECM with a feedback signal (linear analog voltage) that indicates the operator's demand for power. The APS is installed in the accelerator pedal assembly.

Magnetic Pickup Sensors

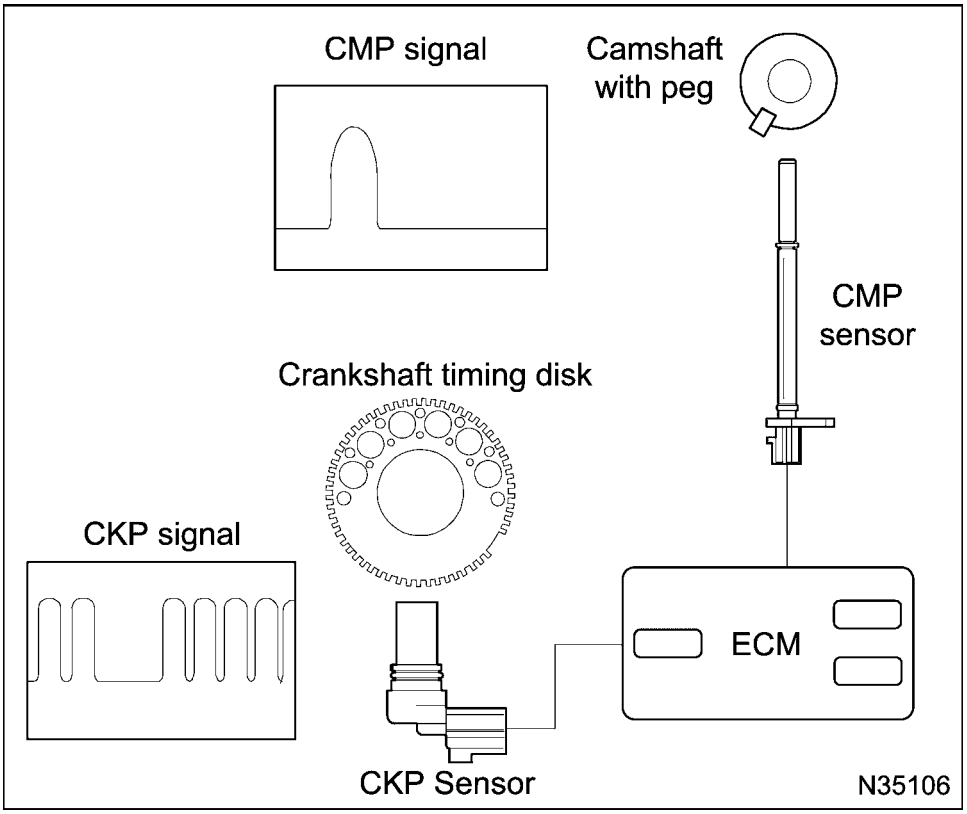

Figure 40 Magnetic pickup

Magnetic pickup sensors:

- Crankshaft Position (CKP)
- Camshaft Position (CMP)

Magnetic pickup sensors have a permanent magnetic core surrounded by a wire coil. Signal frequency is generated by the rotation of gear teeth that disturb the magnetic field and generate an alternating frequency current that indicates rotational speed. Magnetic pickups have a two wire connection for signal and ground.

Crankshaft Position (CKP) Sensor

The CKP sensor provides the ECM with a signal that indicates crankshaft speed and position. As the crankshaft turns the CKP sensor detects a 60 tooth timing disk on the crankshaft. Teeth 59 and 60 are missing. By comparing the CKP signal with the CMP signal, the ECM calculates engine rpm and timing requirements. The CKP is installed in the front right side of the lower crankcase.

Camshaft Position (CMP) Sensor

The CMP sensor provides the ECM with a signal that indicates camshaft position. As the cam rotates, the sensor identifies the position of the cam by locating a peg on the cam. The CMP is installed in the front left side of the lower crankcase.

Switches

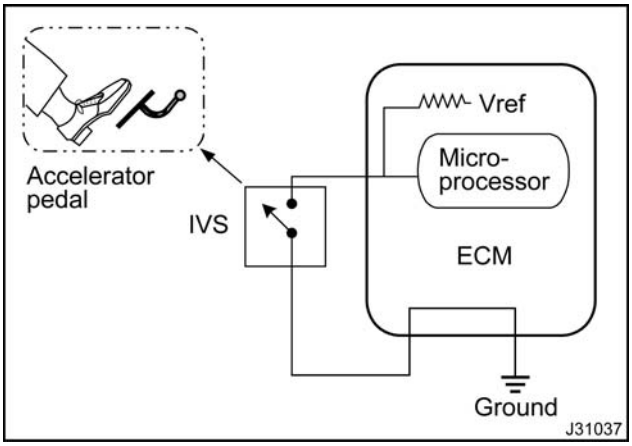

Figure 41 Switch

Switches:

- Driveline Disengagement Switch (DDS) (transmission select)
- Idle Validation Switch (IVS)
- Water In Fuel (WIF)
- Engine Oil Pressure (EOP)
- Engine Coolant Level (ECL)
- Engine Fuel Pressure (EFP) switch

Switches indicate position or condition. They operate OPEN or closed, allowing or preventing the flow of current. A switch can be a voltage input switch or a grounding switch. A voltage input switch supplies the ECM with a voltage when it is closed. A grounding switch grounds the circuit when closed, causing a zero voltage signal. Grounding switches are usually installed in series with a current limiting resistor.

Driveline Disengagement Switch (DDS)

The Transmission Control Module (TCM) monitors the transmission shifter position. A signal from the TCM functions as the DDS signal to the ECM. Manual transmission applications will have a clutch switch for the DDS signal.

Idle Validation Switch (IVS)

The IVS is a redundant switch that provides the ECM with a signal that verifies when the APS is in the idle position.

Water In Fuel (WIF) Switch

A WIF switch detects water in the fuel filter of the HFCM. When enough water accumulates in the filter housing, the WIF switch sends a signal to the ECM. The ECM sets a Diagnostic Trouble Code (DTC) and illuminates the amber water in fuel lamp (fuel pump next to a fuel tank) on the right side of the instrument panel. The WIF switch is installed in the HFCM.

Engine Oil Pressure (EOP) Switch

The ECM monitors the EOP signal for reference only. The ECM uses the EOP signal to control EWPS warning, and lights the red Stop Engine Lamp for low oil pressure. The EOP switch closes a circuit to ground when the engine oil pressure reaches 34 to 48 kPa (5 to 7 psi). The EOP switch is installed in the oil filter base assembly.

Engine Coolant Level (ECL) Switch

The ECL is part of the Engine Warning Protection System (EWPS). The ECL switch is used in plastic deaeration tanks. When a magnetic switch is OPEN, the tank is full.

If engine coolant is low, the red Stop Engine Lamp on the instrument panel is illuminated.

Engine Fuel Pressure (EFP) switch

The ECM monitors the EFP to detect low fuel supply pressure. If fuel supply pressure drops below 30 psi, due to a fuel filter restriction or other problem, the ECM reduces ICP pressure to 14 MPa. The EFP is installed in the secondary fuel filter housing.

Glow Plug System

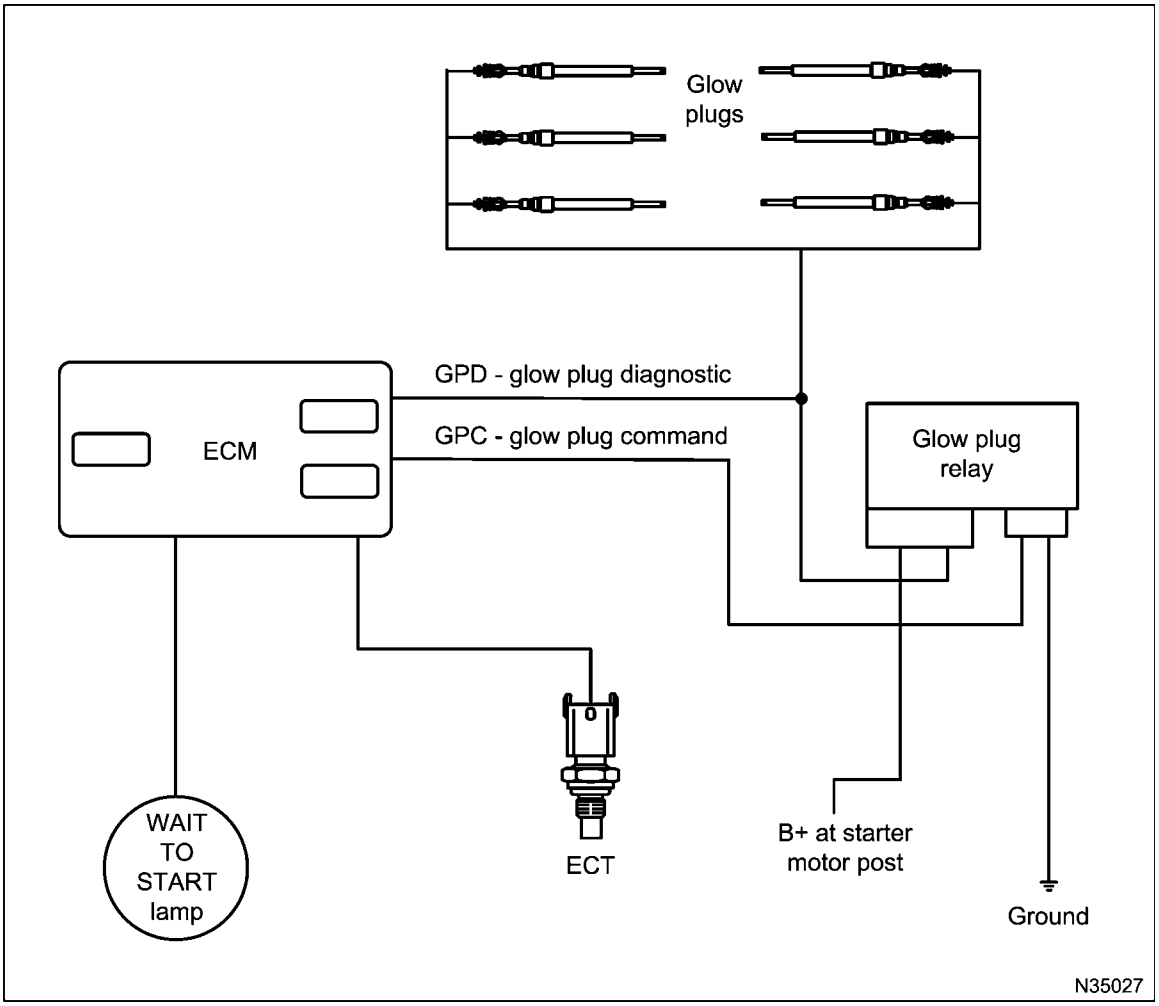

Figure 42 Glow plug system

The glow plug system warms the engine cylinders to aid cold engine starting and reduce exhaust emissions during warm-up.

The ECM energizes the glow plugs, by energizing the glow plug relay, while monitoring engine coolant temperature and atmospheric pressure. Glow plug activation time is increased, if the engine is cold and barometric pressure is low (high altitude).

The ECM monitors battery voltage and uses information from its internal barometric pressure sensor and the ECT sensor to determine WAIT TO START lamp ON time and the activation of the glow plug relay. The ECM controls the WAIT TO START lamp and the glow plug relay separately. The glow plugs are self-limiting and do not require cycling on and off. The glow plug relay will cycle on and off repeatedly if system voltage is greater than 14.0 volts.

The engine is ready to start when the WAIT TO START lamp is turned off by the ECM. The glow plugs can remain on up to 120 seconds while the engine is running to reduce exhaust emissions during engine warm-up.

Inlet Air Heater (IAH) System

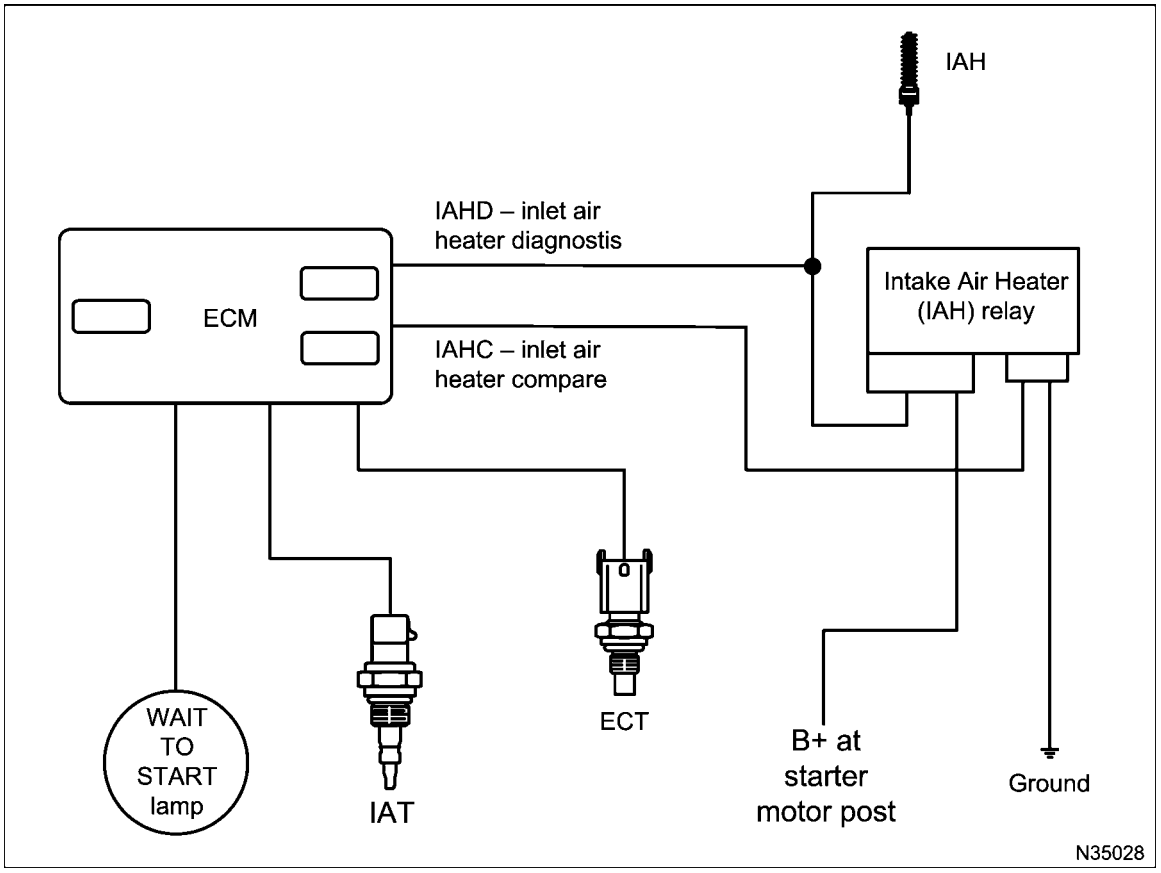

Figure 43 Inlet air heater system

The inlet air heater system warms the incoming air to aid cold engine starting and reduce exhaust emissions during warm-up.

The ECM energizes the inlet air heater, by energizing the inlet air heater relay, while monitoring programmed conditions for engine oil temperature, inlet air temperature, and atmospheric pressure.

The ECM controls the WAIT TO START lamp and inlet air heater relays separately.

The engine is ready to start when the WAIT TO START lamp is turned off by the ECM. The ECM will turn the inlet air heater on for a predetermined amount of time, based on ECT, IAT, and BAP. The inlet air heater can remain on while the engine is running to reduce exhaust emissions and white smoke during engine warm-up.

If the ECT is above 70 °C (158 °F), the inlet air heater will not reactivate when restarting the engine unless the IAT is 15 °C (59 °F) or colder.

Once the engine starts to crank, the IAH is turned off. Depending on factory calibration, once the engine starts the IAH can be reactivated for a calibrated amount of time.

Table of Contents

Standard Features

American Trucking Association (ATA) Datalink

Vehicles are equipped with an ATA datalink for communications between the Electronic Control Module (ECM), ATA Electronic Gauge Cluster (EGC) and the Electronic Service Tool (EST).

For additional information, see ATA (American Trucking Association) Datalink in the “Electronic Control Systems Diagnostics” section of this manual.

Controller Area Network (CAN) Datalink

The CAN provides communication between the ECM and all connecting modules, sending and receiving digital messages. CAN J1939 is a broadcast serial network standard.

Vehicles are equipped with two CAN networks:

- The public CAN is used for diagnostics and calibration of the Electronic Gauge Cluster (EGC), Antilock Brake System (ABS), Transmission Control Module (TCM), and the Electronic Control Module (ECM).
- The private CAN is used for communications between the ECM and Exhaust Gas Recirculation (EGR) valve. Private CAN is not accessible through the EST connector.

The public CAN is accessed through EST connector pins C and D and provides communication between the ECM and EST.

The CAN datalink supports:

- Transfer of engine parameter data
- Transmitting and clearing of DTCs
- Diagnostics and troubleshooting
- Intermodule communication between the ECM, TCM, EGC, ABS, EGR valve, and EST.
- Programming engine and vehicle features
- Programming calibrations and strategies

For additional information, see CAN Communications (Controller Area Network) (Public) in the “Electronic Control Systems Diagnostics” section of this manual.

Service Diagnostics

The Electronic Service Tool (EST) communicates with the control system through the public CAN network. The EST allows the user to retrieve and clear fault codes, run special diagnostic tests and monitor control system sensors and actuators, update control system software, and adjust special features.

Engine Crank Inhibit (ECI)

Prevents starter engagement when the engine is running or when the transmission is in gear.

Electronic Governor Control

Controls engine rpm within a safe and stable operating range.

Low idle governor prevents engine rpm from dropping below a stable speed to prevent stalling when various loads are demanded on the engine.

High idle governor prevents engine rpm from going above a safe speed that would cause engine damage.

Electronic Speedometer and Tachometer

The ECM uses Camshaft Position (CMP) sensor and Crankshaft Position (CKP) sensor input to detect engine speed. The Vehicle Speed Sensor (VSS) signal is sent from the Transmissions Control Module (TCM) to the ECM. The Tach and VSS signals are sent through the J1939 public CAN network to the Electronic Gauge Cluster (EGC). The TACH signal is also supplied on one circuit to the body builder blunt cut-off circuits.

Aftertreatment System

The Aftertreatment System processes engine exhaust to meet strict tailpipe emission requirements and traps particulate matter (soot) to prevent it from leaving the tail pipe. Regeneration heats the exhaust to turn trapped soot into ash. For additional information, see AFT System (Aftertreatment) (page 200).

Engine Fan (EFAN)

The EFAN increases air flow through the radiator when the Engine Coolant Temperature (ECT) goes above a set temperature (CityStar™ only).

Glow Plugs

The glow plugs warm engine cylinders to aid cold engine starting and reduce exhaust emissions during engine warm-up.

Inlet Air Heater (IAH)

The IAH system warms inlet air to reduce exhaust emissions during engine warm-up and aids cold engine starting.

Fast Idle (Cold Idle Kicker)

Fast Idle increases minimum idle speed from 700 to 1000 rpm for faster engine warm-up depending on Engine Coolant Temperature (ECT) sensor input. Low idle speed is increased when ECT is between -40 °C (-40 °F) and 35 °C (95 °F). Fast Idle protects against cold weather damage, which may occur due to build-up of exhaust emission condensates in engine components (turbocharger, EGR, valves).

Cold Ambient Protection (CAP)

CAP sustains engine heat during extended cold weather idle periods. CAP is active only when the engine is idling for more than 5 minutes, Engine Coolant Temperature (ECT) is below 65 °C (149 °F) and Manifold Air Temperature (MAT) is below 0 °C (32 °F). Minimum idle speed is increased from 700 rpm up to 1400 rpm depending on MAT. Engine speed is increased to maintain ECT greater than 82 °C (180 °F).

CAP protects against cold weather damage, which may occur due to build-up of exhaust emission condensates in engine components (turbocharger, EGR, valves).

Coolant Temperature Compensation (High Temperature Protection)

CTC reduces engine fueling and torque when Engine Coolant Temperature (ECT) is above specifications. Torque and EGR rate reductions begin when ECT reaches approximately 111 °C (232 °F). Torque is reduced 10% as ECT increases to approximately 112.5 °C (235 °F). Torque is reduced 40% as ECT increases to approximately 117 °C (243 °F).

Idle Shutdown Timer (IST)

GOVERNMENT REGULATION: State and local regulations may limit engine idle time. The vehicle owner or operator is responsible for compliance with those regulations.

The IST allows the Electronic Control Module (ECM) to shut down the engine during extended engine idle times.

Thirty seconds before IST-defined engine shutdown, a vehicle instrument panel indicator activates. There are two types of indicators:

- Amber flashing idle shutdown indicator for multiplex electrical systems.
- Red flashing indicator with audible alarm for non-multiplex electrical systems (MaxxForce 5).

This continues until the engine shuts down or the low idle shutdown timer is reset.

IST for California ESS Compliant Engines

Engine idle duration is limited for California Engine Shutdown System (ESS) compliant engines as follows:

- When vehicle parking brake is set, the idle shutdown time is limited to the California Air Resources Board (CARB) requirement of 5 minutes.
- When vehicle parking brake is released, the idle shutdown time is limited to the CARB requirement of 15 minutes.

The duration of CARB mandated values can be reduced by programming the customer IST programmable parameter to a value lower than 15 minutes.

Engine Idle Shutdown Timer (Federal–Optional)

Idle time can be programmed from 5 to 120 minutes. While the Electronic Service Tool (EST) is installed, the IST function will be active with the programmed shutdown time in effect. Parking brake transitions reset the idle timer in all 2008 engines. If the IST is enabled, the Cold Ambient Protection (CAP) will not function.

For additional information, see IST (Idle Shutdown Timer) (page 354).

Event Logging System

The event logging system records engine operation above maximum rpm (over speed), high coolant temperature, or low oil pressure. The readings for the odometer and hourmeter are stored in the ECM memory at the time of an event and can be retrieved using the EST.

Engine Warning Protection System (EWPS)

EWPS warns the operator of conditions that can damage the engine.

The Standard Warning System is the base system in which all engines are equipped. If one of these faults are detected, the ECM will illuminate the red Oil/Water (OWL) lamp and set a corresponding Diagnostic Trouble Code (DTC).

Standard Warning – No engine shut down available.

- RPM - Engine over-speed warning
- ECT - Engine over-heat warning

The following optional features to this base system provide added warning or protection.

2-way Warning (optional) – No engine shut down available.

- ECT - Engine over-heat warning
- EOP - Low engine oil pressure warning

3-way Warning (optional) – No engine shut down available.

- ECT - Engine over-heat warning
- EOP - Low engine oil pressure warning
- ECL - Low engine coolant level warning

3-way Protection (optional) – Engine shut down is available if critical condition is detected.

NOTE: This protection mode is not offered on school buses or emergency vehicles.

Same as 3-way Warning

- ECT - Engine over-heat critical protection
- EOP - Low engine oil pressure critical protection
- ECL - Low engine coolant level critical protection

Warning – Temperature above specific threshold will sound a buzzer, illuminate the red Oil/Water (OWL) lamp and set a DTC.

Critical – Temperature above specific threshold will shut down the engine and set a DTC. The operator has 30 seconds to safely pull vehicle off the road before the engine shuts off. A red warning lamp will illuminate before engine shutdown. The lamp will flash for 30 seconds to warn the operator engine shutdown is approaching. The ECM allows the engine to be restarted and run for 30 second periods.

Optional Features

Cruise Control

Cruise control is a function of the ECM. With the use of the cruise control switches, the operator is able to set, resume, accelerate or coast to any desired vehicle speed within range of the system.

The ECM continuously monitors the clutch, brake, and accelerator pedals before cruise can be activated and to deactivate after cruise has been set.

Road Speed Limiting (RSL)

RSL limits vehicle speed to the maximum speed programmed by the customer.

Service Interval

Service interval warns the operator of the need to change the engine oil and oil filter.

See Reset Service Interval Message in the “Diagnostic Software Operation” section of this manual.

Table of Contents

MasterDiagnostics® Software

Open Application

1. Connect interface cable to the vehicle diagnostic connector and the Electronic Service Tool (EST).
2. From the EZ-Tech® opening screen select Engine Diags button, and then select the Service Assistant button from the drop-down menu.
3. Turn ignition switch to ON. Do not start the engine.

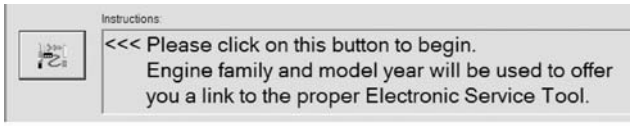

Figure 44 Diagnostic window

NOTE: If the EST does not communicate with the vehicle, refer to the IC4 Interface Device Self Test (page 60).

4. Click the button indicated on the Service Assistant screen to establish communication with the vehicle.

Retrieve Engine Information

Figure 45 Engine information

1. The Service Assistant displays the detected engine information and model year.
2. Make sure the View CAN Data button on the right side of Service Assistant window is selected.
3. Verify the collected data matches the engine being diagnosed.
4. To view the Service Assistant version number, right click the title bar and select About Service Assistant.

Open MasterDiagnostics®

1. Make sure the View CAN Data button on the right side of Service Assistant window is selected.
2. The engine family and model year should match the engine being diagnosed. If incorrect, use the drop-down menu to select the correct engine family and model year.
3. Select Launch EST.

Electronic Service Tool (EST) Communication Diagnostics

IC4 Interface Device Self Test

1. Connect the interface cable to the diagnostic connector and the EST.
2. Turn ignition switch to ON. Do not start the engine.

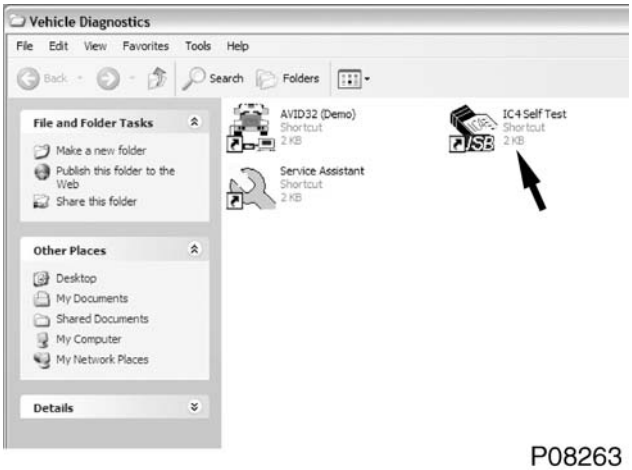

Figure 46 Vehicle diagnostics folder

3. From the EST desktop open the Vehicle Diagnostics folder.
4. Double-click the IC4 Self Test icon.

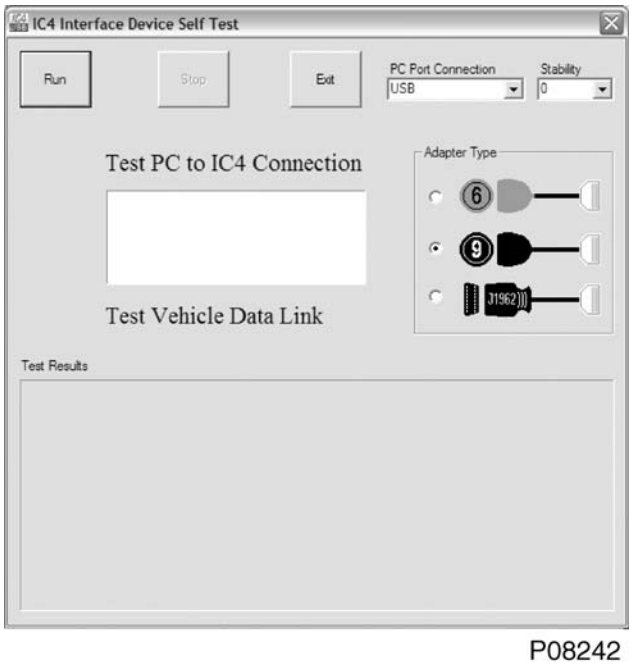

Figure 47 Self Test Run command

5. Select Run button.

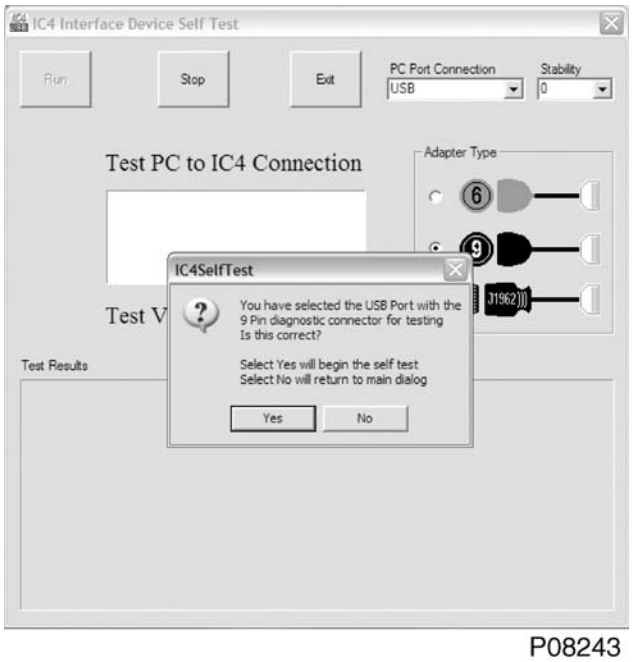

Figure 48 Connector confirmation

6. Verify the correct interface connector is selected.

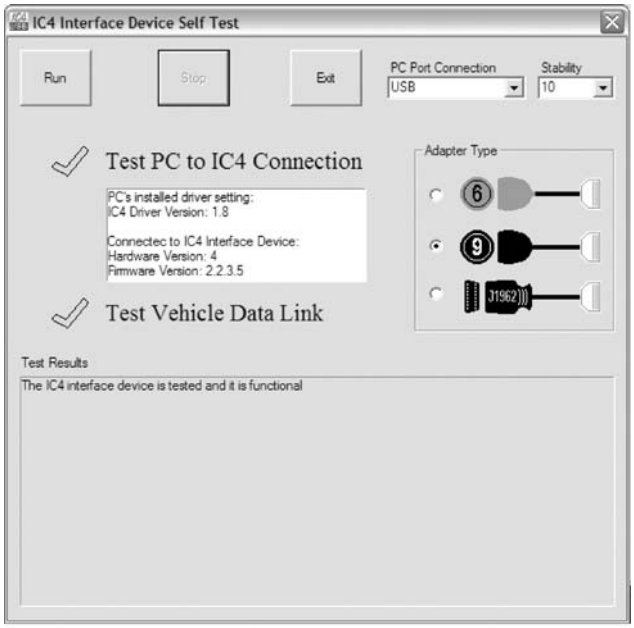

Figure 49 Test result

NOTE: If the connection could not be established, follow the instructions on the self test window.

7. The test result is displayed in the lower half of the self test window.

Communications (COM)

Open Communications

Figure 50 COM open

1. Select COM from the menu bar.
2. Select Open from the drop down menu.

Figure 51 COM open confirmation

3. A green light and flashing red light indicates a successful communication link has been established.

   If green and red flashing light is not visible, COM is not available.

Close Communications

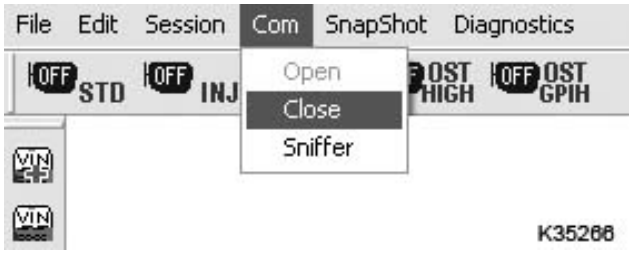

Figure 52 COM close

1. Select COM from the menu bar.
2. Select Close from the drop down menu.

Diagnostic Trouble Codes (DTCs)

Reading DTCs with EST

1. Turn ignition switch to ON. Do not start the engine.
2. Open EST to establish communication.

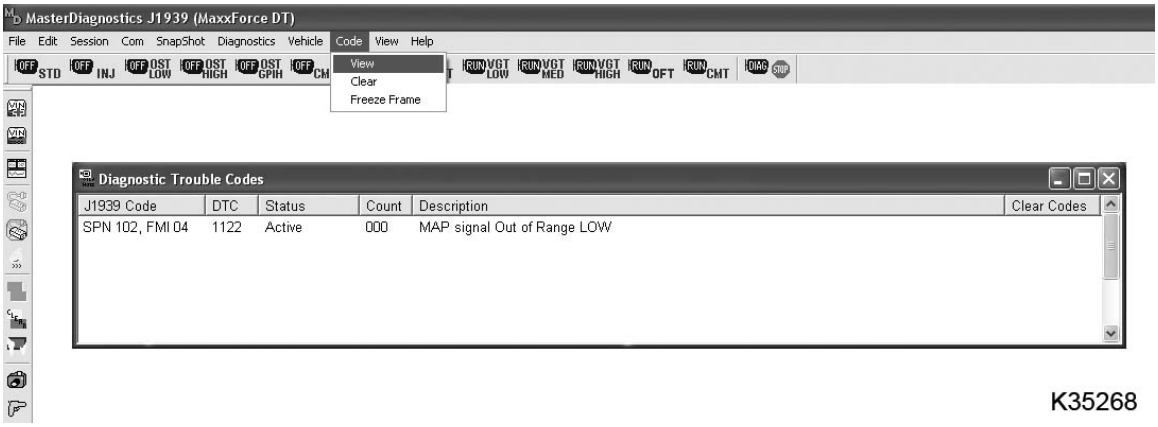

Figure 53 Viewing DTCs

3. Select Code from the menu bar.
4. Select View from the menu.
5. The DTC window will display active and inactive DTCs stored in the ECM.

DTC Help Menu

1. Double-click desired DTC to launch the Help program.

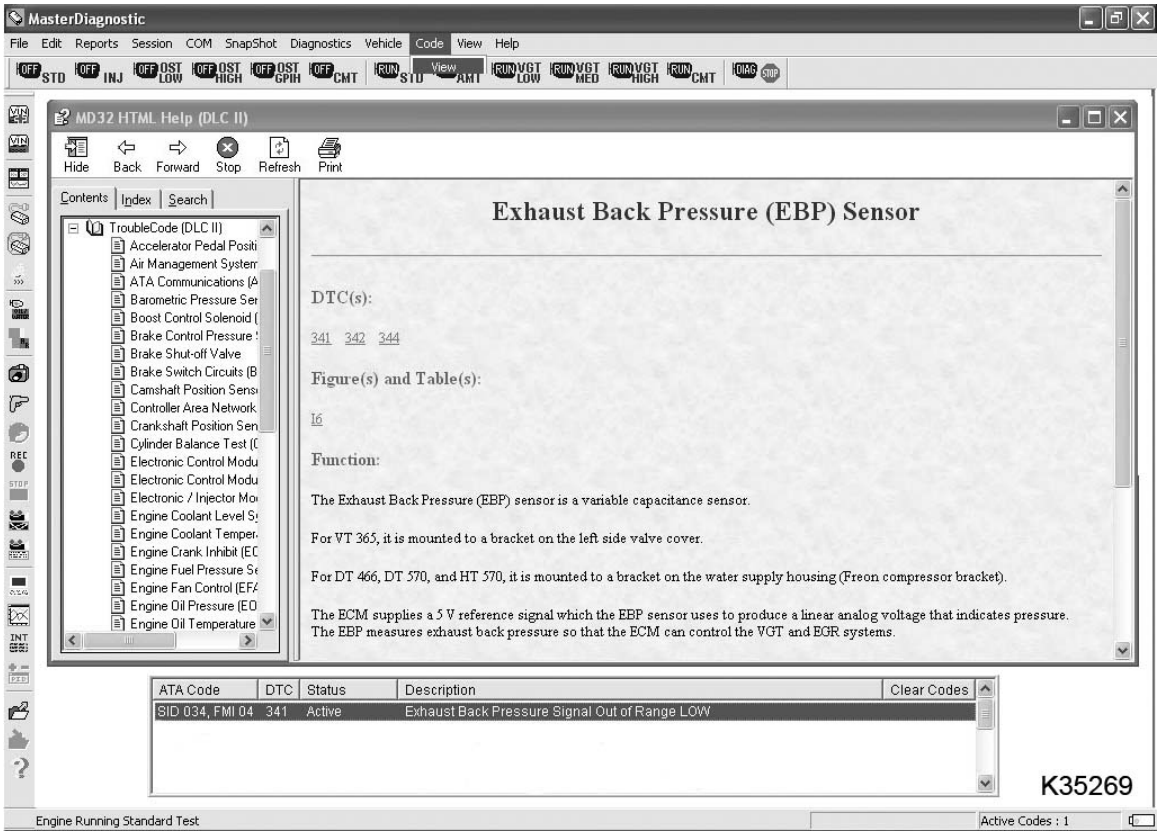

Figure 54 DTC Help Menu

2. The Help program will display information for the circuit associated to the DTC.

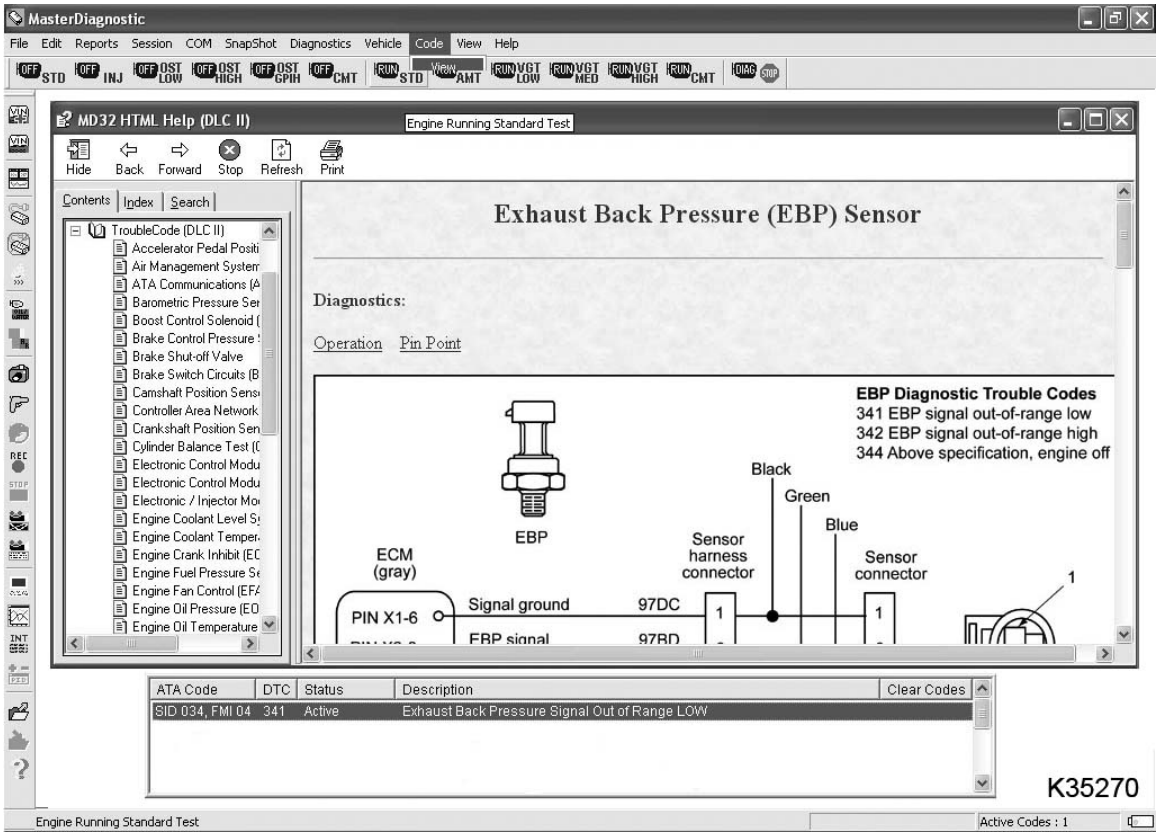

Figure 55 DTC Help Menu – Circuit Information

3. Select the DTC number from the list to display specific information.

Clearing DTCs

1. Turn ignition switch to ON. Do not start engine.
2. Open MasterDiagnostics® and establish communication with the vehicle.

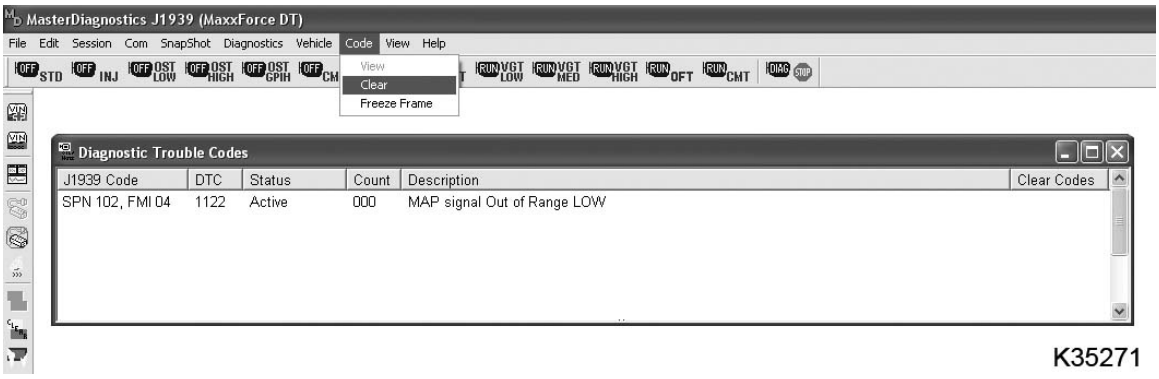

Figure 56 Clearing DTCs

3. Select Code from the menu bar.
4. Select Clear from the drop-down menu.
5. DTCs are cleared from the control module's memory. Active codes may return if the fault conditions remain.

Session Files

All session files are pre-configured with set parameters and graphs. If parameters and graphs are added or modified, the window layout changes and the data may no longer fit on the EST screen. Always select No when prompted to save the session before closing.

Opening Session File

1. Turn ignition switch to ON. Do not start the engine.
2. Open MasterDiagnostics® to establish communication.

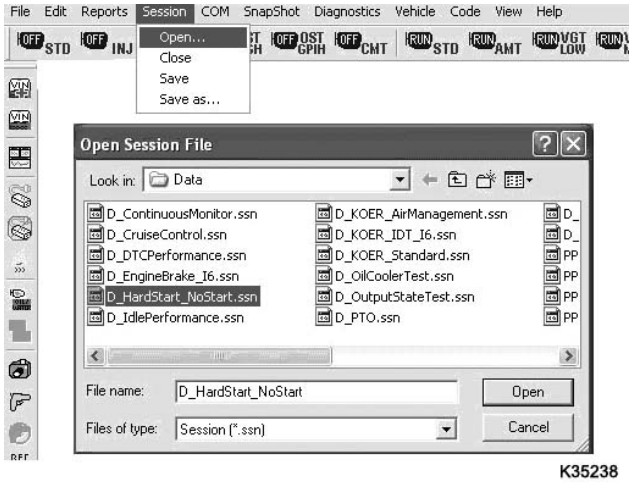

Figure 57 Open session file

3. Select Session from the menu bar.
4. Select Open from the drop down menu.
5. Choose the desired session file located within Open Session File window.
6. Select Open.

Adding and Deleting Session Parameter Identifiers (PIDs)

1. Open desired session file.

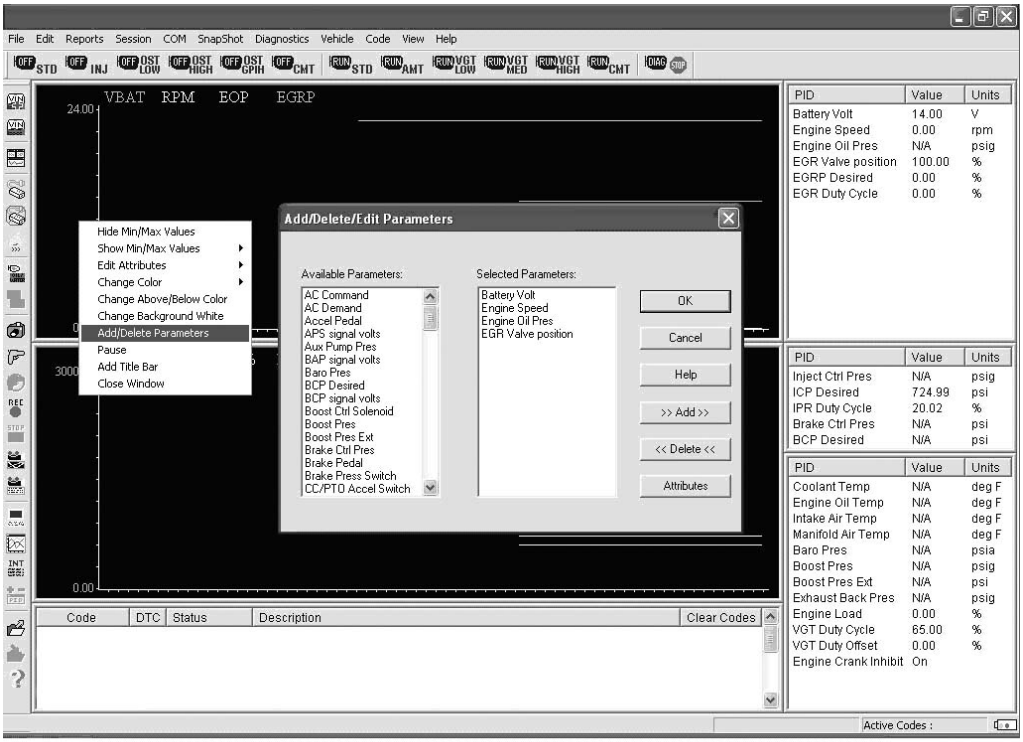

Figure 58 Add/Delete/Edit PIDs

2. On the session file, click the window where PIDs are to be added or edited.
3. Select Edit from the menu bar, or right click the desired window.
4. Select Add/Delete/Edit Parameters from the menu.

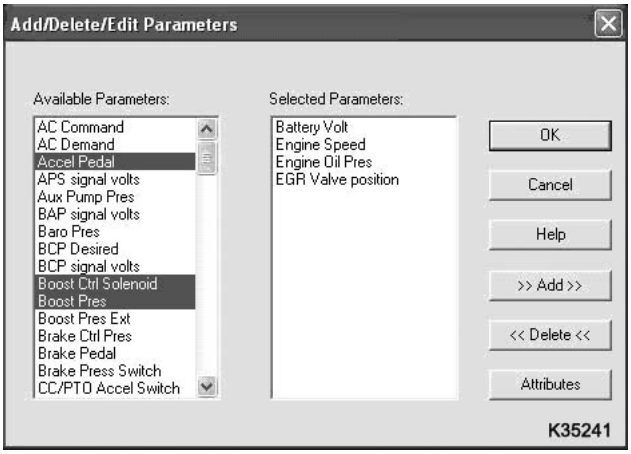

Figure 59 Selecting additional PIDs

5. Select additional PIDs in the left column.
6. Select Add to move selected PIDs to the right column.

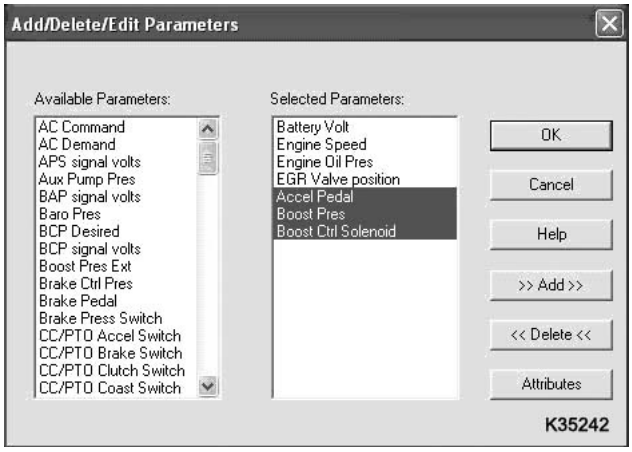

Figure 60 Additional PIDs added to session

7. To delete PIDs from the session, select the PIDs to remove from Selected Parameters and then select Delete.

8. Select OK to return to the session file.

Closing Session File

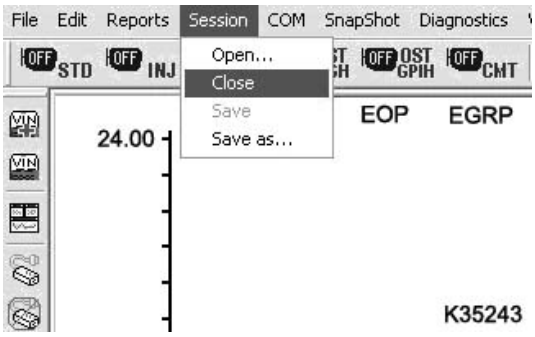

Figure 61 Closing session file

1. Select Session from the menu bar.
2. Select Close from the drop down menu.
3. Select No when prompted to save the session before closing. By selecting Yes, closing the session risks altering the default session setup.

VIN+ Session

The VIN+ provides VIN, the control module's calibration, engine serial number, transmission information, stored DTCs, and some other preset parameters. The information contained in the VIN+ session can be used to fill in part of the Hard Start and No Start Diagnostic Form.

1. Turn ignition switch to ON. Do not start the engine.
2. Open MasterDiagnostics® and establish communication with the vehicle.

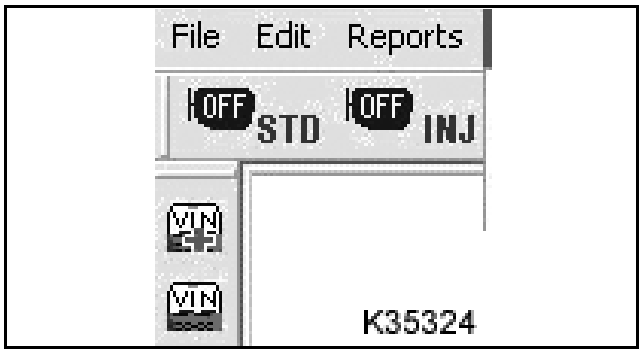

Figure 62 Select VIN+ icon

3. Select the VIN+ icon.

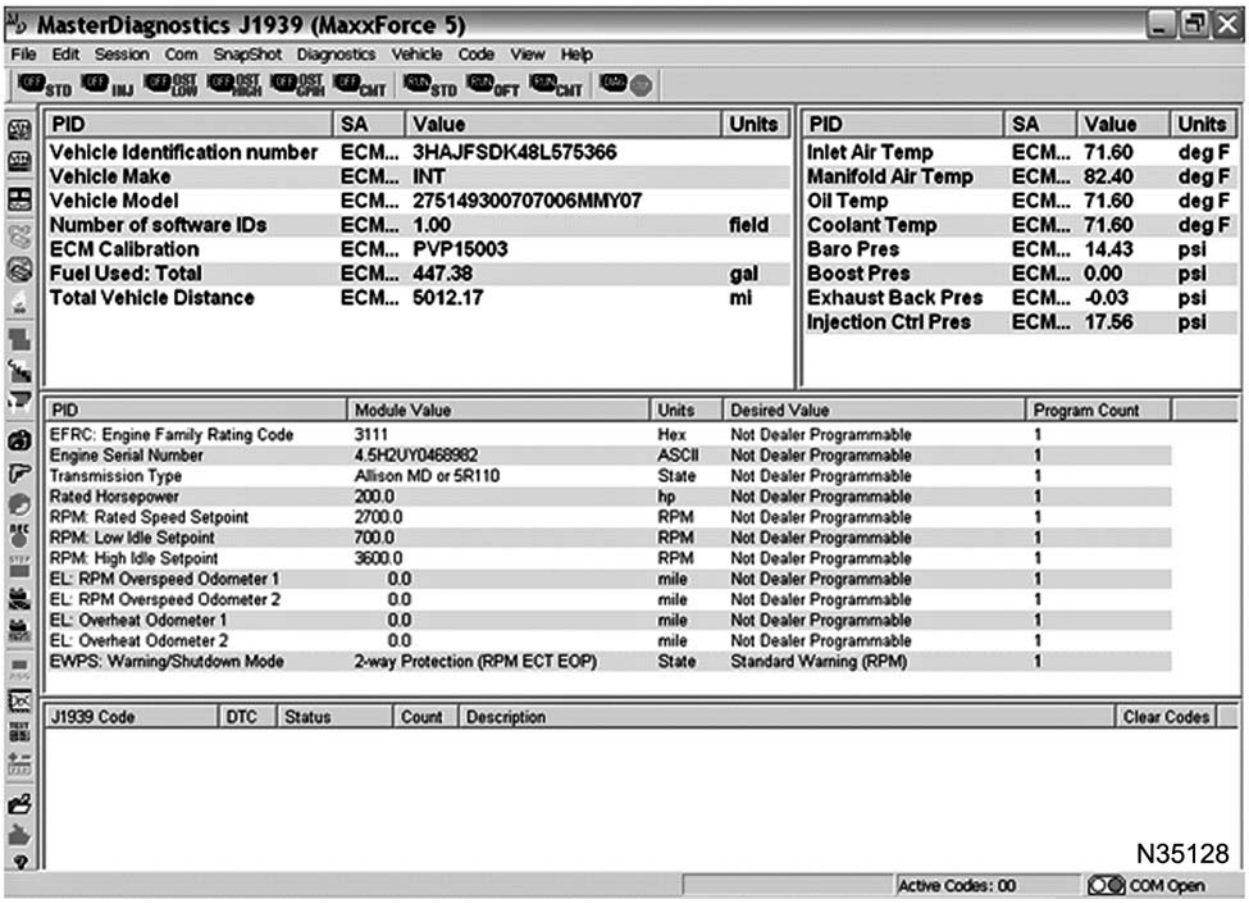

Figure 63 VIN+ session (example)

4. The VIN+ session is displayed on screen.

Snapshots

Opening Specific Snapshots

1. Open MasterDiagnostics® to establish communication.
2. Open desired session file.

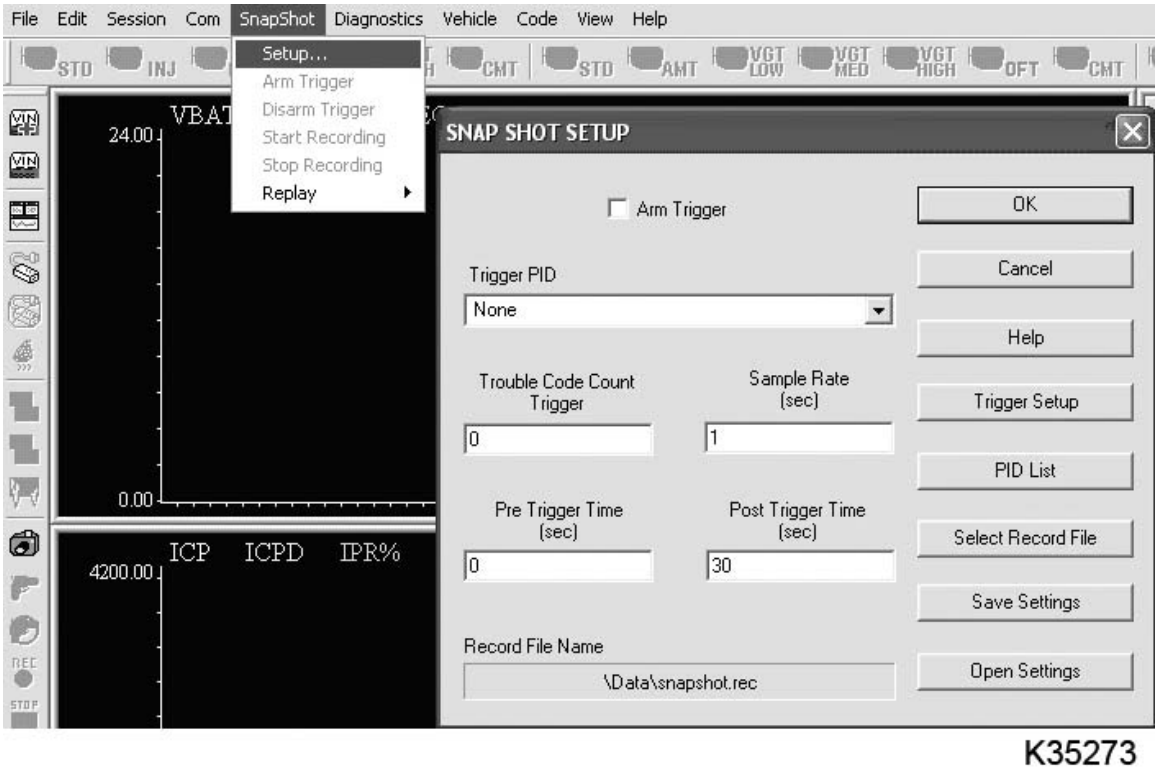

Figure 64 Opening specific snapshot

3. Select Snapshot from the menu bar.
4. Select Setup from the drop-down menu.
5. To modify default settings, refer to other snapshot setup steps in this section.

Opening Basic Snapshots

Opening a basic snapshot requires that all settings be adjusted to obtain a useful snapshot.

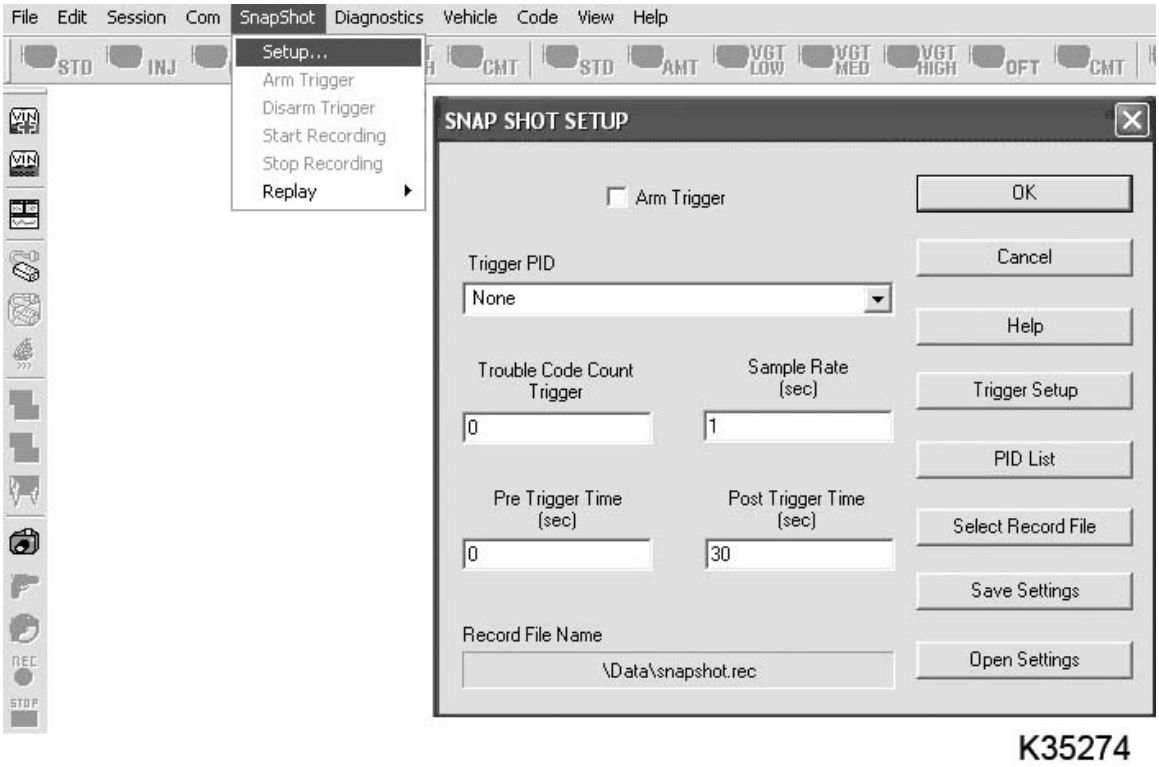

Figure 65 Opening basic snapshot

1. Select Snapshot from the menu bar.
2. Select Setup from the drop-down menu.

Snapshot Set-Up

Snapshot Trigger using Active DTCs

Snapshots can be triggered at the desired number of active DTCs. This is useful for road trip diagnostics.

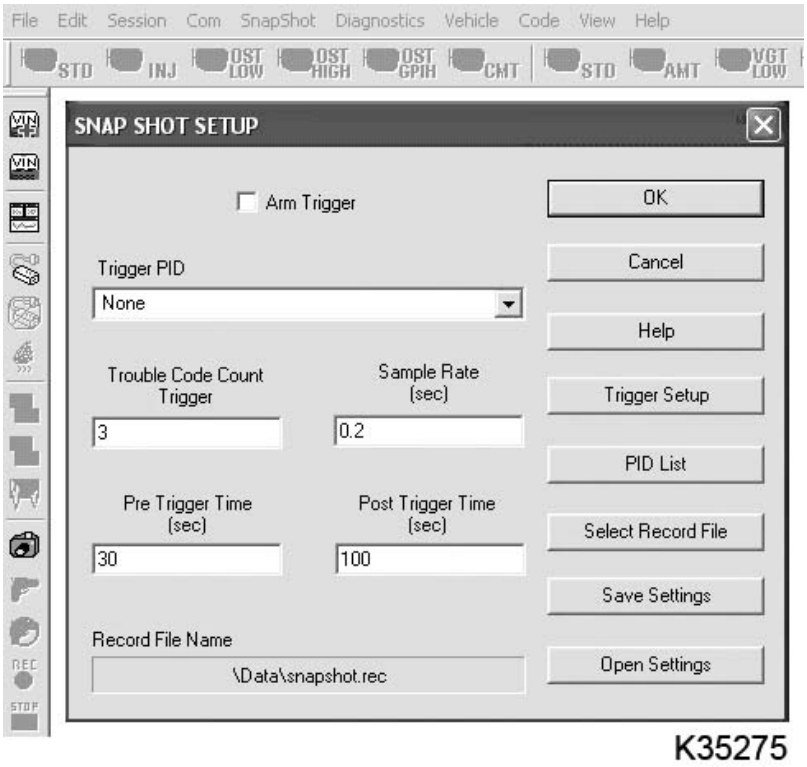

Figure 66 Snapshot for active DTC trigger

1. Enter None in Trigger PID drop-down menu.
2. Enter desired number of active DTCs in Trouble Code Count Trigger field

Figure 67 Arm trigger box

Snapshot Trigger using Parameter Identifier (PID)

Snapshots can be triggered by desired PID values. This is useful for workshop or road trip diagnostics.

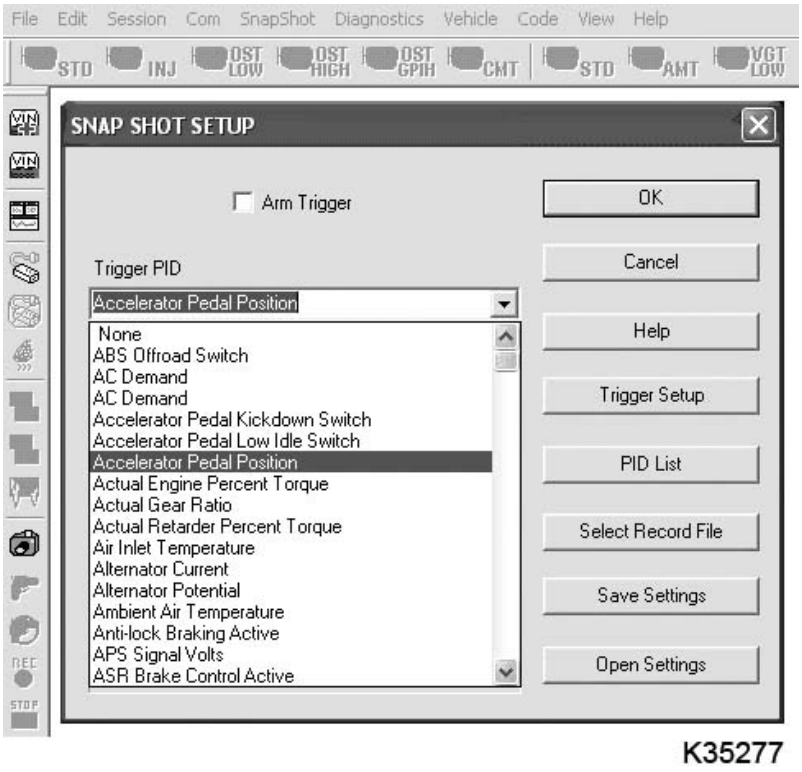

Figure 68 Selecting PID trigger

1. Select desired PID in the Trigger PID drop-down menu.

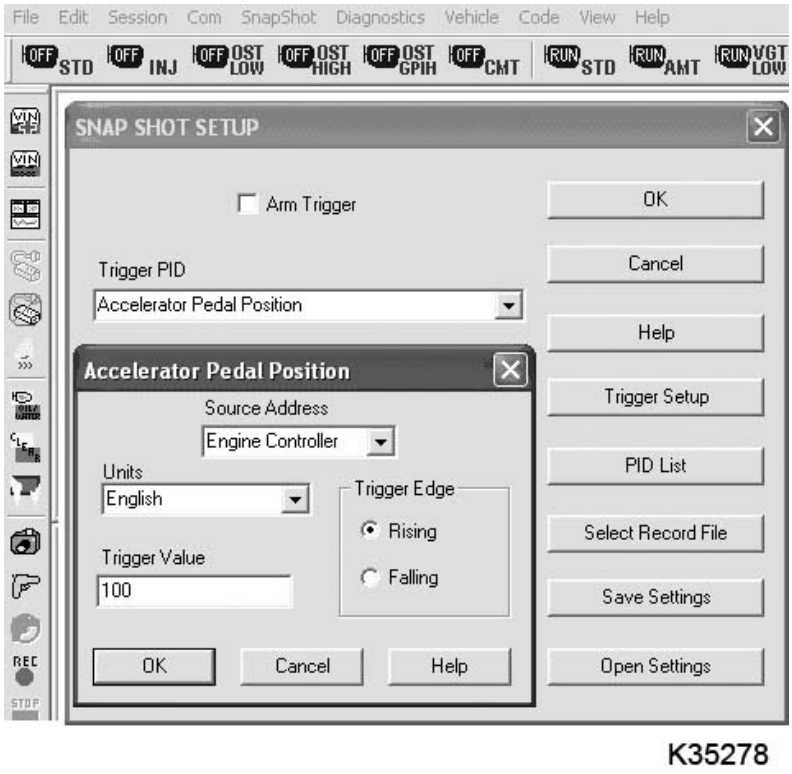

Figure 69 PID trigger set-up

2. Select Trigger Setup button.
3. Adjust units, trigger value, and trigger edge.
   - Units can be switched between decimal and metric values.
   - Trigger Value will set the PID value that begins snapshot recording.

     Example: Trigger using APS at 100 percent will start the recording when the APS reaches 100 percent.
   - Trigger Edge can be switched between rising and falling. Rising edge is used if the PID value starts lower than the Trigger value. Falling edge is used if the PID value starts higher than the Trigger value.
4. Select OK button on the Trigger Setup window.

Figure 70 Arm trigger box

5. Check Arm Trigger box in the Snapshot Setup window.

Sample Rates, Pre-Trigger, and Post-Trigger Times

Snapshot timing and intervals can be changed for the desired recording situation.

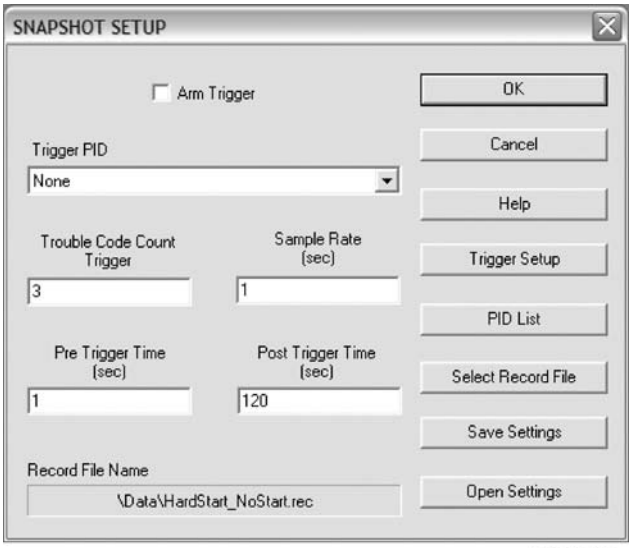

Figure 71 Adjusting snapshot times

1. Enter desired time interval in the Sample Rate box.

   Sample Rate adjusts the interval for each recording.

   Example: Entering 0.2 will record PID list data every two-tenths of a second for a total of five frames per second.

   NOTE: Use smaller sample rates for most snapshots to maximize snapshot precision. Larger sample rates are useful when recording for lengthy periods of time.

2. Enter desired time (seconds) in Pre-Trigger box.

   Pre-Trigger sets time to begin snapshot recording prior to trigger event.

   Example: Entering 30 enables the snapshot recording to begin 30 seconds before the trigger event occurs.

   NOTE: Pre-Trigger is useful when recording conditions before a diagnostic event or fault occurs.

3. Enter desired time (seconds) in Post-Trigger box.

   Post-Trigger sets time to stop snapshot recording after the trigger event is completed.

   Example: Entering 100 enables the snapshot recording to continue for 100 seconds after the trigger event is completed.

Snapshot PID List

Verify the snapshot PID list contains each PID of concern. Adding or deleting PIDs from the PID session list does not alter the snapshot PID list.

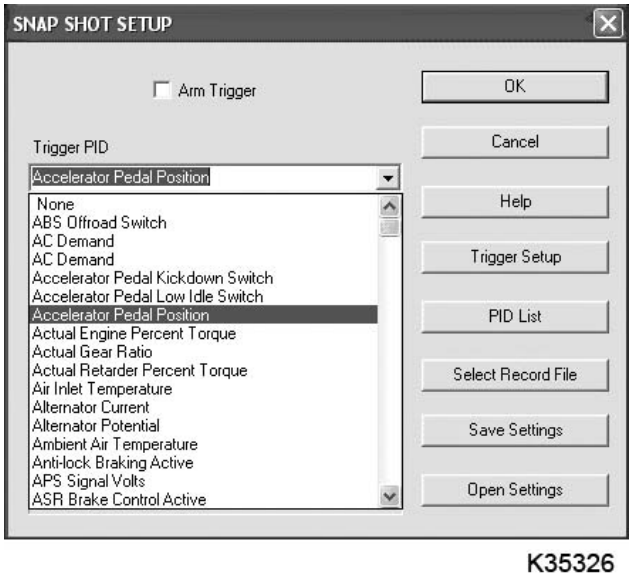

Figure 72 Selecting PIDs to record

1. Select PID List button from the Snapshot Setup window.

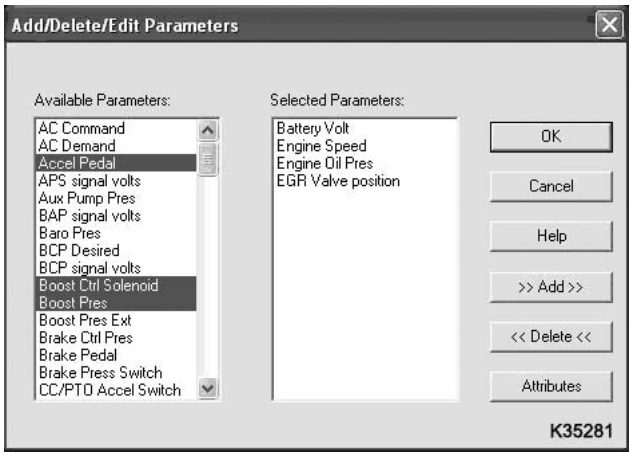

Figure 73 Selecting additional PIDs for snapshot

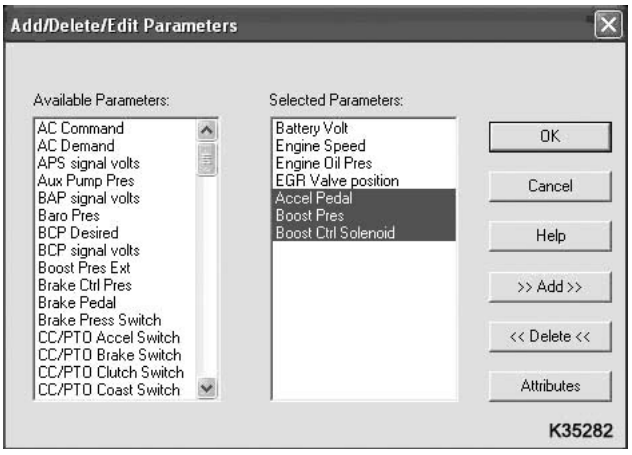

Figure 74 Additional PIDs added to snapshot

2. Select additional PIDs in the left column.
3. Select the ADD button to move the selected PIDs to the right column.
4. To delete PIDs from the snapshot, select the PIDs to remove from Selected Parameters and then select Delete.
5. Select the OK button to return to the Snapshot Setup window.

Rename REC Files

Changing the name of the REC file can assist in finding the file for review or data exchange for technical help. Default will save the REC file with a generic name and overfile when new snapshot is recorded. The default name can be changed to a VIN or ID label for example.

Figure 75 Naming REC file

1. Select the Record File button from the Snapshot Setup window.
2. Type the desired file name in the dialog box.
3. Select the Save button and save file in desired directory. After save is complete, program will return to the Snapshot Setup window.

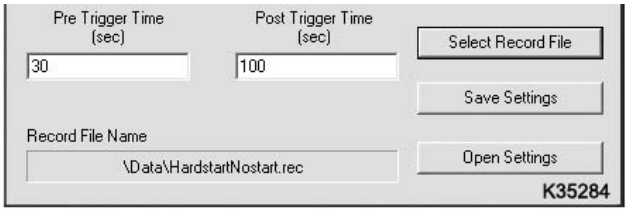

Figure 76 Verify REC file name

4. Verify that the Record File Name dialog box matches the changes.

Manual Trigger Snapshots

1. Open MasterDiagnostics® to establish communication.
2. Open desired session file.
3. Open desired snapshot. Setup for desired recording.
4. Select snapshot REC button on the side toolbar.

Figure 77 Recording active

5. The recording status changes to active and the REC button is displayed on the status bar at the bottom of the screen.

NOTE: The snapshot recording can be stopped at anytime if required.

6. Select snapshot STOP button on the side toolbar.

   The recording status will change to inactive.

Figure 78 Recording not active

7. The recording status changes to inactive and the REC button is no longer displayed on the status bar at the bottom of the screen.

Replay Snapshot Graphic

1. Open MasterDiagnostics®.

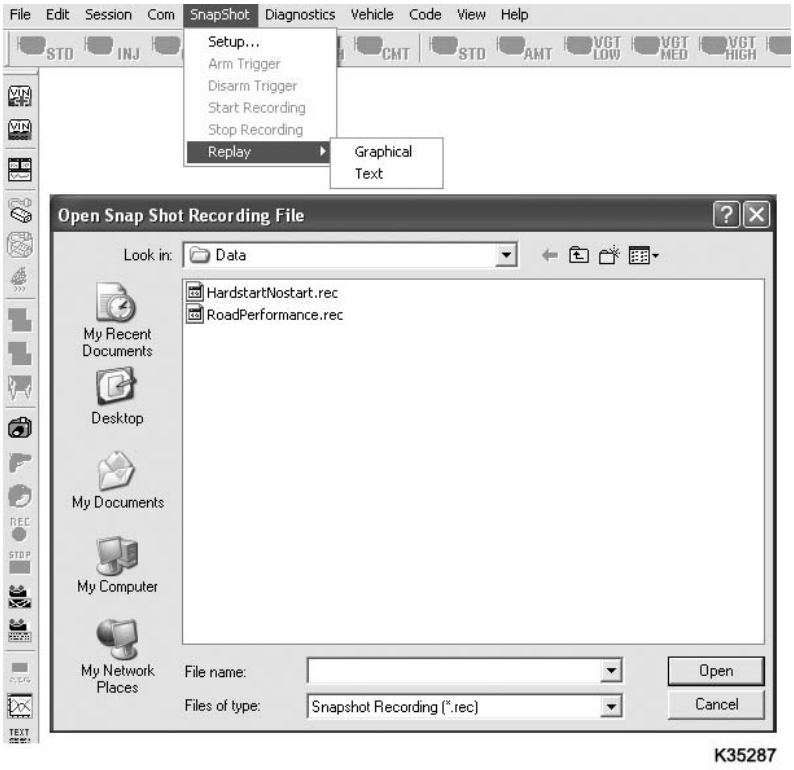

Figure 79 Replaying REC file

2. Select Snapshot from the menu.
3. Select Replay from the drop down menu, then select Graphical or Text.

   NOTE: Selecting Graphical replays the recording in the form of a graph. Selecting Text replays the recording in the form of a chart.
4. Select the desired snapshot file.
5. Select Open.

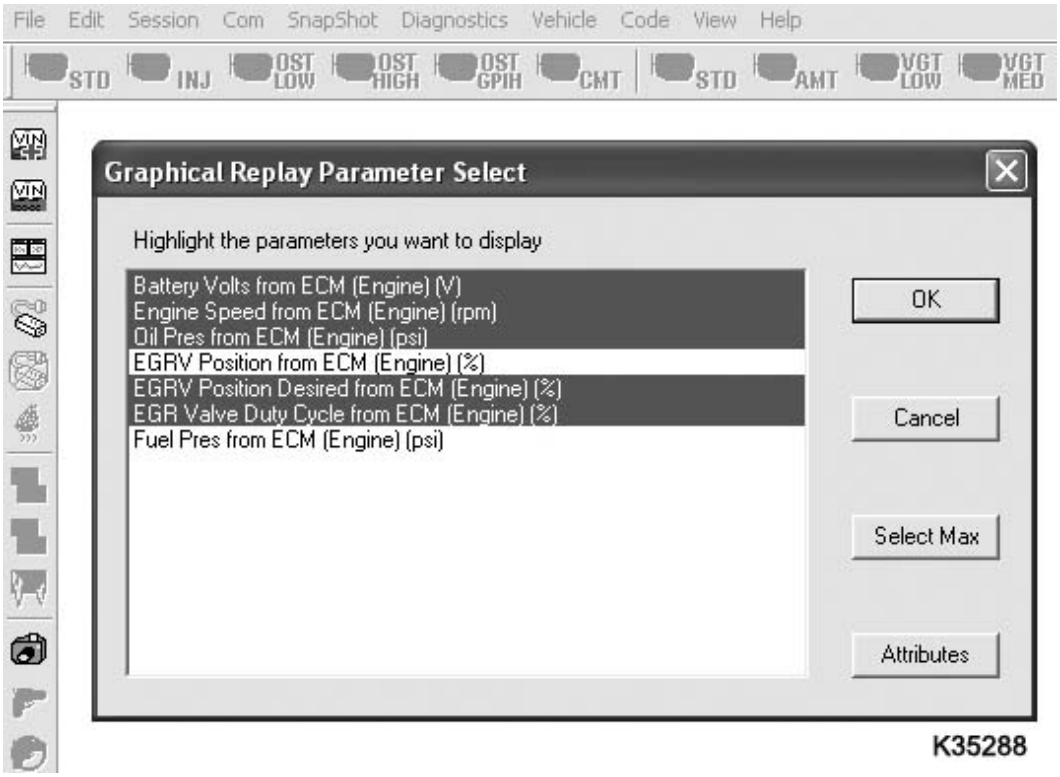

Figure 80 Selecting PIDs to replay

6. Select desired PIDs. Select the Max button to select all recorded PIDs.
7. Select the OK button.

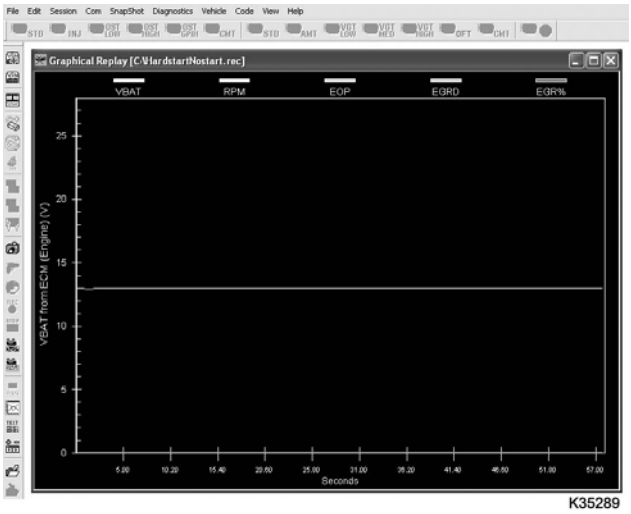

Figure 81 REC file graph view

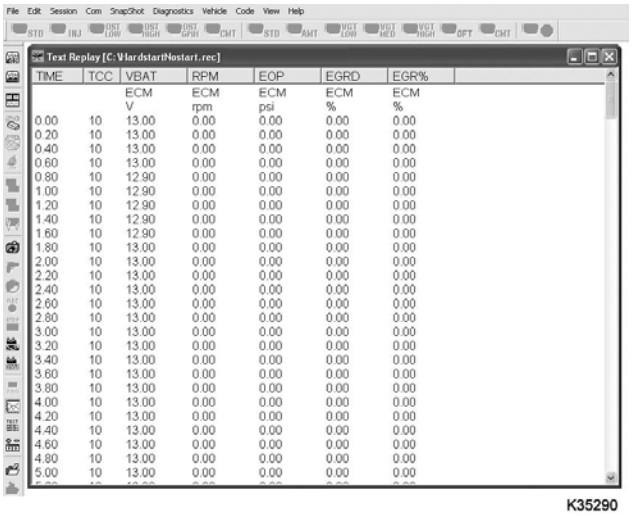

Figure 82 REC file text view

8. The graph or text replay of the recording is displayed.

Diagnostic Tests

Key On Engine Off (KOEO) Tests

Standard Test

The KOEO Standard test is controlled by the Electronic Control Module (ECM). The technician runs this test by using the Electronic Service Tool (EST) with MasterDiagnostics® software.

During the KOEO Standard test, the ECM does an internal test of its processing components and memory followed by an Output Circuit Check (OCC). The OCC evaluates the electrical condition of the circuits, not mechanical or hydraulic performance of the systems. By operating the ECM output circuits and measuring each response with a DMM the technician can detect shorts or opens in the circuits.

The ECM cycles all the actuators.

When the OCC is done, the DTC window will display DTCs that identify the problem.

1. Turn ignition switch to ON. Do not start engine.
2. Open COM port or select a session.

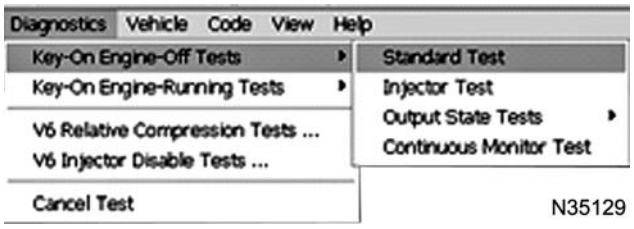

Figure 83 KOEO standard test menu

3. Select Key On Engine Off Tests and Standard Test from the drop down menu.
4. Follow the on-screen instructions.

NOTE: When using the EST to do KOEO or KOER diagnostic tests, Standard test is always selected and run first. If the ignition switch is not cycled, the Standard test does not have to be run again.

Injector Test

NOTE: When using the EST to do KOEO or KOER diagnostic tests, Standard test is always selected and run first. If the ignition switch is not cycled, the Standard test does not have to be run again.

The Injector test diagnoses electrical problems in ECM wiring or injectors. Before doing the Injector test, DTCs should be accessed, noted, and cleared. This allows DTCs to be displayed as Active DTCs.

During the Injector test, the ECM actuates the injectors in numerical order (1 through 6), not in firing order. The ECM monitors the electrical circuit for each injector, evaluates the performance of the injector coils, and checks the operation of the electrical circuit. If an electronic component in the injector drive circuit fails the expected parameters, the ECM logs the fault. A DTC will be set and sent to the EST.

NOTE: The technician can monitor injector operation by listening to the sound of each injector when activated by the ECM. During Hard Start and No Start conditions, when oil is very cold and thick, injectors may be hard to hear.

The DTC window will display DTCs that identify the problem.

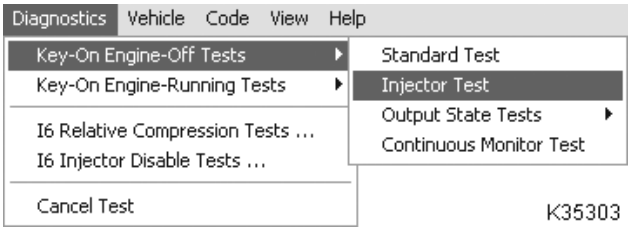

Figure 84 Injector test menu

1. Turn ignition switch to ON. Do not start engine.
2. Open COM port or select a session.
3. Select Key On Engine Off Tests and Injector Test from the drop down menu.
4. Follow the on-screen instructions.

Output State Low Test

The Output State Low test allows the technician to diagnose the operation of the output signals and actuators.

In the Output State Low test mode, the ECM pulls down the output voltage to the low state. This grounds the low side driver circuits and actuates the output components controlled by the ECM.

During Output State Low test, the output of the circuit in question can be monitored with a DMM. The DMM measures a low voltage state as the outputs are toggled. The actual voltage will vary with the circuit tested.

NOTE: A breakout box or breakout harness and a DMM are required to monitor the suspected circuit or actuator. DTCs are not set by the ECM during this test.

No actuators are activated when toggled low during the test.

1. Turn ignition switch to ON.

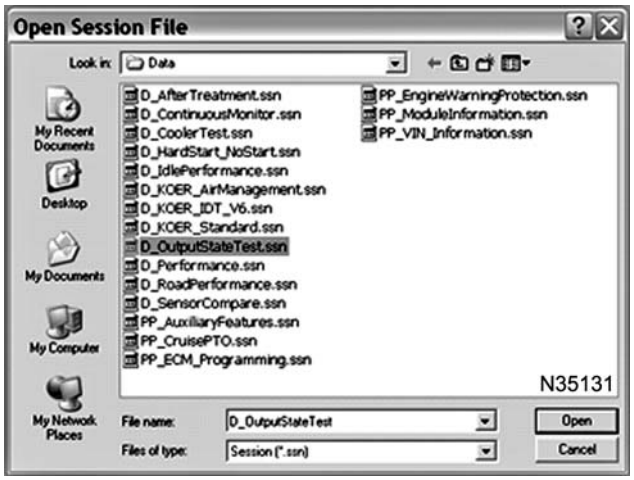

Figure 85 Output state test session

2. Open session and select D_OutputStateTest session from menu.

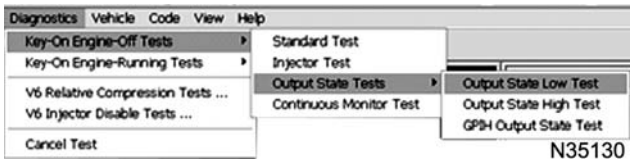

Figure 86 Output state low test menu

3. Select Key On Engine Off Tests. From the drop down menu, select Output State Tests, then select Output State Low Test.
4. Follow the on-screen instructions.

Output State High Test

The Output State High test allows the technician to diagnose the operation of the output signals and actuators.

In the Output State High test mode, the ECM pulls up the output voltage to the high state. This energizes the control high side driver circuits and actuates the output components controlled by the ECM.

During this test, the output of the circuit in question is monitored with a DMM. The DMM measures a high voltage state, as the outputs are toggled. The actual voltage will vary with the circuit tested.

NOTE: A breakout box or breakout harness and a DMM are required to monitor the suspected circuit or actuator. DTCs are not set by the ECM during this test.

Actuators are activated when toggled high during the test.

1. Turn ignition switch to ON.

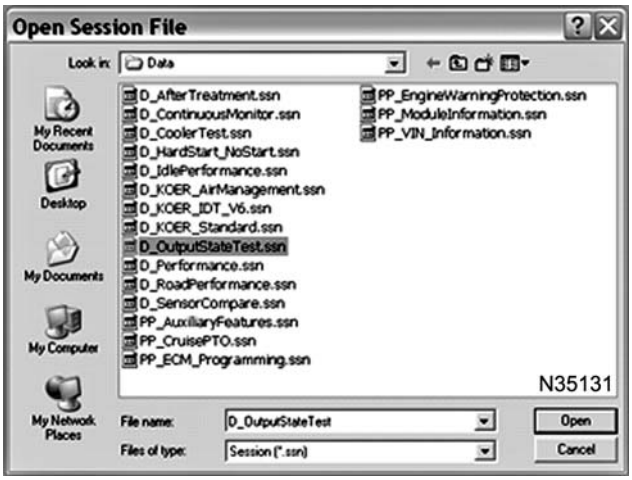

Figure 87 Output state test session

2. Open session and select D_OutputStateTest session from menu.

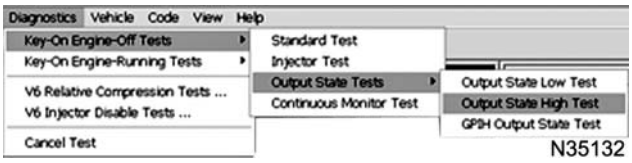

Figure 88 Output state high test menu

3. Select Key On Engine Off Tests. From the drop down menu, select Output State Tests, then select Output State High Test.
4. Follow the on-screen instructions.

Glow Plug/Inlet Air Heater Output State Test

The Glow Plug/Inlet Air Heater Output State test allows the technician to determine if the Glow plug and the Inlet Air Heater Systems are operating correctly.

The inlet air heater relay operation is activated for 30 seconds. A DMM and current clamp are used to measure the time the relay is on and the amperage that is drawn for the inlet air heater.

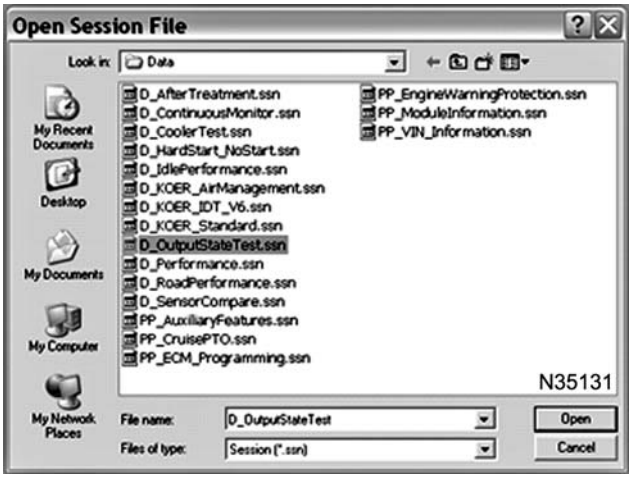

Figure 89 Output state test session

1. Open session and select D_OutputStateTest session from menu.

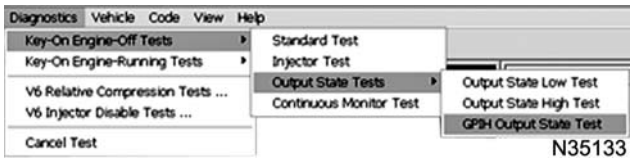

Figure 90 Inlet air heater output state test menu

2. Select Key On Engine Off Tests. From the drop down menu, select Output State Tests, then select Inlet Air Heater Output State Test.
3. Follow the on-screen instructions.

Key On Engine Running (KOER) Tests

Standard Test

During the KOER Standard test, the ECM commands the IPR through a step test to determine if the ICP system is performing as expected. The ECM monitors signal values from the ICP sensor and compares those values to the expected values. When the Standard test is done, the ECM returns the engine to normal operation and transmits DTCs set during the test.

NOTE: Ensure that engine is above minimum operating temperature of 70 °C (158 °F) before starting test.

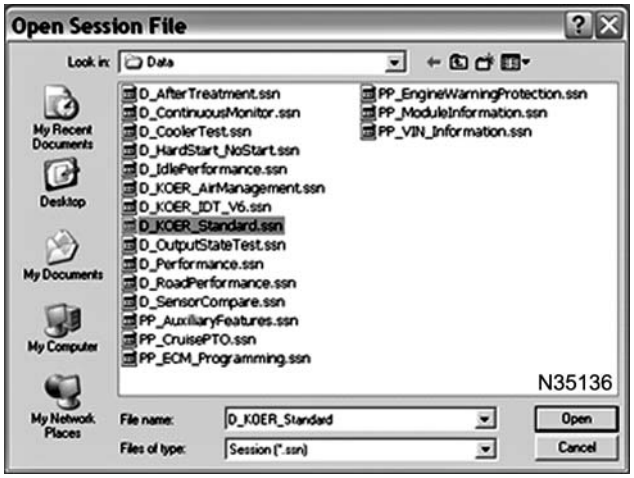

Figure 91 KOER standard session menu

1. Open session and select D_KOER_Standard session from menu.

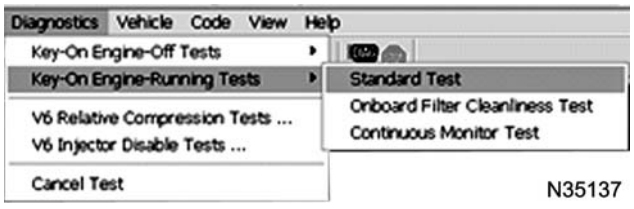

Figure 92 KOER standard test menu

2. Select Key On Engine Running Tests and Standard Test from the drop down menu.
3. Follow the on-screen instructions.
   - The ECM will start the KOER Standard Test by commanding the engine speed to rise to a predetermined level.
   - When the test is finished, the ECM will return the engine speed to low idle.

Engine Aftertreatment Test

The Exhaust Aftertreatment Test allows the technician to determine if the exhaust aftertreatment system is operating correctly.

1. Open MasterDiagnostics® and establish communication with the vehicle.
2. If needed, open a desired session file.

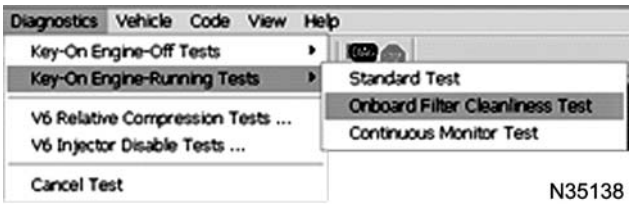

Figure 93 Engine aftertreatment test menu

3. Select Key On Engine Running Tests, then the On-Board Filter Cleanliness Test from the drop-down menu.

   The ECM will start the On-Board Filter Cleanliness Test and command the engine to accelerate to a default engine speed to prepare for regeneration.

   The ECM will monitor the effects of the regeneration system by using feedback signals from the temperature and pressure sensors.
4. Follow the on-screen instructions.

Continuous Monitoring – Troubleshooting Intermittent Connections

The Continuous Monitor test is very helpful in troubleshooting intermittent connections between the control modules and sensors. The key must be ON and the engine can be OFF or running.

The continuous monitor session monitors all sensor voltages. Sensors that read N/A are not turned on in the control module.

1. Open MasterDiagnostics® and establish communication with the vehicle.
2. Open the D_ContinuousMonitor session.

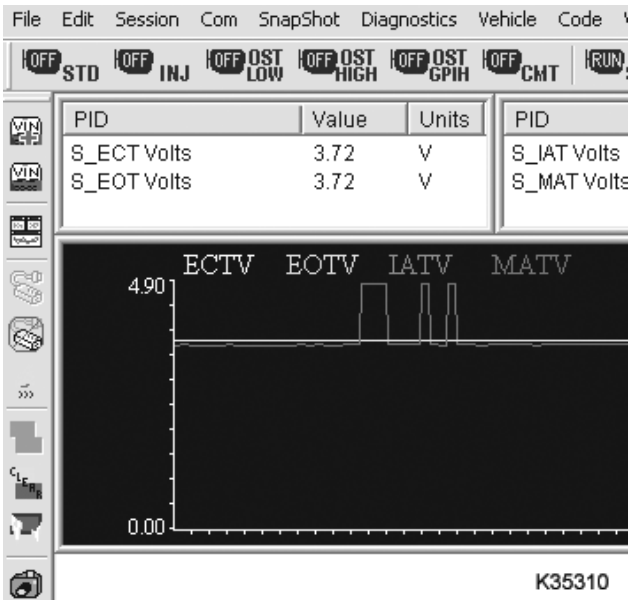

Figure 94 Continuous monitoring

NOTE: All sensors active in the software are reading an actual value. Refer to the DTC pin-point test to find the minimum or maximum value that sets the DTC being diagnosed.

3. Monitor the graphs on the screen while wiggling the connectors and wires at all suspected problem locations.

NOTE: Refer to the electrical information to find all circuits that might cause the intermittent problem.

4. Disconnect and inspect connectors for damage, corrosion, or loose pins. Repair if necessary.

Injector Disable Test

The Injector Disable tests allows the technician to shut off injectors to determine the cause of rough engine idle. This test is used in conjunction with Relative Compression test to identify an injector problem or a mechanical problem.

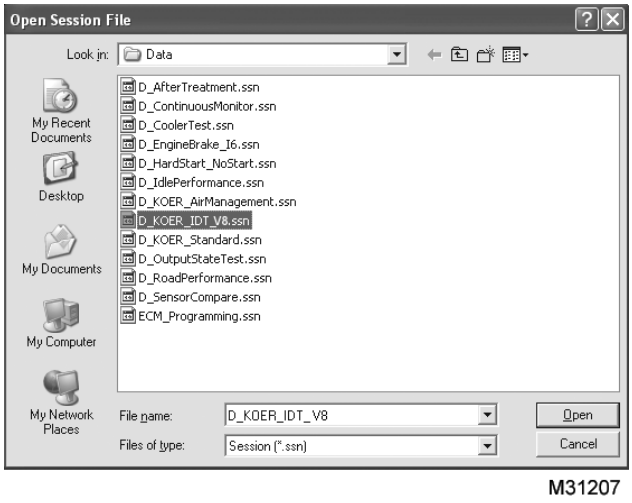

Figure 95 Injector disable session

1. Open session and select D_IDT_V6 session from menu.

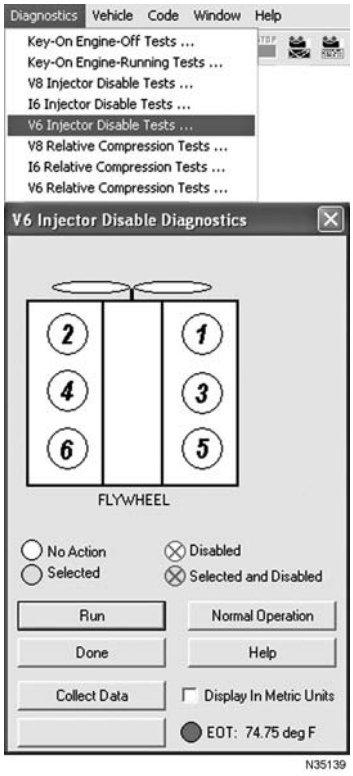

Figure 96 Injector disable test menu

2. Select Diagnostics from menu bar and V6 Injector Disable Test from drop down menu.
3. Select cylinder number and select Run. The selected injector will be disabled and engine noise should change.
4. Select Normal Operation. The selected injector will be enabled and engine noise should return to previous state of operation.
5. Repeat steps 3 and 4 for the remaining cylinders.

Relative Compression

Do not use this test to diagnose a cylinder balance problem. Currently it is unreliable to detect low compression cylinders.

See the “Performance Diagnostics” section for Manual Compression test using a Cylinder Compression Gauge and Compression Test Adapter.

Reset Engine Change Oil Message

Reset Message with EST

1. Set parking brake.
2. Turn ignition switch to ON. Do not start the engine.
3. Open MasterDiagnostics® to establish communication.
4. Open session file window.
5. Select PP_ServiceInterval.ssn file.
6. Select Open.
7. Right click in the session window.
8. Select enter Password from pop-up menu.
9. Enter password in dialog box.
10. Select OK.
11. Right click on SI: Service Interval Reset parameter to display pop-up menu.
12. Select Program from the pop-up menu. The Edit Parameter window will open.
13. Click the arrow in the New Value dialog box.
14. Select Yes in the pull-down menu.
15. Select OK.
16. Verify that the following changes have been made to SI: Service Interval Reset parameter and accepted by the ECM:
    - Module Value has changed from No to Yes.
    - Original number in Program Count has increased by one.
17. Oil change interval has been set. Close session window.

General Information

Installed MasterDiagnostics® Version

1. Open MasterDiagnostics® on EST computer.
2. Select Help from the menu bar.
3. Select About from the drop-down menu.
4. The software release version is displayed.

Approved Interface Cable

1. Current approved interface cables are verified for full functionality for the MasterDiagnostics® software.

   NOTE: Unapproved or outdated interface cables may have limited or no functionality or low accuracy.
2. The Tech Central representative may ask which interface cable is being used in addition to the diagnostic issues.

Table of Contents

Description

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

GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a hazard to human health and the environment. Handle all fluids and other contaminated materials (e.g. filters, rags) in accordance with applicable regulations. Recycle or dispose of engine fluids, filters, and other contaminated materials according to applicable regulations.

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

WARNING: To prevent personal injury or death, read all safety instructions in the foreword of this manual. Follow all warnings, cautions, and notes.

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

Coolant System

Combustion Leaks to Coolant

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

Symptom

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

Tools

- Radiator Pressure Testing Kit
- Cylinder Head Pressure Test Plate

Possible Causes

- Failed injector sleeve
- Failed glow plug sleeve
- Failed head gasket
- Failed Exhaust Gas Recirculation (EGR) cooler
- Porous or cracked crankcase

The likely cause of combustion gas leakage to the cooling system is an injector sleeve in one of the cylinder heads. A failed cylinder head gasket or porous/cracked crankcase is also possible if the engine was overheated.

Combustion Leak Test (Low-pressure)

WARNING: To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow the engine to cool for 15 minutes or more.
- Wrap a thick cloth around the radiator cap or deaeration cap.
- Loosen cap slowly a quarter to half turn to vent pressure.
- Pause for a moment to avoid being scalded by steam.
- Continue to turn cap counterclockwise to remove.

1. Install cooling system pressure tester with appropriate adapter on the deaeration tank.
2. Pressurize cooling system to 96 kPa (14 psi).
3. Plug in the coolant heater, if available, to warm coolant.
4. Remove glow plug harnesses and glow plugs for all cylinders.
5. Clean glow plug sleeves with cotton swabs.

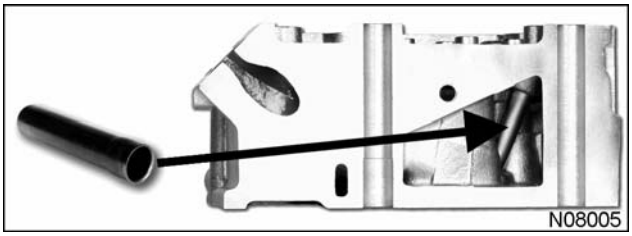

Figure 97 Cutaway of cylinder head showing glow plug sleeve

6. Verify cooling system is still pressurized at 96 kPa (14 psi).
7. Bar engine over by hand and check for coolant flooding the top of the piston and flowing out glow plug sleeve bores or injector sleeve bores. If injector or glow plug sleeve is leaking, replace and retest.
   - If leak is slight, pressure may have to be left on overnight and inspect cooling system for leakage in morning. Leave coolant heater plugged in, if available.
   - If leak is found, do the next step.
   - If no leakage is found, do Combustion Leakage Test (High-pressure).

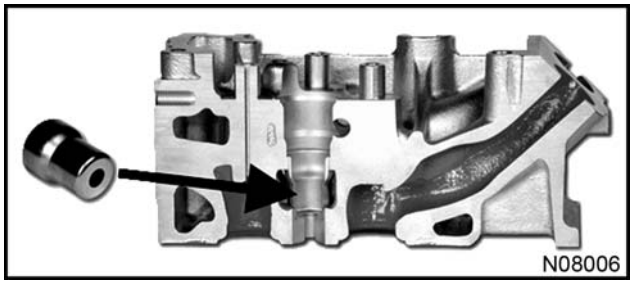

Figure 98 Cutaway of cylinder head showing injector sleeve

NOTE: It is not necessary to remove the cylinder heads to remove and replace the injector and glow plug sleeves.

8. Remove cylinder head from engine as described in the *Engine Service Manual*. Perform all inspections and pressure test cylinder head to verify leak path. Inspect cylinder head gasket for coolant leaks and verify crankcase and cylinder head surface flatness using a straight edge and feeler gauge.

   NOTE: It is recommended to replace the injector sleeves and glow plug sleeves if a cylinder head shows combustion leakage.

9. If the injector and glow plug sleeves were replaced, retest the cylinder head with pressure test plate to verify repair.

Combustion Leak Test (High-pressure)

1. Plug in coolant heater, if available, to warm coolant.
2. Remove glow plug harnesses and glow plugs for all cylinders, following directions in the *Engine Service Manual*.

WARNING: To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow engine to cool for 15 minutes or more.
- Wrap a thick cloth around the radiator cap or deaeration cap.
- Loosen cap slowly a quarter to half turn to vent pressure.
- Pause for a moment to avoid being scalded by steam.
- Continue to turn cap counterclockwise to remove.

3. Fill deaeration tank, with coolant, to full mark.

WARNING: To prevent personal injury or death, be aware the crankshaft may rotate suddenly when a cylinder is pressurized.

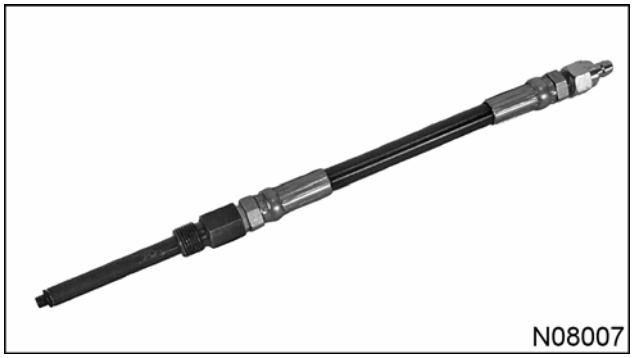

Figure 99 Compression Test Adapter

4. Install Compression Test Adapter in the glow plug bore and pressurize with shop air to 690 to 1100 kPa (100 to 160 psi).

   NOTE: Verify O-ring is on the Compression Test Adapter both when it is installed and removed from the glow plug bore.

5. Bar engine over so valves are shut on cylinder to be tested. Apply shop air for a minimum of three minutes to ensure leaking air can arrive at deaeration tank.
6. Observe deaeration tank for escaping air. If there is a leak in the pressurized cylinder, bubbles of air will be seen in the deaeration tank.
7. Release air pressure, bar engine over so the next set of valves are shut on cylinder to be tested. Repeat steps 5 through 7 until all cylinders are tested.
8. Unplug coolant heater.
9. If a leak is found, continue with step 10.

   If no leak is found, first remove one cylinder head following procedures in the *Engine Service Manual*. Do all inspections and pressure test cylinder head. Inspect cylinder head gasket for coolant leaks and verify crankcase and cylinder head surface flatness using a straight edge and feeler gauge. Inspect crankcase and cylinder bores. If leak is not found, remove second cylinder head and do all inspections and pressure test cylinder head.

10. Remove leaking cylinder head from engine following procedures in the *Engine Service Manual*. Do all inspections and pressure test cylinder head to verify leak path. Inspect cylinder head gasket for coolant leaks and verify crankcase and cylinder head surface flatness using a straight edge and feeler gauge. Inspect crankcase and cylinder bores.

    NOTE: It is recommended to replace the injector sleeves and glow plug sleeves for a cylinder head that shows combustion leakage.

11. If the injector and glow plug sleeves were replaced, retest the cylinder head with pressure test plate to verify repair.

Coolant Leak to Exhaust

Symptoms

- Coolant leaking from exhaust
- Coolant residue at exhaust manifold flanges
- Coolant loss without engine coolant leak seen
- Coolant smell in exhaust
- Severe case - engine hydraulic lock

Tools

- Radiator Pressure Testing Kit
- EGR Valve Block Off Plug (page 396)
- EGR Cooler Pressure Test Plates (page 396)

Possible Causes

- Failed EGR cooler
- Injector cup leak
- Porosity or cracks in cylinder head or crankcase
- Blown or leaking head gasket

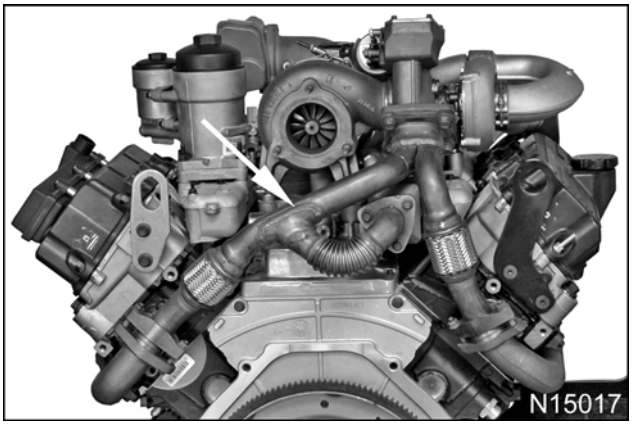

Figure 100 Exhaust tube assembly

WARNING: To prevent personal injury or death, make sure engine has cooled before removing components.

1. Remove exhaust tube assembly following procedures in the *Engine Service Manual*.
2. Check for coolant in the exhaust tubing, exhaust manifolds, and EGR cooler exhaust inlet.
3. Plug in coolant heater, if available, to warm coolant.

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

WARNING: To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow engine to cool for 15 minutes or more.
- Wrap a thick cloth around the radiator cap or deaeration cap.
- Loosen cap slowly a quarter to half turn to vent pressure.
- Pause for a moment to avoid being scalded by steam.
- Continue to turn cap counterclockwise to remove.

4. Install cooling system pressure tester with the appropriate adapter.
5. Pressurize cooling system to 96 kPa (14 psi).
6. Check EGR cooler exhaust inlet for coolant.
   - If coolant is present, replace EGR cooler following procedures in the *Engine Service Manual*.
   - If no leak is found but pressure is dropping, inspect the exhaust manifolds for coolant. Repair as necessary following procedures in the *Engine Service Manual*.
   - If no leak is found, continue to the next step.
7. Remove valve covers and inspect cylinder heads for cracks, porosity, and leaking cup plugs.
8. Remove EGR valve and install EGR Valve Block Off Plug and install EGR Cooler Pressure Test Plate on the EGR cooler exhaust inlet following procedures in the *Engine Service Manual*.
9. Remove cooling system pressure tester from the coolant deaeration tank and fill tank with coolant to the full mark. Leave tank cap off.
10. Apply regulated air pressure of 172 to 414 kPa (25 to 60 psi) at the EGR Cooler Pressure Test Plate.

11. Observe coolant deaeration tank for air bubbles. Air pressure must be left on EGR cooler for a minimum of 5 minutes.
    - If air bubbles are observed in the tank, remove EGR cooler and pressure test EGR cooler following procedures in the *Engine Service Manual*. Replace EGR cooler if necessary.
    - If air bubbles are observed and the EGR cooler passes additional pressure testing, inspect the intake manifold for cracks and leaks. Replace intake manifold if necessary.

Coolant in Lube Oil

Symptom

Crankcase lube oil contaminated with coolant will generally cause the oil to thicken and turn gray. The crankcase may also be overfilled.

Possible Causes

- Glow plug sleeve leak
- Injector sleeve leak
- Cylinder head cup plug failure
- Cylinder head gasket leak
- Oil filter base assembly and oil cooler bundle failure
- Front cover gasket damage
- Front cover, cylinder head, or crankcase porosity or crack

Tools

Radiator Pressure Testing Kit

Lube Oil Contamination

1. Check coolant level and oil level gauge to verify oil contamination complaint.
    - Coolant in the oil will generally cause the oil to thicken and turn gray black.
    - If coolant in the oil can not be verified, an oil sample can be taken for analysis.
2. Plug in coolant heater, if available, to warm coolant.
3. Remove glow plug harnesses, glow plugs, and valve covers. Drain engine oil and remove oil filter. Leave oil drain plug out of pan and oil filter cap off.

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

WARNING: To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow engine to cool for 15 minutes or more.
- Wrap a thick cloth around the radiator cap or deaeration cap.
- Loosen cap slowly a quarter to half turn to vent pressure.
- Pause for a moment to avoid being scalded by steam.
- Continue to turn cap counterclockwise to remove.

4. Install cooling system pressure tester with the appropriate adapter.
5. Pressurize cooling system to 96 kPa (14 psi).
6. If coolant system pressure is dropping and no coolant is leaking from oil pan, do the next step. If coolant is leaking from the oil pan, inspect the following:
    - Inspect entire cylinder head area for leaks at the cup plugs.
    - Inspect oil filter housing for coolant leaks from the oil cooler.
    - If no leaks are found in above areas, do step 8, and inspect for upper crankcase leakage.
7. Bar engine over by hand and check for coolant flooding the top of piston and flowing out of the glow plug bore.
    - If leaks are found, do the next step.
    - If leaks are not found, do step 9.

8. Remove cylinder head from engine following procedures in the *Engine Service Manual*. Perform all inspections and pressure test cylinder head. Inspect cylinder head gasket for damage at sealing areas. Inspect crankcase and verify crankcase and cylinder head surface flatness using a straight edge and feeler gauge. Repair as necessary.

   If glow plug or injector sleeve was replaced, retest cylinder head with pressure test plate to verify repair.

9. Remove upper and lower oil pans following procedures in the *Engine Service Manual*.

10. Inspect for leakage in crankcase.

    - Verify 96 kPa (14 psi) pressure is maintained on cooling system pressure tester.
    - If no leakage is found, do the next step.

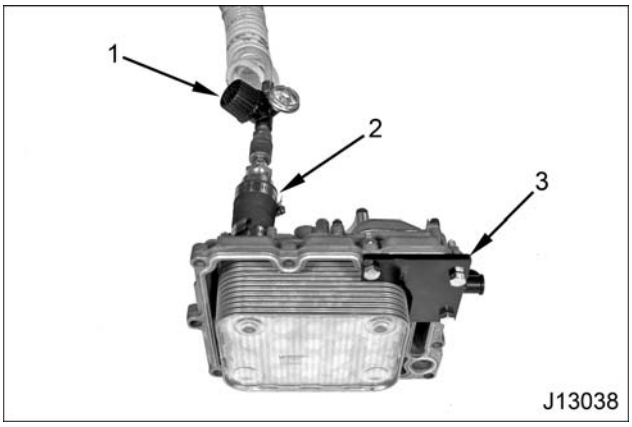

Figure 101 Oil cooler air pressure leakage test

1. Air pressure regulator
2. Air adapter (make locally)
3. Test plate

11. Remove and test oil cooler and oil filter housing following procedures in the *Engine Service Manual*.

    - If a leak is found, replace oil cooler assembly.
    - If no leak is found, do the next step.

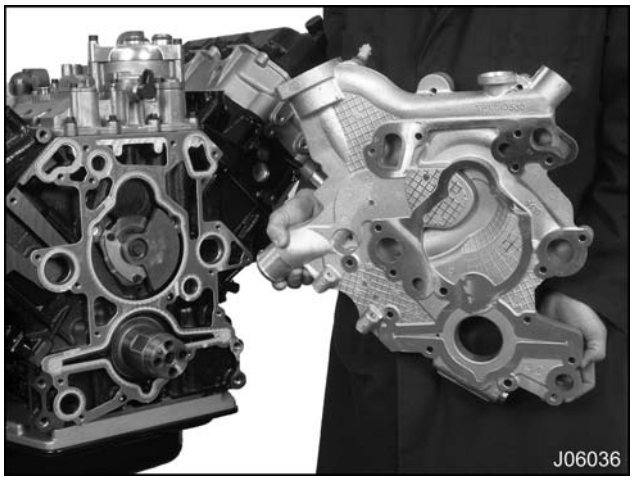

Figure 102 Front cover and gasket

12. Remove front cover and inspect gaskets and sealing surfaces following procedures in the *Engine Service Manual*.

13. Retest cooling system after any repair to confirm repairs.

Cylinder Head Leak Test

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

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

WARNING: To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow engine to cool for 15 minutes or more.
- Wrap a thick cloth around the radiator cap or deaeration cap.
- Loosen cap slowly a quarter to half turn to vent pressure.
- Pause for a moment to avoid being scalded by steam.
- Continue to turn cap counterclockwise to remove.

2. Install cooling system pressure tester with the appropriate adapter.
3. Pressurize cooling system to 96 kPa (14 psi)
4. Inspect both cylinder heads for cracks and leaks at the cup plugs.
    - If leaking, repair or replace cracked or leaking component.
    - If not leaking, do the next step.
5. Drain coolant from system.
6. Remove one cylinder head from engine following procedures in the *Engine Service Manual*.
7. Inspect and pressure test cylinder head following procedures in the *Engine Service Manual*.
    - Inspect cylinder head gasket for damage at sealing points. Verify crankcase and cylinder head surfaces flatness using a straightedge and feeler gauge. Replace head gasket and head bolts. Repair or replace cylinder head if necessary.
    - Inspect cylinder head for cracks in the coolant passages. Repair or replace.
8. Inspect crankcase coolant passages and cylinders for cracks following procedures in the *Engine Service Manual*.
9. If no leak is found, repeat steps 5 through 7 for the second cylinder head.
10. Pressure test cooling system to confirm repair.

Coolant Over-temperature

Symptom

When coolant temperature is above 111 °C (232 °F), Diagnostic Trouble Code (DTC) 2319 will set and the Electronic Control Module (ECM) will command less fueling. A torque loss will occur.

When coolant temperature is above 113 °C (235 °F), the red ENGINE lamp will illuminate and DTC 2321 will set.

When coolant temperature is above 116 °C (240 °F), the red ENGINE lamp will flash, an audible alarm will sound, and DTC 2322 will set. If vehicle has the warning protection feature enabled, the engine will shutdown after 30 seconds.

Possible Causes

- Low engine coolant level
- Coolant leaks
- Internal or external radiator blockage or wrong radiator
- Water pump failure
- Coolant thermostat missing or stuck (closed)
- Engine cooling fan failure
- Broken/worn accessory drive belt
- Accessory belt tensioner failure
- Instrument panel gauge error
- Engine Coolant Temperature (ECT) sensor biased
- Chassis effects, transmission, or aftermarket equipment

Tools

- Radiator Pressure Testing Kit
- EZ-Tech® Electronic Service Tool (EST) with MasterDiagnostics® Software (page 389)
- IC4–USB Interface Cable (page 390)
- Digital Multimeter (DMM) (page 388)

Coolant Over-temperature Diagnosis and Repair

1. Check coolant deaeration tank for correct fill level.

   If coolant level is low, look for leaks at radiator, engine, and all coolant tubes and hoses.

2. Inspect condition of the following items: cooling fan, shroud, accessory drive belt, accessory drive belt tensioner, and radiator.

   - If vehicle is new or recently repaired, verify the correct part number for any component related to the cooling system.
   - Verify cooling fan and radiator are clean of debris and dirt build-up. Clean areas as required.

   CAUTION: To prevent radiator damage, when using high-pressure washer, be careful not to get the wand too close to radiator fins.

3. Connect EST and check for active and inactive DTC related to engine coolant over-temp conditions. Compare Engine Coolant Temperature (ECT), Engine Oil Temperature (EOT), Manifold Air Temperature (MAT), and Intake Air Temperature (IAT) with Key On Engine Off. After a cold soak of at least eight hours, all temperature sensors should read within 2 °C (5 °F) of each other.

4. Run engine up to an operating temperature of at least 70 °C (158 °F). Monitor ECT using the EST.

5. Attempt to duplicate the operator’s concern of coolant over-temperature.

   - If concern cannot be duplicated, clean radiator fins (if not done previously). Flush the radiator fins with water on the cooling fan side of the radiator. Do not continue further with diagnostics.
   - If coolant over-temperature is duplicated, continue with the next step.

WARNING: To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow engine to cool for 15 minutes or more.
- Wrap a thick cloth around the radiator cap or deaeration cap.
- Loosen cap slowly a quarter to half turn to vent pressure.
- Pause for a moment to avoid being scalded by steam.
- Continue to turn cap counterclockwise to remove.

6. Install cooling system pressure tester on the deaeration tank and run engine at elevated idle. Monitor pressure tester gauge.
    - If pressure is higher than the pressure rating of the cooling system cap, continue with Combustion Leaks to Coolant (page 93).
    - If pressure gauge reading is below pressure rating of system, continue to next step.
7. Remove and inspect thermostat following the procedure in the *Engine Service Manual*. Check for correct thermostat opening temperature.
    - Replace if needed. Retest over-temperature condition after repair.
    - If thermostat passes test, continue to next step.
8. Use vehicle diagnostics manual to review automatic transmission diagnostics.
9. If over-temperature condition remains, remove radiator and have it flow tested and cleaned or replaced. Retest engine for over-temperature condition with repaired or new radiator.

Temperature Sensor Validation Test

1. Connect EST and check for active and inactive DTCs related to engine coolant over-temp conditions.
    - Repair problems relating to coolant over-temp DTCs before continuing.
    - If no DTCs exist, do next step.
2. Using the EST, compare ECT, EOT, and MAT with Key On Engine Off. After a cold soak of at least 8 hours, all temperature sensors should read within 2° C (5° F) of each other.
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 ECT Sensor (Engine Coolant Temperature) - Operational Voltage Check (page 266).
    - If the gauge is reading correctly and the engine is running over-temperature, go to Cooling System Operating Pressure Test.

Cooling System Operating Pressure Test

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

Install cooling system pressure tester on the deaeration tank and run engine at elevated idle. Monitor system pressure using the tester gauge. 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 93).
- If pressure gauge reading is below pressure rating of system, replace the thermostat.

Engine Inspection

Symptom

Rough idle

Possible Causes

- Engine oil (aerated, incorrect grade, low oil level, extended drain interval)
- Poor fuel quality
- Low fuel pressure
- Aerated fuel
- Electronic control system faults
- Injection Control Pressure (ICP) system problems
- Fuel injectors not working properly
- Exhaust Gas Recirculation (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
- Mismatched balance shaft

Tools

Digital Multimeter (DMM) (page 388)

Rough Idle

1. Confirm conditions when rough idle complaint is present. When does rough engine idle occur?
   - Hot - operating temperature
   - Cold
   - After high speed operation
   - Over entire engine speed range
   - Combination of the above conditions
   - Is chassis vibration or any other conditions or observations present when engine idles rough.
2. Inspect exhaust system for contact with frame or body of vehicle. Exhaust pipe contact with cab or frame may transmit excessive vibrations and noise to the cab.

Complete the following performance diagnostic tests in the “Performance Diagnostics” section of this manual.

3. Check engine oil level. See Engine Oil (page 154). See *Engine Operation and Maintenance Manual* for proper oil grade at specific temperatures.
4. Check quality and quantity of diesel fuel, fuel aeration, and fuel pressure. Do Fuel Supply System (page 161) procedures. See *Engine Operation and Maintenance Manual* for necessary fuel grade and cetane rating.
5. Do KOEO Standard Test (page 156). The KOEO Standard test will verify electrical operation of actuators.
6. Do ECM Calibration and Diagnostic Trouble Codes (DTCs) (page 156) procedure. Sensor, injector, or wiring harness faults can affect engine idle. The ECM may detect and record these conditions.
7. Do KOEO Injector Test (page 157). This test will verify the injectors are working properly electronically.
8. Do KOER Standard Test (page 159).
9. Do Injection Control Pressure (ICP) (page 167) test.
10. Do Injector Disable Test (page 177). This test will help diagnosis a cylinder power imbalance.

    NOTE: Injector Disable Test is used in conjunction with Relative Compression to distinguish between an injector and a mechanical problem.
11. Do Relative Compression procedure. This test shows the contributions of individual power cylinders.

    NOTE: Relative Compression is used in conjunction with Injector Disable Test to distinguish between an injector and a mechanical problem.
12. Do Crankcase Pressure (page 176) procedure.

Engine and Flexplate Balance Inspection

Inspect engine and drivetrain balance. Rough idle that gets worse with no-load acceleration may be caused by an out of balance engine, flexplate, or torque converter. Remove the accessory drive belt to isolate accessories during balance testing.

Inspect vibration damper for cracks and misalignment.

Inspect flexplate for cracks, damage and verify proper orientation. When removing or installing the flexplate, ensure the locating dowel is in the right place and the flexplate is located properly on the dowel.

Inspect the primary balancer shaft to ensure it is properly installed.

Isolate the engine from transmission by removing the transmission and torque converter. Start the engine and evaluate imbalance. If the engine runs smooth, diagnose the torque converter and transmission, see applicable vehicle *Service Manual*.

Electrical System

ECM 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
- Glow plugs recycle 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 will set and engine speed will go to low idle. The ECM will not allow accelerator pedal authority until the Accelerator Pedal Sensor (APS) is released.

Possible Causes

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

- Poor (intermittent OPEN or high resistance) ground connection
- Poor battery power feed harness connection
- Poor fuse connection
- Intermittent open at connectors
- Poor power relay connection
- Poor module connection, corrosion, or water

1. Using the Electronic Service Tool (EST), check for DTCs for both the engine and chassis.
   - If any engine DTCs are active, perform appropriate diagnostics and repairs before continuing.
   - If any chassis DTCs are active when checking the Electronic System Controller (ESC), perform appropriate diagnostics and repairs before continuing.
2. Check all ECM related fuses.
3. Check all battery, VIGN, and ground connections for the ECM.
4. Monitor ECM powers and grounds with breakout box under operator complaint conditions.
5. Monitor injector powers and grounds with breakout harness under operator complaint conditions.
6. If root cause has not been identified in previous steps, continue diagnosis by doing the remaining tests in “Performance Diagnostics” section of this manual.

Fuel System

WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

WARNING: To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked DIESEL FUEL.

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

Priming the Fuel System

1. Turn ignition switch to ON and wait 60 seconds. Fuel pump will run and fill fuel system.
2. Turn ignition switch OFF.
3. Check for fuel system leaks. Repair any fuel system leaks.
4. Turn ignition switch to ON and wait 60 seconds.
5. Crank engine.

Excessive Fuel Consumption

Symptom

Engine using more fuel then previously to perform the same task.

Possible Causes

Operator effects

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

Application effects

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

Chassis effects

- Brake drag
- Transmission slippage/shifting
- Fuel tank plumbing or venting
- Intake or exhaust restriction

Engine effects

- Incorrect or inoperative thermostat
- Failed turbocharger boost control system
- Oil aeration
- Fuel system leaks
- Base engine performance loss

Verifying Excessive Fuel Consumption Complaints

1. Review operator and fueling records.
2. Loss of fuel economy is normal if winter blend fuel, kerosene 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 the Performance Diagnostic form or in “Performance Diagnostics” section of this manual.

Fuel in Coolant

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

Symptom

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

Tools

Fuel Line Test Adapter (page 397)

Possible Causes

- Leaking or cracked injector sleeve with injector O-ring failure
- Cracked or porous head casting in the fuel rail area

Fuel in Coolant Leakage Test (High-pressure)

WARNING: To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow engine to cool for 15 minutes or more.
- Wrap a thick cloth around the radiator cap or deaeration cap.
- Loosen cap slowly a quarter to half turn to vent pressure.
- Pause for a moment to avoid being scalded by steam.
- Continue to turn cap counterclockwise to remove.

1. Verify coolant contamination.
   - Check for diesel fuel odor in coolant.
   - Coolant may be discolored if diesel fuel is present.
2. Fill deaeration tank with coolant to the full mark.
3. Plug in the coolant heater, if available, to warm coolant.
4. Place a suitable container under the secondary fuel filter housing to catch draining fuel.

WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

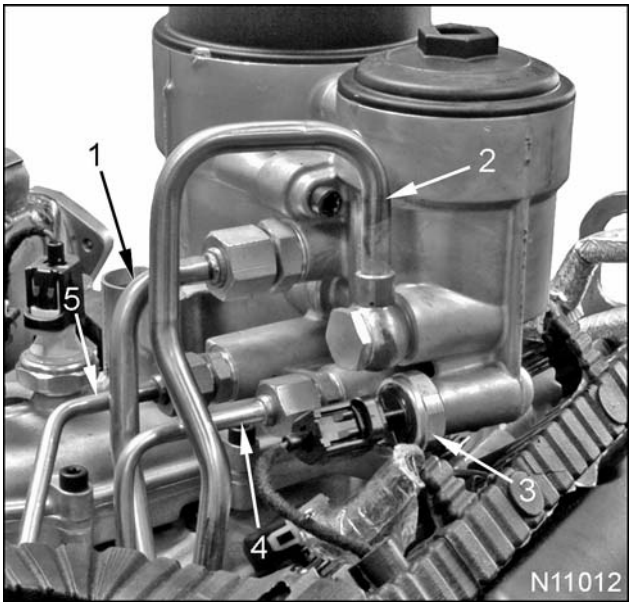

Figure 103 Secondary fuel filter tubes and housing

1. Fuel return to HFCM tube
2. Fuel supply to filter tube
3. Engine Fuel Pressure (EFP) switch
4. Fuel filter to left cylinder head tube
5. Fuel filter to right cylinder head tube

5. Remove the Engine Fuel Pressure (EFP) switch, installed in the bottom of secondary fuel filter housing.
6. Remove secondary fuel filter cap to allow air into filter housing so fuel will drain.
7. Remove the left and right cylinder head connections from the secondary fuel filter housing following procedures in the *Engine Service Manual*.

8. Individually pressurize both cylinder head fuel supply lines to 550 to 690 kPa (80 to 100 psi) using the Fuel Line Test Adapter. Observe deaeration tank for air bubbles or loss of pressure at gauge.
    - If leak is found, do all inspections and test cylinder heads to verify leak path. Repair cylinder head, as necessary. If an injector sleeve was replaced, retest.
    - If no leak is found, continue with Fuel in Coolant Leakage Test (Low-pressure) .

Fuel in Coolant Leakage Test (Low-pressure)

WARNING: To prevent personal injury or death, do the following when removing the radiator cap or deaeration cap:

- Allow engine to cool for 15 minutes or more.
- Wrap a thick cloth around the radiator cap or deaeration cap.
- Loosen cap slowly a quarter to half turn to vent pressure.
- Pause for a moment to avoid being scalded by steam.
- Continue to turn cap counterclockwise to remove.

1. Verify coolant contamination.
    - Check for diesel fuel odor in coolant.
    - Coolant may be discolored if diesel fuel is present.
2. Fill with coolant to deaeration tank full mark.
3. Plug in the coolant heater, if available, to warm coolant.
4. Install cooling system pressure tester on the coolant deaeration tank and pressurize to 96 kPa (14 psi).
5. Remove fuel line banjo fittings/check valves from front of cylinder heads following procedures in the *Engine Service Manual*.
6. Observe fuel rail bores at cylinder heads for air or coolant leaks.
    - If leak is found, remove valve cover and fuel injectors from the suspect cylinder head, following procedures in the *Engine Service Manual*. Observe injector bores for leakage. Repair cylinder head, as necessary. After repair, pressurize cooling system to confirm repair.
    - If no leak is found, remove each cylinder head one at a time following procedures in the *Engine Service Manual*. Perform all inspections and pressure test cylinder head to check for leak paths.

Fuel In Lube Oil

Symptom

Oil contaminated with diesel fuel will have diesel fuel odor and the oil level in engine will go up.

Tools

Fuel Line Test Adapter (page 397)

Possible Causes

- Leaking fuel injector or injector O-ring.
- Porous cylinder head (most likely on low mileage vehicles)

Verify Fuel Dilution in Engine Oil

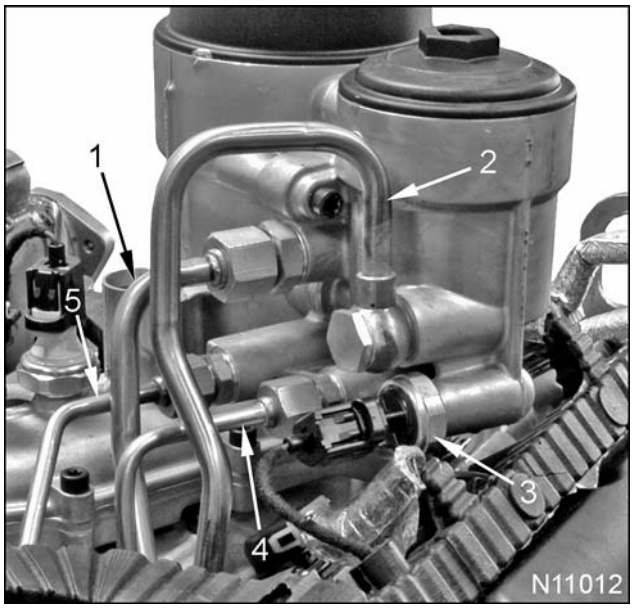

Figure 104 Secondary fuel filter tubes and housing

1. Fuel return to HFCM tube
2. Fuel supply to filter tube
3. Engine Fuel Pressure (EFP) switch
4. Fuel filter to left cylinder head tube
5. Fuel filter to right cylinder head tube

1. Verify engine oil is contaminated with fuel. Oil contaminated with diesel fuel will have diesel fuel odor and the engine oil level will rise.
2. Place a suitable container under the secondary fuel filter housing to catch draining fuel.

⚠ WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

3. Remove the EFP switch, installed in the bottom of secondary fuel filter housing.
4. Remove the left and right cylinder head connections from the secondary fuel filter following procedures in the *Engine Service Manual*.

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

5. Individually pressurize both cylinder head fuel supply passages to 550 to 690 kPa (80 to 100 psi) using the Fuel Line Test Adapter.
6. Remove valve cover at suspected cylinder head and inspect for leaks at injector areas. Repair fuel leaks as needed.

Air or Combustion Leaks to Fuel

Possible Causes

- Loose fuel injector hold down
- Missing or damaged copper injector gasket
- Combustion leaks to fuel will have one or more of these characteristics:
  - Rough running engine
  - Engine stall
  - Extended engine crank time (hard start)
  - Fuel pressure slow to build while cranking
  - Excessive fuel pressure while cranking
  - Pulsating fuel pressure (low-pressure fuel system) during crank or engine running at idle.

Tools

- Fuel Pressure Test Gauge (page 393)
- Fuel/Oil Pressure Test Coupler (page 395)
- Fuel Pressure Test Adapter (page 397)

Air or Combustion Leak to Fuel Test

1. Verify operator complaint.
2. Deactivate the fuel pump by disconnecting the fuel pump relay.
3. Place a suitable container under the secondary fuel filter housing to catch draining fuel.

WARNING: To prevent personal injury or death, do not smoke or park vehicle near flames or sparks when draining fuel.

4. Remove the Engine Fuel Pressure (EFP) switch, installed in the bottom of secondary fuel filter housing.
5. Remove the left and right cylinder head connections from the secondary fuel filter following procedures in the *Engine Service Manual*.

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

6. Turn ignition switch to START to crank the engine. Crank engine for 3 to 5 seconds while checking fuel supply lines for the following:
   - Fuel forced back through lines from combustion
   - Combustion gasses or smoke coming from lines
   - Audible sound of air or compression from lines
7. If diagnostic tests confirm a combustion leak to fuel, remove valve cover on the suspected side following procedures in the *Engine Service Manual*. Inspect for loose injector hold down clamps on side of engine suspect of combustion in fuel. Repair if necessary and retest.

Aerated Fuel

A leak on the suction side of the fuel pump can allow air into the system and cause low fuel pressure (most noticeable under load).

Symptoms

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

Possible Causes

- Failed seal for inlet fitting in primary fuel filter housing
- Supply filter or water separator leaking
- Strainer drain valve loose or damaged
- Missing O-ring from strainer bowl
- Damaged seals on steel inlet tube to fuel pump

See Fuel Supply System (page 161) diagnostics procedure.

Water In Fuel (WIF) Lamp On (Drain Water from HFCM)

Possible Causes

- Water or ice in fuel supply system
- Short circuit or damaged connection
- Corrosion on connector, sensor, or cover plate assembly
- Failed Electronic Control Module (ECM)
- Failed WIF sensor

Tools

Clean drain pan

1. If the WIF lamp is on or fuel system contamination is suspected, continue to the next step.
2. Put a drain pan under the HFCM drain plug.

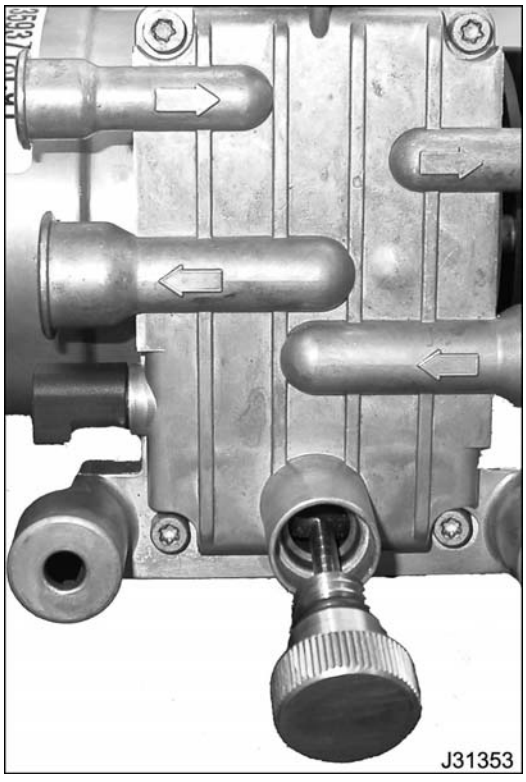

Figure 105 Horizontal Fuel Conditioning Module (HFCM) and drain plug

WARNING: To prevent personal injury or death, do not smoke or park vehicle near flames or sparks when draining fuel.

3. Loosen HFCM drain plug and drain fuel and water into a clean drain pan.
4. Replace drain plug O-ring.
5. Install and hand tighten drain plug when finished draining.
6. Check fuel in drain pan for contamination.
   - Excessive water or contaminants may indicate the fuel tank and fuel system need to be flushed and cleaned.
   - Fuel should be clear, not cloudy. Cloudy fuel indicates fuel is not a suitable grade for cold temperatures.
   - Fuel should not be dyed red or blue, these colors indicate off-highway fuel.
   - Fuel should not be waxing or gelling. Waxing or gelling in cold weather can clog the fuel system.
7. Recycle or dispose of contents in the drain pan according to applicable regulations.
8. Turn ignition switch to ON and wait 60 seconds for the fuel system to prime. If the WIF lamp is still ON, continue to next step.
9. Take a second fuel sample. Put a clean drain pan under the HFCM drain plug. Loosen drain plug and drain fuel into drain pan. Install and hand tighten drain plug when fuel is finished draining. Check fuel in drain pan for contamination.
10. If the second fuel sample is contaminated, go to the next step.

    If the second fuel sample is not contaminated and the WIF light is on see WIF Sensor (Water In Fuel) (page 379).
11. Check fuel lines and tanks for water and other contamination. Drain and clean fuel lines and tanks if needed.

Lubrication System

WARNING: To prevent personal injury or death, when routing test line, do not crimp line, run line too close to moving parts, or let line touch hot engine. Secure the gauge and test line to not obstruct vehicle operation.

Low Oil Pressure

Tools

- Fuel/Oil Pressure Test Coupler (page 395)
- Gauge Bar Tool (page 393)
- Fuel Pressure Test Fitting (page 395)
- ICP System Test Adapter (page 395)

Possible Causes

- 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
- Fuel in oil
- Stuck oil pressure regulator
- Scored or damaged oil pump
- Engine Oil Pressure (EOP) switch biased
- Missing oil gallery cup plugs (front or rear)
- Broken, missing or loose piston cooling tube(s)
- Missing, damaged or worn main bearings, connecting rod bearings or camshaft bushings
- Lifter missing (will also have performance problems)
- Aeration (cracked pickup tube, missing O-ring)

1. Verify engine oil level, using the oil level gauge while vehicle is parked on level ground. Check to see if oil is contaminated with fuel or coolant.
   - Engine oil level will vary depending on temperature of engine
   - If oil is contaminated, go to Fuel in Lube Oil (page 107) or Coolant in Lube Oil (page 97).
2. Connect fitting on test line with Fuel/Oil Pressure Test Coupler to the 0 to 160 psi gauge on the Gauge Bar Tool.

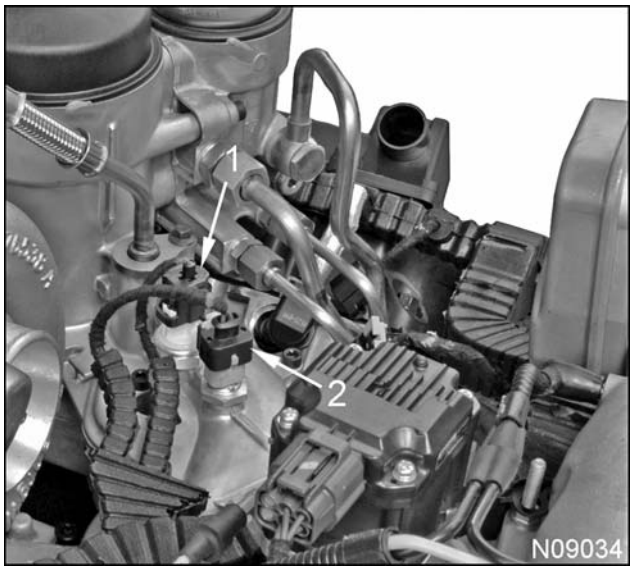

Figure 106 EOP switch and EOT sensor

1. Engine Oil Pressure (EOP) switch
2. Engine Oil Temperature (EOT) sensor

3. Remove EOP switch and install Fuel Pressure Test Fitting.
4. Connect Fuel/Oil Pressure Test Coupler to Fuel Pressure Test Fitting
5. Start engine and measure oil pressure at both low and high idle, under no load conditions. Engine must be at normal operating temperature.
   - If oil pressure gauge bar tool reads within specification, listed in “Appendix A: Performance Specifications” (page 427), and the instrument panel indicator indicates low pressure, see EOP (Engine Oil Pressure) switch (page 295).
   - If oil pressure gauge bar tool does not read within specification, turn engine off and continue to next step.

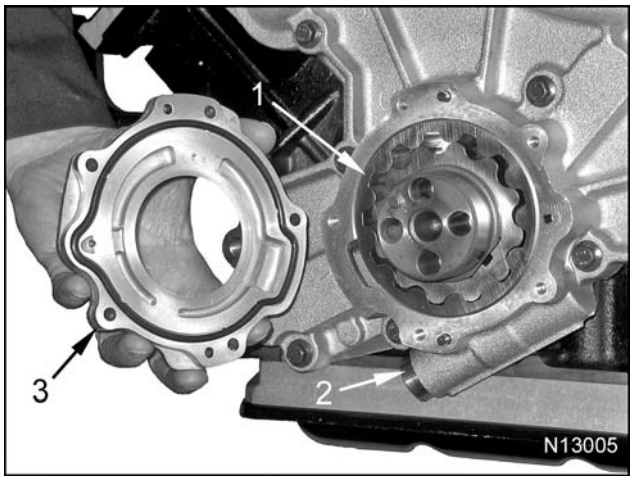

Figure 107 Oil pump, gerotor cover and oil pressure regulator

1. Oil pump assembly
2. Oil pressure regulator
3. Gerotor cover assembly

6. Remove and inspect oil pressure regulator as described in the *Engine Service Manual* "Front Cover, Vibration Damper, Oil Pump, and Cooling System". The oil pressure regulator piston should move freely in its bore in the front cover.
   - If oil pressure regulator is functional and passes inspection, reinstall regulator following procedures in the *Engine Service Manual*. Redo step 5.
   - If oil pressure remains low, continue to next step.
7. Remove and inspect the lube oil pump following procedure in the *Engine Service Manual*.
   - Inspect the lube oil pump housing and cover for gouging or deep scratches. Inspect the gerotor gears for excessive wear or damage. Replace oil pump or front cover if needed.
   - If no excessive damage is found, continue to next step.
8. Drain engine oil into a clean drain pan. Inspect oil drain plug magnet, drained oil, and oil filter for foreign debris.

   An oil sample can be taken to determine engine wear, metals and contaminants in the oil.
9. Remove both the upper and lower oil pans following procedure in the *Engine Service Manual*. Look for missing, loose or damaged oil pickup tube, O-ring, piston cooling tubes, bearing inserts, and cam bushings.
10. Reinstall the oil filter, oil filter cap, oil pump, and oil pump cover.

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

11. Connect regulated shop air line to the ICP System Test Adapter in the lube oil filter base.
12. Slowly apply air pressure in 34.5 kPa (5 psi) increments to 345 kPa (50 psi).
13. Inspect for gross leaks internally.
    - If a major leak is observed from the front cover area, continue to next step.
    - If a major leak is observed from the rear cover area, continue with step 16.
    - If a major leak is not observed, remove engine from vehicle. Disassemble engine and perform full inspection of all components following procedures in the *Engine Service Manual*.
14. Remove the front cover from the engine following procedures in the *Engine Service Manual* and complete inspection of the lube oil pump.
15. With the front cover removed from engine, verify the front main oil gallery cup plugs are in position and not damaged.

⚠ WARNING: To prevent personal injury or death, support engine (if in chassis) before removing the rear cover or flywheel housing.

16. Remove the rear cover from the engine as described in the *Engine Service Manual*. Verify the rear main oil gallery cup plugs are in position and not damaged.

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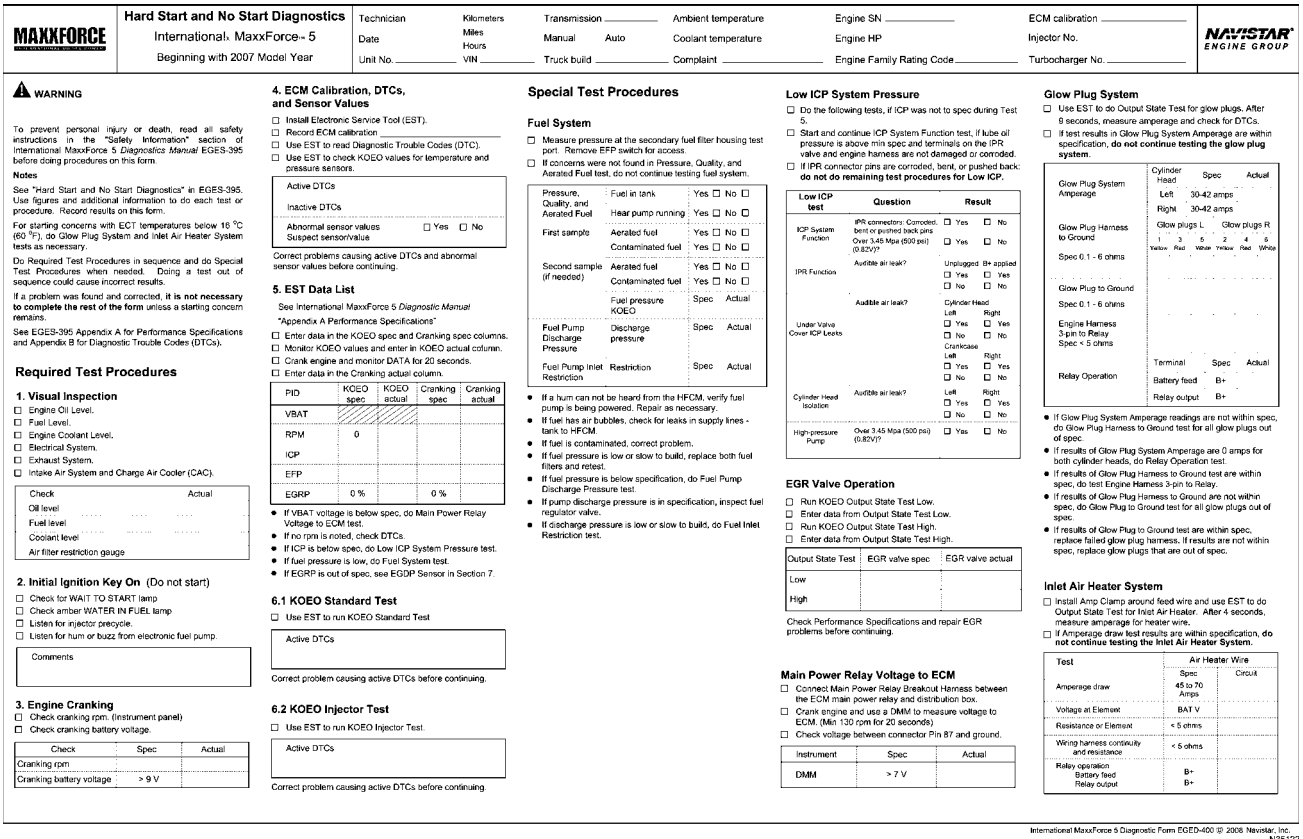
Diagnostic Form EGED-400



MAXXFORCE

Hard Start and No Start Diagnostics
International® MaxxForce® 5
Beginning with 2007 Model Year

Technician | Kilometers / Miles / Hours
Date
Unit No. | VIN

Transmission | Manual | Auto
Truck build | Complaint

Ambient temperature
Coolant temperature

Engine SN | Engine HP | Engine Family Rating Code

ECM calibration | Injector No. | Turbocharger No.

NAVISTAR ENGINE GROUP

⚠ WARNING

To prevent personal injury or death, read all safety instructions in the "Safety Information" section of International MaxxForce 5 *Diagnostics Manual* EGES-395 before doing procedures on this form.

Notes

See "Hard Start and No Start Diagnostics" in EGES-395. Use figures and additional information to do each test or procedure. Record results on this form.

For starting concerns with ECT temperatures below 16 °C (60 °F), do Glow Plug System and Inlet Air Heater System tests as necessary.

Do Required Test Procedures in sequence and do Special Test Procedures when needed. Doing a test out of sequence could cause incorrect results.

If a problem was found and corrected, **it is not necessary to complete the rest of the form** unless a starting concern remains.

See EGES-395 Appendix A for Performance Specifications and Appendix B for Diagnostic Trouble Codes (DTCs).

Required Test Procedures

1. Visual Inspection

- ☐ Engine Oil Level.
- ☐ Fuel Level.
- ☐ Engine Coolant Level.
- ☐ Electrical System.
- ☐ Exhaust System.
- ☐ Intake Air System and Charge Air Cooler (CAC).

Check	Actual
Oil level	
Fuel level	
Coolant level	
Air filter restriction gauge	

2. Initial Ignition Key On (Do not start)

- ☐ Check for WAIT TO START lamp
- ☐ Check amber WATER IN FUEL lamp
- ☐ Listen for injector precycle.
- ☐ Listen for hum or buzz from electronic fuel pump.

Comments

3. Engine Cranking

- ☐ Check cranking rpm. (Instrument panel)
- ☐ Check cranking battery voltage.

Check	Spec	Actual
Cranking rpm		
Cranking battery voltage	> 9 V	

4. ECM Calibration, DTCs, and Sensor Values

- ☐ Install Electronic Service Tool (EST).
- ☐ Record ECM calibration _____
- ☐ Use EST to read Diagnostic Trouble Codes (DTC).
- ☐ Use EST to check KOEO values for temperature and pressure sensors.

Active DTCs

Inactive DTCs

Abnormal sensor values Suspect sensor/value ☐ Yes ☐ No

Correct problems causing active DTCs and abnormal sensor values before continuing.

5. EST Data List

See International MaxxForce 5 *Diagnostic Manual* "Appendix A Performance Specifications"

- ☐ Enter data in the KOEO spec and Cranking spec columns.
- ☐ Monitor KOEO values and enter in KOEO actual column.
- ☐ Crank engine and monitor DATA for 20 seconds.
- ☐ Enter data in the Cranking actual column.

PID	KOEO spec	KOEO actual	Cranking spec	Cranking actual
VBAT				
RPM	0			
ICP				
EFP				
EGRP	0 %		0 %	

- If VBAT voltage is below spec, do Main Power Relay Voltage to ECM test.
- If no rpm is noted, check DTCs.
- If ICP is below spec, do Low ICP System Pressure test.
- If fuel pressure is low, do Fuel System test.
- If EGRP is out of spec, see EGDP Sensor in Section 7.

6.1 KOEO Standard Test

- ☐ Use EST to run KOEO Standard Test

Active DTCs

Correct problem causing active DTCs before continuing.

6.2 KOEO Injector Test

- ☐ Use EST to run KOEO Injector Test.

Active DTCs

Correct problem causing active DTCs before continuing.

Special Test Procedures

Fuel System

- ☐ Measure pressure at the secondary fuel filter housing test port. Remove EFP switch for access.
- ☐ If concerns were not found in Pressure, Quality, and Aerated Fuel test, do not continue testing fuel system.

Pressure, Quality, and Aerated Fuel	Fuel in tank	Yes ☐ No ☐	
	Hear pump running	Yes ☐ No ☐	
First sample	Aerated fuel	Yes ☐ No ☐	
	Contaminated fuel	Yes ☐ No ☐	
Second sample (if needed)	Aerated fuel	Yes ☐ No ☐	
	Contaminated fuel	Yes ☐ No ☐	
	Fuel pressure KOEO	Spec	Actual
Fuel Pump Discharge Pressure	Discharge pressure	Spec	Actual
Fuel Pump Inlet Restriction	Restriction	Spec	Actual

- If a hum can not be heard from the HFCM, verify fuel pump is being powered. Repair as necessary.
- If fuel has air bubbles, check for leaks in supply lines - tank to HFCM.
- If fuel is contaminated, correct problem.
- If fuel pressure is low or slow to build, replace both fuel filters and retest.
- If fuel pressure is below specification, do Fuel Pump Discharge Pressure test.
- If pump discharge pressure is in specification, inspect fuel regulator valve.
- If discharge pressure is low or slow to build, do Fuel Inlet Restriction test.

Low ICP System Pressure

- ☐ Do the following tests, if ICP was not to spec during Test 5.
- ☐ Start and continue ICP System Function test, if lube oil pressure is above min spec and terminals on the IPR valve and engine harness are not damaged or corroded.
- ☐ If IPR connector pins are corroded, bent, or pushed back: **do not do remaining test procedures for Low ICP.**

Low ICP test	Question	Result
ICP System Function	IPR connectors: Corroded, bent or pushed back pins	☐ Yes ☐ No
	Over 3.45 Mpa (500 psi) (0.82V)?	☐ Yes ☐ No
IPR Function	Audible air leak?	Unplugged ☐ Yes ☐ No; B+ applied ☐ Yes ☐ No
	Audible air leak?	Cylinder Head Left ☐ Yes ☐ No; Right ☐ Yes ☐ No
Under Valve Cover ICP Leaks		Crankcase Left ☐ Yes ☐ No; Right ☐ Yes ☐ No
Cylinder Head Isolation	Audible air leak?	Left ☐ Yes ☐ No; Right ☐ Yes ☐ No
High-pressure Pump	Over 3.45 Mpa (500 psi) (0.82V)?	☐ Yes ☐ No

EGR Valve Operation

- ☐ Run KOEO Output State Test Low.
- ☐ Enter data from Output State Test Low.
- ☐ Run KOEO Output State Test High.
- ☐ Enter data from Output State Test High.

Output State Test	EGR valve spec	EGR valve actual
Low		
High		

Check Performance Specifications and repair EGR problems before continuing.

Main Power Relay Voltage to ECM

- ☐ Connect Main Power Relay Breakout Harness between the ECM main power relay and distribution box.
- ☐ Crank engine and use a DMM to measure voltage to ECM. (Min 130 rpm for 20 seconds)
- ☐ Check voltage between connector Pin 87 and ground.

Instrument	Spec	Actual
DMM	> 7 V	

Glow Plug System

- ☐ Use EST to do Output State Test for glow plugs. After 9 seconds, measure amperage and check for DTCs.
- ☐ If test results in Glow Plug System Amperage are within specification, **do not continue testing the glow plug system.**

		Spec	Actual
Glow Plug System Amperage	Cylinder Head Left	30-42 amps	
	Right	30-42 amps	

Glow Plug Harness to Ground — Glow plugs L: 1 Yellow, 3 Red, 5 White; Glow plugs R: 2 Yellow, 4 Red, 6 White

Spec 0.1 - 6 ohms

Glow Plug to Ground

Spec 0.1 - 6 ohms

Engine Harness 3-pin to Relay
Spec < 5 ohms

	Terminal	Spec	Actual
Relay Operation	Battery feed	B+	
	Relay output	B+	

- If Glow Plug System Amperage readings are not within spec, do Glow Plug Harness to Ground test for all glow plugs out of spec.
- If results of Glow Plug System Amperage are 0 amps for both cylinder heads, do Relay Operation test.
- If results of Glow Plug Harness to Ground test are within spec, do test Engine Harness 3-pin to Relay.
- If results of Glow Plug Harness to Ground are not within spec, do Glow Plug to Ground test for all glow plugs out of spec.
- If results of Glow Plug to Ground test are within spec, replace failed glow plug harness. If results are not within spec, replace glow plugs that are out of spec.

Inlet Air Heater System

- ☐ Install Amp Clamp around feed wire and use EST to do Output State Test for Inlet Air Heater. After 4 seconds, measure amperage for heater wire.
- ☐ If Amperage draw test results are within specification, **do not continue testing the Inlet Air Heater System.**

Test	Air Heater Wire Spec	Air Heater Wire Circuit
Amperage draw	45 to 70 Amps	
Voltage at Element	BAT V	
Resistance of Element	< 5 ohms	
Wiring harness continuity and resistance	< 5 ohms	
Relay operation Battery feed	B+	
Relay output	B+	

International MaxxForce 5 Diagnostic Form EGED-400 © 2008 Navistar, Inc.
N35122

The Hard Start and No Start Diagnostic Form directs technicians to systematically troubleshoot a hard start or no start condition and avoid unnecessary repairs.

This Diagnostics Manual section shows detailed instructions of the tests on the form. The manual should be used with the form and referenced for supplemental test information. Use the form as a worksheet to record test results.

Do Required Test Procedures in sequence and do Special Test Procedures when needed. Doing a test out of sequence can cause incorrect results. If the customer complaint is found and corrected, it is not necessary to complete the remaining tests.

See appendices for Diagnostic Trouble Codes (DTCs) and performance specifications.

Header Information

Technician _____	Kilometers _____	Transmission	Ambient temperature _____	Engine SN _____	ECM calibration _____
Date _____	Miles _____ Hours _____	Manual ____ Auto ____	Coolant temperature _____	Engine HP _____	Injector No.
Unit No. _____	VIN _____	Truck build _____	Complaint _____	Engine Family Rating Code _____	Turbocharger No. _____

N35108

Enter Header Information

1. Technician
2. Date
3. Unit No. (dealer's quick reference number)
4. Customer complaint (interview driver)

Enter Vehicle Information

The Vehicle Identification Number (VIN) is located on the VIN plate. The VIN information can be obtained online in ISIS.

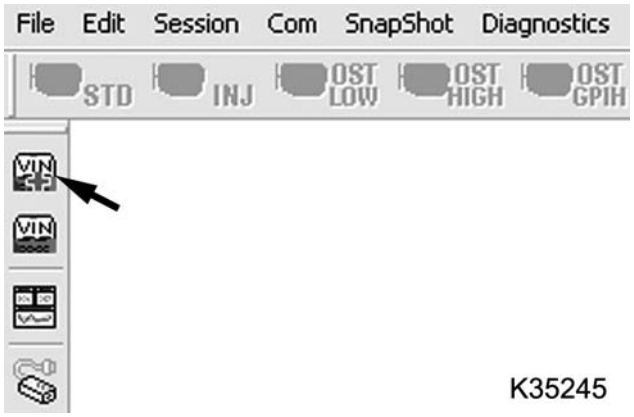
5. VIN – the last 8 digits (verify to VIN plate)
6. Truck Build date (verify to VIN plate)
7. Engine hp
8. ECM calibration
9. Transmission type
10. Engine SN

Enter Performance Specification Information

11. See "Performance Specifications" (page 427) appendix in this manual or TSI to obtain the following header information:

NOTE: Performance specifications are periodically published in TSI format to support new model year products. Check service bulletin listing on ISIS® for appropriate model year application.

- Engine Family Rating Code (EFRC)
- Injector No.
- Turbocharger No.



K35245

12. Using the EST with MasterDiagnostics®, open the VIN session by selecting the VIN+ icon.

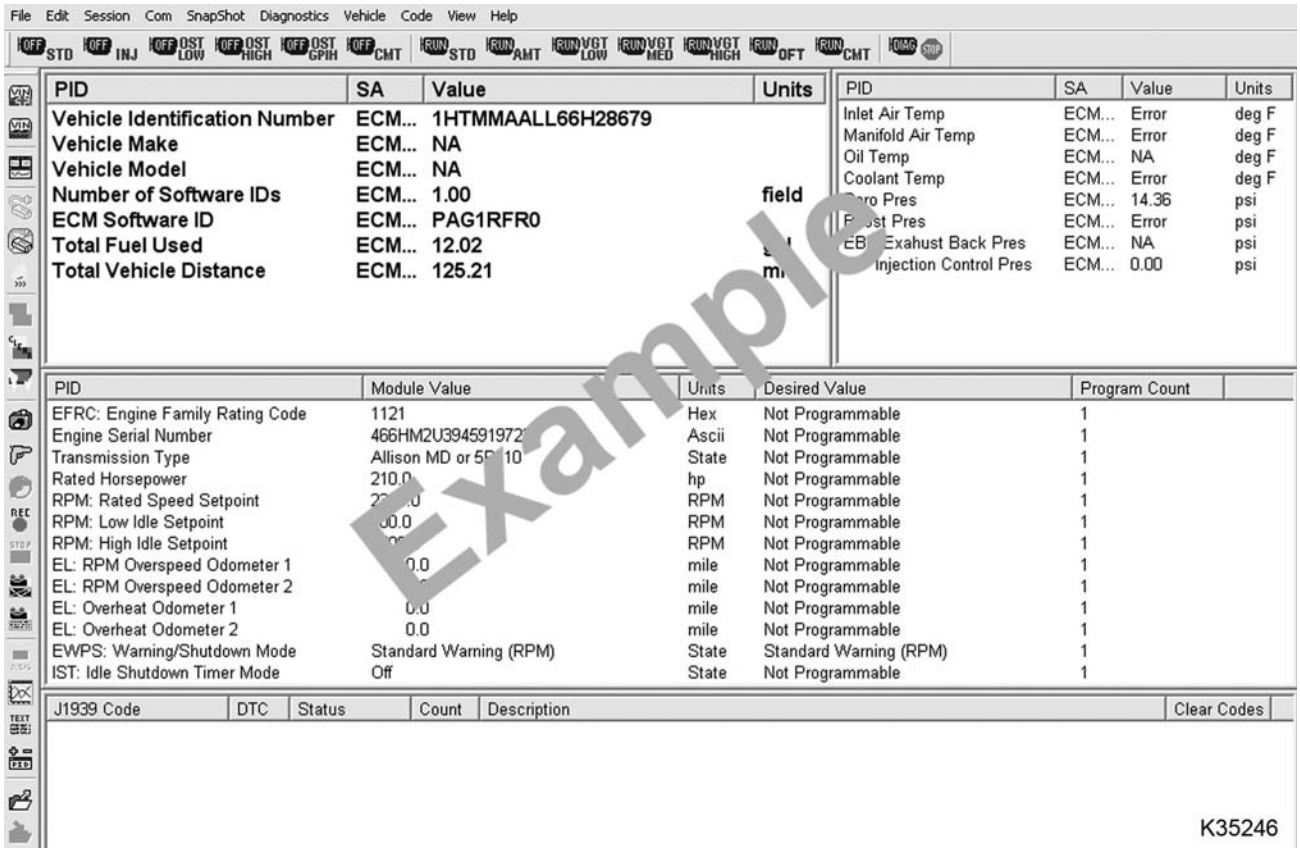


Figure 111 VIN session (example)

13. Verify the following match vehicle specification:
    - VIN
    - ECM calibration
    - Rated hp
    - EFRC
    - Transmission
    - Engine SN

      Note: The engine serial number is stamped on the left rear of the crankcase below the cylinder head. It is also located on the engine emission label on the crankcase breather.
14. Enter the following information:
    - Kilometers, Miles, or Hours
    - Ambient temperature
    - Coolant temperature

Required Test Procedures

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

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

1. Visual Inspection

Purpose

Check fluid levels, look for intake and exhaust restrictions, and electrical system problems.

Tools

- Inspection lamp
- Flash light

Engine Oil

1. Park vehicle on level ground. Turn engine off. Wait 15 minutes for oil level to stabilize.
2. Use oil level gauge (dip stick) to verify engine oil level. Record results on Diagnostic Form.
   - If oil level is below specification, inspect for leaks, oil consumption, or improper servicing.
   - If oil level is above specification, inspect for fuel dilution, coolant contamination, or improper servicing.

Fuel Level

1. Park vehicle on level ground. Turn engine off.
2. Use dash gauge to check fuel level. Inspect fuel tank fill ports to verify. Record results on Diagnostic Form.
   - If fuel tank is empty, put the correct grade of diesel fuel in the fuel tank.
   - If fuel level is low or below dash gauge reading, inspect for leaks, or fuel gauge problems.
   - If fuel level is above empty, and no tank contamination is evident, no repair is required.

Engine Coolant Level

1. Park vehicle on level ground.

   NOTE: Turn engine off. Wait 15 minutes or more for engine to cool.
2. Check coolant level on surge tank level window. Record results on Diagnostic Form.
   - If coolant level is low, inspect for leaks, coolant in the oil, coolant in the exhaust, improper servicing, or problems causing engine overheating.
   - If coolant level is full, and no tank contamination or leaks are evident, no repair is required.

Electrical System

1. Inspect batteries and electrical system (engine and vehicle) for loose or disconnected connections, corroded terminals, or broken and damaged wires.
2. Repair electrical problems as required.

Exhaust System

1. Inspect exhaust system (engine and vehicle) for restrictions, damage, and leaks.
2. Repair exhaust system problems as required.

Intake Air System and Charge Air Cooler (CAC)

1. Inspect CAC system, including intercooler and all intake piping and ducts for leaks and damage.

   Inspect the following parts for restriction, damage or incorrect installation:

   - Air inlet hoses and ducts
   - Air filter housing, filter element, and gaskets
   - CAC and piping
   - Air filter inlet and duct - look inside duct and remove any restrictions.

Figure 112 Air filter restriction gauge

2. Check the air filter restriction gauge.
3. Inspect all CAC and intake air connections and clamps.
4. If a CAC or intake air system problem is found, repair as required.

2. Initial Ignition Key ON (Do Not Start)

Purpose

To determine the following:

- Is the Electronic Control Module (ECM) powered up?
- Does the electric fuel pump hum or buzz?
- Is there water in the fuel?

Possible Causes

WAIT TO START lamp does not illuminate

- No key power (VIGN)
- Failed ECM ground circuit
- No power from main power relay to ECM
- ECM failure
- Amber WAIT TO START lamp is out (will not cause hard start or no start).
- CAN Public link to instrument panel not working (will not cause hard start or no start).

No injector pre-cycle

- No key power (VIGN)
- ICP sensor bias high
- Failed ECM ground circuit
- No power from main power relay to ECM
- ECM failure

WATER IN FUEL lamp illuminates

- Water in fuel
- Electrical circuit failure

Electric fuel pump does not run

- Failed fuel pump
- Failed fuel pump relay
- Failed ECM relay
- No key power (VIGN)
- OPEN or short circuit from ECM to ECM relay, ECM relay to fuel pump, or from fuel pump relay to fuel pump
- OPEN fuel pump ground
- Failed ECM

Procedure

1. Turn ignition switch to ON, do not start engine. Check or listen for the following:
   - WAIT TO START lamp
   - WATER IN FUEL lamp
   - Injector pre-cycle (Shop noise can drown out the sound of injector pre-cycle.)
   - Electric fuel pump hum or buzz (will run for 60 seconds)
2. If the WAIT TO START lamp and WATER IN FUEL lamp come on and off, injectors pre-cycle, and the electric fuel pump comes on, continue to Engine Cranking (page 121).
3. If pre-cycle noise was not heard or missed, cycle the ignition switch and listen again.
   - If pre-cycle noise is still not heard, the ECM may not be powered up. Check for DTCs. If the EST is not communicating with the ECM, do Main Power Relay Voltage to ECM procedure (page 142).
4. If the Water In Fuel (WIF) light turns on and stays on, do Fuel System procedure (page 125).
5. If the electric fuel pump does not hum or buzz, do Fuel System procedure (page 125).

3. Engine Cranking

Purpose

Determine if crankshaft rotates at correct rpm, if battery and starting system are working properly, and if instrument panel is receiving signals.

Possible Causes

Engine will not crank

- Low or no battery power
- No key power (VIGN)
- Insufficient power to ECM
- Starting system failure or high electrical resistance
- Circuit fault for Engine Crank Inhibit (ECI)
- Cylinder hydraulic lock
- Cylinder mechanical lock (timing incorrect, valve/piston contact, etc.)
- Starter gear locked on flywheel ring gear

Insufficient rpm

- Low battery power
- High resistance in battery cables or connections
- Starter motor problem
- Incorrect oil viscosity
- Cold temperature

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- Battery / starter tester
- Digital Multimeter (DMM) (page 388)

Procedure

1. See “Performance Specifications” (page 427) appendix in this manual for engine cranking specifications. Enter data on Diagnostic Form in spec column.
2. Turn ignition switch to START. Check rpm on instrument panel.

   Record results on Diagnostic Form.

   - If engine cranking speed is below specification, check batteries, starter, starting system wiring, and engine problems.
   - Check DTCs if engine seems to be turning over fast enough to start and no rpm is indicated on the instrument panel.

4. ECM Calibration, DTCs, and Sensor Values

NOTE: See “Diagnostic Software Operation” section in this manual for specific Electronic Service Tool (EST) software procedures to do this test.

Purpose

Verify Electronic Control Module (ECM) vehicle information matches the actual vehicle, identify Diagnostic Trouble Codes (DTCs), and verify KOEO sensor values are in a normal range.

Tools

- EZ-Tech® Electronice Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)

ECM Calibration Verification

1. Turn ignition Key ON Engine OFF (KOEO).
2. Connect EST, open the VIN+ session. Select the VIN+ icon.
3. Verify ECM vehicle information matches the actual vehicle. See Enter Vehicle Information (page 116).
4. Record ECM calibration level on Diagnostic Form.

Diagnostic Trouble Codes (DTCs)

1. Use EST to check DTCs.
2. Record active and inactive DTCs on the Diagnostic Form.

CAN code: Codes associated with a Suspect Parameter Number (SPN) and Failure Mode Indicator (FMI)

Status: Indicates active or inactive DTCs

- **Active**: With the ignition switch to ON, indicates a DTC for a condition currently in the system. When the ignition switch is turned off, an active DTC becomes inactive. (If a problem remains, the DTC will be active on the next ignition switch cycle and the EST will display active/inactive.)
- **Inactive**: With the ignition switch to ON, indicates a DTC for a condition during a previous key cycle. When the ignition switch is turned to OFF, inactive DTCs from a previous ignition switch cycle remain in the ECM memory until cleared.
- **Active/Inactive:** With the ignition switch to ON, indicates a DTC for a condition currently in the system and was present in previous key cycles, if codes were not cleared.

3. Fix problems causing active DTCs before continuing. See “Electronic Control Systems Diagnostics” section of this manual.
4. Clear DTCs.

KOEO Sensor Values

1. Use the EST to check KOEO values for temperature and pressure sensors.
2. Are sensor values normal? Record results on the Diagnostic Form. After a cold soak of at least 8 hours, all temperature sensors should read within 2° C (5° F) of each other. See “Electronic Control Systems Diagnostics” section in this manual for specific sensor circuit information and testing.

5. EST Data List

NOTE: See “Diagnostic Software Operation” section in this manual for specific Electronic Service Tool (EST) software procedures to do this test.

Purpose

Determine if engine systems meet operating specifications to start engine.

Tools

- EZ-Tech® Electronice Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)

Procedure

1. Turn ignition switch Key ON Engine OFF (KOEO).
2. Connect EST, open the HardStart_NoStart session.
3. See “Appendix A: Performance Specifications” (page 427). Record RPM, ICP, EFP, and EGRP specifications on the Diagnostic Form.
    - Engine speed (RPM)
    - Injection Control Pressure (ICP)
    - Engine Fuel Pressure (EFP)
    - Exhaust Gas Recirculation Position (EGRP)
4. Monitor KOEO readings and record on the Diagnostic Form.
5. Crank engine for a maximum of 20 seconds.
6. Record cranking readings on the Diagnostic Form.

- If results are in specification, continue to the next test.
- If VBAT voltage is below specification, do Main Power Relay Voltage to ECM procedure (page 142).
- If RPM readings are not in specification, recheck for cam and crank sensor DTCs, check batteries and engine starting system.
- If ICP readings are not in specification, do Low ICP System Pressure procedure (page 132).
- If fuel pressure is not in specification, do Fuel System procedure (page 125).
- If EGRP is out of specification, see EGDP Sensor (Exhaust Gas Differential Pressure) (page 274).

6. KOEO Tests

6.1 KOEO Standard Test

NOTE: See “Diagnostic Software Operation” section in this manual for specific Electronic Service Tool (EST) software procedures to do this test.

Purpose

Inspect for electrical malfunctions detected by the ECM self-test and Output Circuit Check (OCC).

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)

Possible Causes

- Failed electrical components or circuitry
- OCC faults detected by ECM.

Procedure

1. Turn ignition Key ON Engine OFF (KOEO).
2. Open COM device.
3. Select KOEO Tests. Select Standard Test from the drop down menu.
4. Follow the on-screen instructions.
5. Record DTCs on the Diagnostic Form.
6. If DTCs are detected, correct problems causing DTCs. See “Appendix B: Diagnostic Trouble Code (DTC) Index” (page 435).
7. Clear DTCs.
8. Run the KOEO Standard Test again.

6.2 KOEO Injector Test

NOTE: When using the EST for KOEO or KOER diagnostic tests, Standard Test is always selected and run first. If the ignition switch is not cycled, the Standard Test does not have to be run again.

NOTE: KOEO Standard Test must be selected and run before KOEO Injector Test.

Purpose

Inspect for fuel injector malfunctions by energizing injectors sequentially.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)

Possible Causes

- OPEN or short in injector circuits
- Poor ECM power or ground connection
- Failed injector coil
- Failed ECM

Procedure

1. Turn ignition switch Key ON Engine OFF (KOEO).
2. Open COM device.
3. Select KOEO Tests and Injector Test from the drop down menu.
4. Listen for injectors to pre-cycle (clicking), then cycle in order of cylinder position.
5. Listen again for injectors to pre-cycle, then cycle in reverse order of cylinder position.
6. Record DTCs on Diagnostic Form.
7. If DTCs are detected, correct problems causing DTCs. See “Appendix B: Diagnostic Trouble Code (DTC) Index” (page 435).
8. Clear DTCs.
9. Run KOEO Injector Test again.

Special Test Procedures

GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a hazard to human health and the environment. Handle all fluids and other contaminated materials (e.g. filters, rags) in accordance with applicable regulations. Recycle or dispose of engine fluids, filters, and other contaminated materials according to applicable regulations.

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

WARNING: To prevent personal injury or death, do not mix gasoline, gasohol, or alcohol with diesel fuel. A heat source, spark, or electronic device can ignite fuel mixtures.

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

WARNING: To prevent personal injury or death, do not smoke or park vehicle near flames or sparks when draining fuel. Store diesel fuel properly in an approved container designed for and clearly marked DIESEL FUEL.

WARNING: To prevent personal injury or death, be careful of edge of driver's door, when the cab is tilted and the door is open.

Fuel System

Purpose

- Check to ensure fuel supply is sufficient to sustain engine operation.
- Check for fuel aeration.
- Check for fuel system contamination.

Tools

- 0-160 psi gauge (on Gauge Bar Tool)
- Fuel Pressure Gauge (page 393)
- ICP System Test Adapter (page 395)
- In-line shut off valve
- 3/8 inch clear sample line
- Clear container with a wide opening (approximately 1 liter or 1 quart US)

NOTE: Breaking any fuel system joint will induce air in the fuel system. Cycle ignition switch to ON for 60 seconds, two times, to prime fuel system.

Pressure, Quality, and Aerated Fuel

Possible Causes

Contaminated fuel

- Water, ice, contaminants, or debris in fuel
- Fuel cloudy, or colored
- Fuel waxy or gelled
- Off road fuel red or blue colored

Aeration

- Low fuel level or no fuel in tank(s).
- Failed seals for fuel lines between fuel tank(s) and the Horizontal Fuel Conditioning Module (HFCM), fuel supply line broken or crimped.
- Loose fuel line or fuel line connector on the suction side of the fuel pump
- Cracked or restricted pickup tube screen or pickup tube.
- HFCM fuel filter cap seal damaged, drain plug loose, or drain plug O-ring broken or missing

No fuel

- Low or no fuel in fuel tank(s).
- Failed fuel pump or fuel pump circuit
- Restricted or clogged fuel filter(s)
- Restricted, kinked, bent, loose, cracked, or broken fuel pickup tube or screen.
- Restricted fuel line, failed fuel line seals, ice in fuel lines, fuel line broken or crimped.

Low fuel pressure

- Failed or weak fuel pump
- Dirty restricted fuel filter(s)
- Kinked or bent fuel supply line or a blocked pickup tube screen
- Loose fuel line or fuel line connector on the suction side of the fuel system
- Failed or stuck fuel pressure regulator valve.

High fuel pressure

- Debris in the fuel regulator valve
- Failed fuel pressure regulator valve.
- Restriction in the fuel return to the HFCM
- Combustion gases leaking into fuel system

Fuel restriction

- Debris or ice in fuel
- Kinked or bent fuel supply line or blocked pickup tube strainer
- Dirty or plugged filter element
- Waxed or gelled fuel in fuel filter

Procedure

1. Verify there is fuel in the fuel tank(s). Check fuel in fuel tank(s) for odors other than diesel fuel, for example: kerosene, alcohol, or gasoline.

   NOTE: Low biodiesel blends (up to 5% B5) that meet all ASTM D975-08a standard requirements should not cause engine or fuel system problems. Biodiesel blends higher than 5% and lower than or equal to 20% (B6 to B20) can be used if bought from a BQ9000 certified fuel supplier and meet ASTM D7467-08 standard specifications. If biodiesel blends are used, the odor in the fuel tank(s) or exhaust may not match typical diesel fuel.

2. Turn ignition switch to ON, listen for a hum coming from the fuel pump. The ECM turns the fuel pump on, it should run for 60 seconds. After 60 seconds the ECM turns the fuel pump off unless the engine is running.

   NOTE: Engine may run without the fuel pump, but damage to the injectors could occur.

   If the fuel pump can be heard running, continue with step 3.

   a. If the fuel pump cannot be heard running, turn ignition switch OFF.

   b. Disconnect the fuel pump harness connector and measure voltage between the power and ground circuits.

   c. Turn ignition switch to ON, battery voltage should be present for 60 seconds.

   d. If battery voltage is not present, see FPC (Fuel Pump Control) (page 306), and see the applicable truck *Electrical Circuit Diagrams* for relay and fuse locations.

3. Turn ignition switch OFF.

CAUTION: To prevent engine damage, do not allow foreign material to enter air intake system when removing the air inlet duct.

4. Remove the air inlet duct assembly.

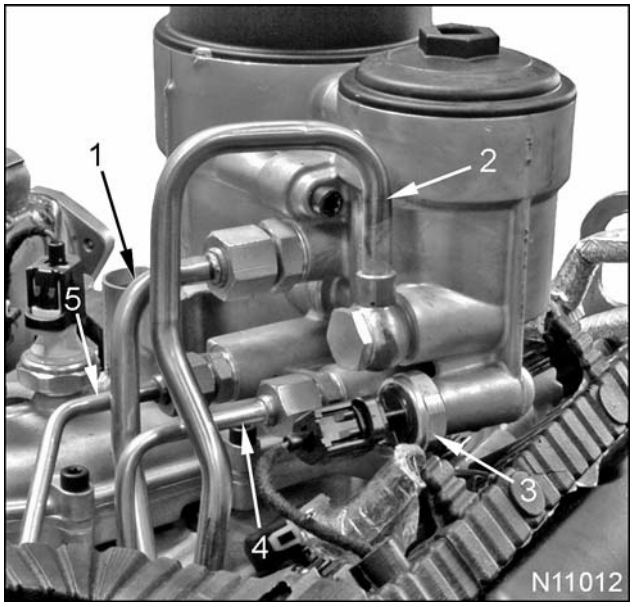


Figure 113 Secondary fuel filter tubes and housing

1. Fuel return to HFCM tube
2. Fuel supply to filter tube
3. Engine Fuel Pressure (EFP) switch
4. Fuel filter to left cylinder head tube
5. Fuel filter to right cylinder head tube

WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

5. Place a suitable container under the secondary fuel filter housing to catch draining fuel.

6. Remove the EFP switch, installed in the bottom of secondary fuel filter housing.

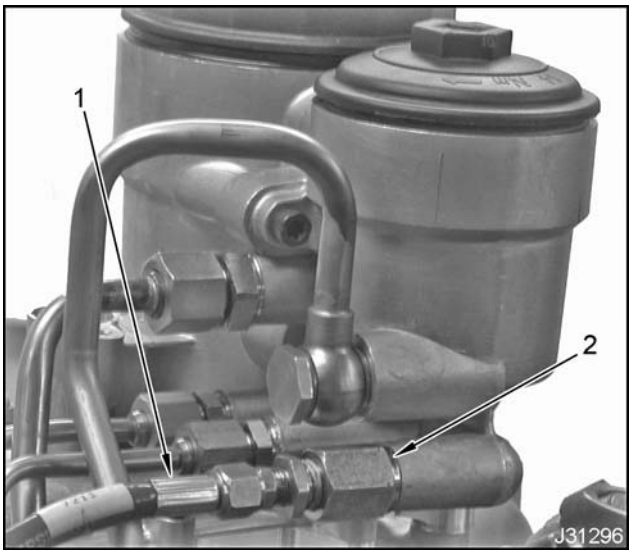


Figure 114 ICP System Test Adapter installed with Fuel Pressure Gauge

1. Test line
2. ICP System Test Adapter

7. Install the ICP System Test Adapter and assemble and attach Fuel Pressure Gauge.
8. Run the clear test line to a clear container.
9. Turn ignition switch to ON (do not crank the engine).
10. Open the in-line shut off valve, drain sample into a clear container, observe the clear test line for air bubbles.
11. Close in-line shut off valve.

12. Check fuel sample for contamination. Sample should be clear, free of debris, water and other contaminates, and should not be cloudy or dyed (blue or red).
    - If air bubbles stop with sample flowing, the fuel is not aerated. If there is no contamination, continue with step 14.
    - If the air bubbles do not clear before the sample container is almost full, take a second sample to determine if air bubbles have cleared. Continue with step 13.
    - If fuel is contaminated with water, debris or other contaminates, take a second sample. Some sediment and water may be present in the fuel sample if the fuel filter has not been replaced for a long time or if the sediment and water have not been drained recently. Continue with step 13.
    - If the fuel sample is cloudy in cold temperatures, this indicates fuel waxing or gelling. Summer fuels are not suitable in cold temperatures. Change to the recommended fuel grade. See *Engine Operation and Maintenance Manual*.
    - If the fuel sample is dyed, either blue or red, this indicates off-road use fuel and could cause a performance problem. Change to a recommended fuel grade. See *Engine Operation and Maintenance Manual*.
13. If a second fuel sample is needed, cycle the ignition switch to restart the fuel pump, drain sample, and check for air bubbles and contamination.
    - If air bubbles did not clear, check the fuel supply system from the fuel tank(s) to the Horizontal Fuel Conditioning Module (HFCM) inlet for leaks. Fix leaks and retest. Checks should include wiggling all fuel line connections, checking the primary fuel filter cover, and HFCM drain plug for leaks with the fuel pump turned off.
    - Excessive water or contaminants may indicate the fuel tank and fuel system needs to be flushed and cleaned. Take a sample from the HFCM drain plug for verification. See Drain Water from HFCM (page 109).
    - If fuel doesn't clear up, the system may need to be flushed. Replace the primary and secondary fuel filters, verify fuel is the recommended grade, and clean.

NOTE: Breaking any fuel system joint will induce air in the fuel system. Cycle ignition switch to ON for 60 seconds, two times, to prime fuel system.

14. Cycle ignition switch OFF and back to ON, check Fuel Pressure Gauge when the pump starts. Pressure should increase to specification quickly. Turn ignition switch OFF. See "Appendix A: Performance Specifications" (page 427).
    - If fuel pressure is within specification, do Low ICP System Pressure test.
    - If fuel pressure is below specification, replace both the primary and secondary fuel filters and retest.
    - If fuel pressure is still below specification, after replacing both primary and secondary fuel filters, measure fuel pump discharge pressure. Do Fuel Pump Discharge Pressure test in this subsection.

Fuel Pump Discharge Pressure

NOTE: This test should only be done when directed by the Pressure, Quality, and Aerated Fuel (page 126) test when fuel pressure is still below specification or slow to build, after replacing both the primary and secondary fuel filters.

NOTE: Breaking any fuel system joint will induce air in the fuel system. Cycle ignition switch to ON for 60 seconds, two times, to prime fuel system.

Purpose

Measure fuel pump discharge pressure.

Tools

- 0-160 psi gauge (on Gauge Bar Tool)
- Fuel Pressure Test Adapter (page 397)
- Fuel Pressure Gauge (page 393)

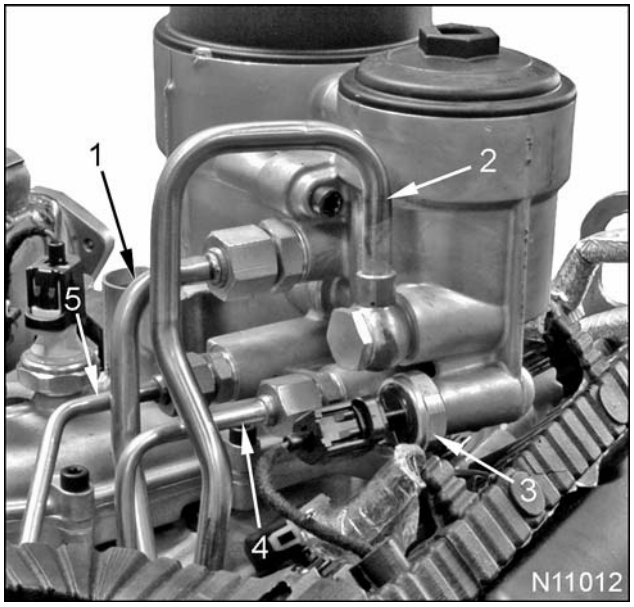


Figure 115 Secondary fuel filter tubes and housing

1. Fuel return to HFCM tube
2. Fuel supply to filter tube
3. Engine Fuel Pressure (EFP) switch
4. Fuel filter to left cylinder head tube
5. Fuel filter to right cylinder head tube

Procedure

1. Place a suitable container under the secondary fuel filter housing to catch draining fuel.

WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

2. Remove the banjo bolt from the fuel supply tube at the bottom of the secondary fuel filter housing. Recycle or dispose of fuel according to applicable regulations.

NOTE: Use existing copper gaskets for testing. Replace copper gaskets when reattaching the fuel supply tube to the filter housing.

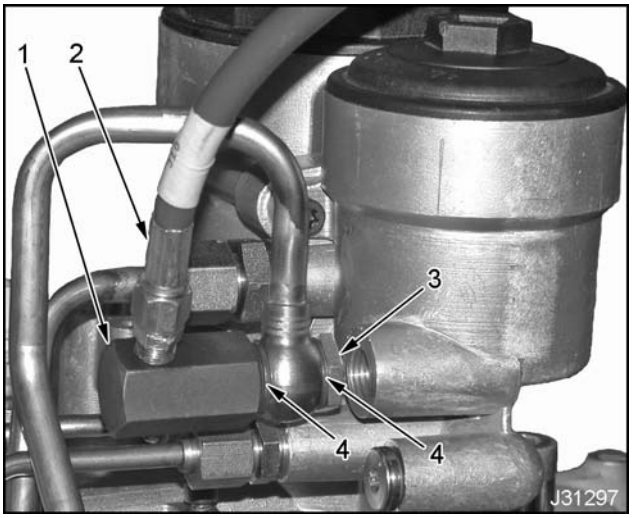


Figure 116 Fuel Pressure Test Adapter installed on fuel supply tube

1. Fuel Pressure Test Adapter
2. Test line
3. Banjo bolt
4. Copper gasket (2)

3. Connect the Fuel Pressure Test Adapter to the fuel supply tube, using the banjo bolt and used copper gaskets.
4. Connect the Fuel Pressure Gauge to the Fuel Pressure Test Adapter.
5. Turn ignition switch to ON, do not crank engine. Check fuel pressure on the test gauge immediately when the pump starts. Fuel pressure should increase to specification quickly. See “Appendix A: Performance Specifications” (page 427).
   - If discharge pressure is within specification, turn ignition switch OFF, continue with step 6.
   - If discharge pressure is not within specifications, turn ignition switch OFF. Reconnect the fuel line and banjo bolt to the secondary fuel filter housing, do Fuel Inlet Restriction test in this subsection.
6. Remove the Fuel Pressure Test Adapter.
7. Remove fuel system tubing, three M6 x 25 screws, and remove the secondary fuel filter housing from the oil filter assembly.

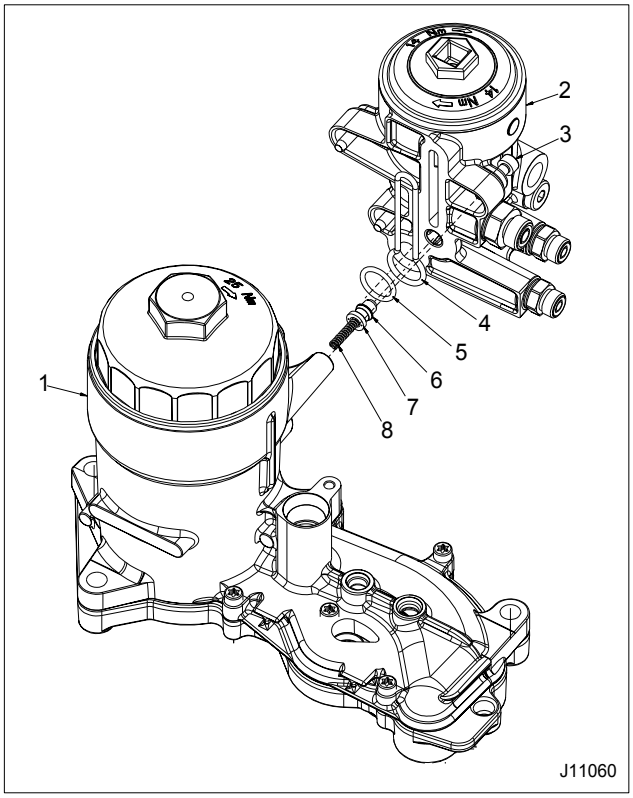


Figure 117 Fuel pressure regulator poppet assembly

1. Oil filter assembly
2. Secondary fuel filter housing
3. M6 x 25 screw (3)
4. Pressure regulator cover gasket
5. Viton O-ring, size #115
6. Poppet gasket seal
7. Brass poppet
8. Pressure regulator valve spring

8. Remove, clean, and inspect the fuel pressure regulator. Replace fuel pressure regulator if required. Reinstall secondary fuel filter housing. See the *Engine Service Manual*.

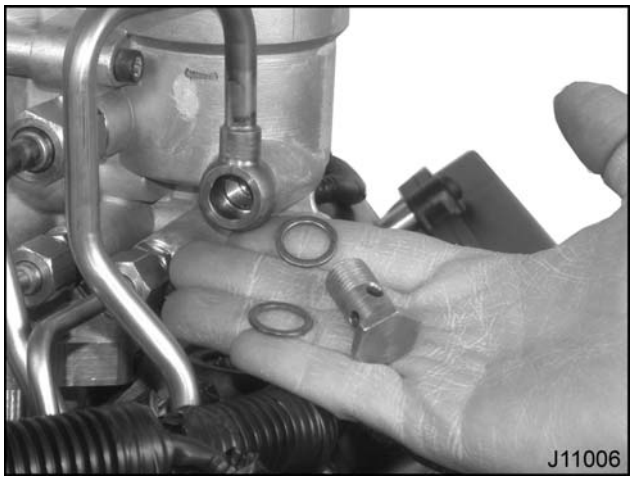


Figure 118 Banjo bolt and two copper gaskets

CAUTION: To prevent engine damage, install two new copper gaskets when reattaching the fuel supply tube.

9. Install the secondary fuel filter housing and fuel system tubing according to the *Engine Service Manual*.
10. Attach the filter pressure gauge to the secondary fuel filter test port, and retest fuel pressure.

Fuel Inlet Restriction

NOTE: This procedure should only be done when directed by Fuel Pump Discharge Pressure test when discharge pressure is within specification or slow to build.

Purpose

Measure fuel pump inlet restriction.

Tools

- 0-30 in Hg gauge (on Gauge Bar Tool)
- Fuel Inlet Restriction Adapter (page 397)
- In-line shut off valve

NOTE: Breaking any fuel system joint will induce air in the fuel system. Cycle ignition switch to ON for 60 seconds, two times, to prime fuel system.

WARNING: To prevent personal injury or death, do not smoke or park vehicle near flames or sparks when draining fuel.

Procedure

1. Put a clean drain pan under the Horizontal Fuel Conditioning Module (HFCM) drain plug.
2. Wipe down the frame and area under the drain plug.
3. Open the HFCM drain plug and drain into drain pan.

NOTE: Collect and dispose of fuel according to applicable regulations.

Figure 119 Fuel Inlet Restriction Adapter

4. Remove the HFCM drain plug, install the Fuel Inlet Restriction Adapter, hand tighten only.

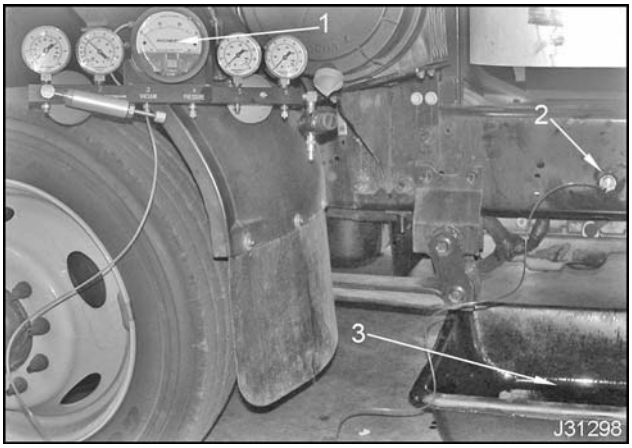


Figure 120 Fuel inlet restriction test setup (typical)

1. Gauge Bar Tool
2. Fuel Inlet Restriction Adapter
3. Catch pan

5. Connect to 0-30 in Hg gauge on the Gauge Bar Tool through an in-line shut off valve. Make sure the shut off valve is in the closed position.

NOTE: The fuel pump runs for 60 seconds when the ignition switch is turned on. The in-line shut off valve must be closed before the fuel pump shuts off.

6. Turn ignition switch to ON, open the in-line shut off valve, and check for restriction indication on the test gauge. Close the in-line shut off valve. Turn ignition switch OFF.
   - If vacuum indication is above the specification, check for restrictions in the fuel supply lines from the fuel pickup tube in the fuel tank to the HFCM. Visually inspect for bent, crimped, or damaged fuel supply lines and connections from the fuel tank(s) to the HFCM. Repair any restrictions and retest fuel pressure at the secondary fuel filter housing test port.
   - If vacuum indication is below the specification and fuel pump discharge pressure is low, replace the fuel pump and retest fuel pressure at the secondary fuel filter housing test port.
7. Remove Fuel Inlet Restriction Adaptor.
8. Inspect HFCM drain plug O-ring for damage and replace if necessary. Reinstall drain plug.

Low ICP System Pressure

Purpose

Determine cause of low Injection Control Pressure (ICP) that prevents engine starting.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)
- Digital Multimeter (DMM) (page 388)
- Actuator Breakout Harness (page 387)
- Pressure Sensor Breakout Harness (page 391)
- ICP System Test Adapter (page 395)
- ICP Adapter/Plug Kit (page 396)
  - ICP Sensor Adapter
  - ICP Leak Test Plug
- Case-to-head Tube Removal Tool (page 396)

NOTE: Do the following procedures in sequence or test results will be incorrect.

ICP System Function

Before doing this procedure make sure the engine lubrication system builds oil pressure while cranking the engine.

Figure 121 IPR valve and connector

1. Disconnect engine wiring harness from IPR valve and inspect connector and IPR valve terminal for corrosion, bent and pushed back pins.

   If corrosion is on either the IPR valve or the wiring harness connector, clean or replace both the IPR valve and wiring harness connector for the IPR valve. Retest ICP pressure.

CAUTION: To prevent engine damage, do not connect engine wiring harness to the Actuator Breakout Harness. If the engine harness is connected to the breakout harness, the ignition switch fuse will blow or cause damage to the wiring harness.

2. Connect Actuator Breakout Harness to the IPR valve.

CAUTION: To prevent engine damage, do not leave IPR valve energized longer than 120 seconds. This can damage the IPR valve.

3. Apply B+ volts and ground to the IPR valve.

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

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

4. Crank the engine and monitor ICP pressure using the EST or DMM and Pressure Sensor Breakout Harness.
5. Evaluate ICP pressures, DTCs, and electrical circuit problems.
   - If ICP increases above 3.45 MPa (500 psi) (0.82 volts), the mechanical system is operating correctly for the engine to start. Do not continue with ICP system diagnostics.
   - For problems in the electrical circuit, see IPR (Injection Pressure Regulator) (page 350).
   - If ICP is below 3.45 MPa (500 psi) (0.82 volts) continue to IPR Function (page 134) test.

IPR Function

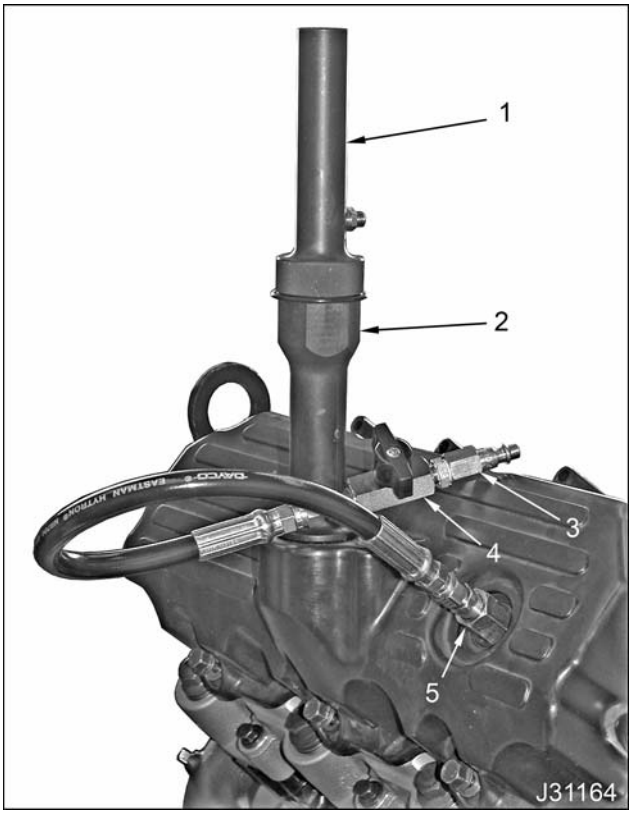


Figure 122 Shop air test hose and Oil Fill Extension

1. Crankcase Pressure Test Adapter
2. Oil Fill Extension (Part No. 1830971C91)
3. Air chuck
4. In-line shutoff valve
5. ICP System Test Adapter

NOTE: Before doing this test, inspect O-ring on the ICP System Test Adapter. Replace O-ring, if worn, cracked or cut.

1. Remove the oil fill cap from valve cover.
2. Insert Oil Fill Extension into valve cover.

NOTE: The Crankcase Pressure Test Adapter will magnify the sound of an air leak.

3. Insert Crankcase Pressure Test Adapter into the Oil Fill Extension.
4. Disconnect engine harness from ICP sensor.
5. Remove ICP sensor from the right oil rail.

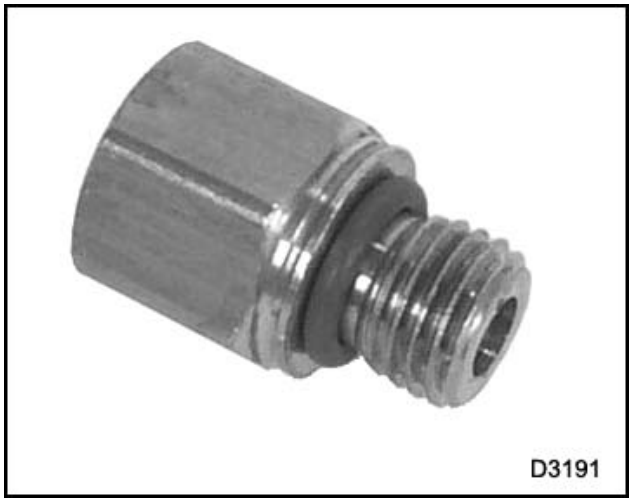


Figure 123 ICP System Test Adapter

6. Install ICP System Test Adapter into the right high-pressure oil rail.

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

7. Assemble a test hose, shutoff valve, and air chuck; connect air chuck to the ICP System Test Adapter.
8. Close in-line shutoff valve and connect shop air line to the test hose.
9. Apply 690 kPa (100 psi) of pressure, open shutoff valve, and use Crankcase Pressure Test Adapter to listen for an air leak.

NOTE: When air pressure is applied for the first time, it may take up to 5 minutes before an air leak can be heard. This allows air to displace engine oil in the ICP system.

A faint air leak should be heard. Air should pass through the IPR valve and return to the crankcase when the IPR valve is not energized.

CAUTION: To prevent engine damage, do not leave IPR valve energized longer than 120 seconds. This can damage the IPR valve.

10. Connect Actuator Breakout Harness to the IPR valve and apply B+ and ground. (Shop air should still be applied to the ICP system.) Use the Crankcase Pressure Test Adapter to listen for an air leak.

11. Evaluate test results:
    - When the IPR valve is energized, the air leak should stop.
    - If a faint air leak is still heard, replace the IPR valve, following procedures in the *Engine Service Manual*. Repeat step 10 to verify the IPR valve is functioning correctly.
    - If a leak is still heard after replacing the IPR valve, continue with Under Valve Cover ICP Leaks (page 135).
    - If an air leak is not heard when the IPR valve is energized, continue with High-pressure Pump (page 139). This test result indicates no leaks in the high-pressure oil system.

Under Valve Cover ICP Leaks

NOTE: Before doing this test, inspect ICP Sensor Adapter and ICP Leak Test Plug D-rings. Replace D-rings if worn, cracked or cut.

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

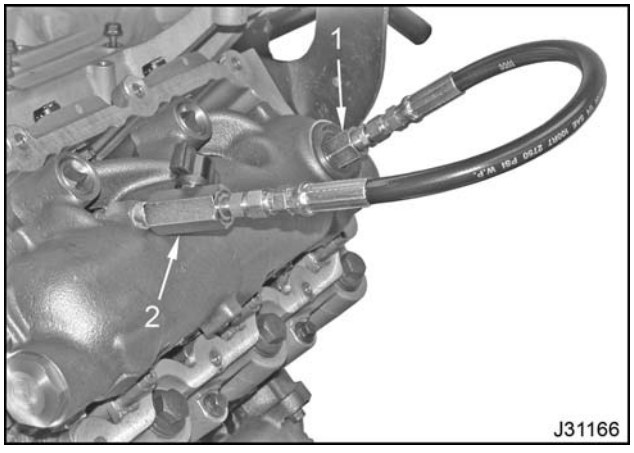


Figure 124 ICP System Test Adapter with test hose (right cylinder head)

1. ICP System Test Adapter
2. In-line shutoff valve

1. Close test hose In-line shutoff valve before disconnecting shop air. Slowly open shutoff valve to release pressure.
2. Remove test hose.
3. Remove the left and right valve covers following procedures in the *Engine Service Manual*. This will help you hear where the leak is coming from / isolate the leak.
4. Reconnect test hose and ICP System Test Adapter.
5. Close in-line shutoff valve and connect shop air line to the test hose.
6. Apply 690 kPa (100 psi) of pressure, open shutoff valve, and listen for air leaks.

   A faint air leak should be heard. Air should be passing through the IPR valve and returning to the crankcase when the IPR valve is not energized.

CAUTION: To prevent engine damage, do not leave IPR valve energized longer than 120 seconds. This can damage the IPR valve.

7. Use the Actuator Breakout Harness to apply B+ and ground to the IPR valve.
8. Evaluate test results:
    - Repair leaks found under the valve covers. For more detailed instructions to isolate leaks in the oil rail area, see Cylinder Head Isolation (page 138). Retest after repairs.
    - If leaks are not found under the valve covers, but air leaks are coming from the crankcase, continue to step 9.
9. Remove test hose and ICP System Test Adapter from right oil rail.
10. Install ICP sensor into right high-pressure oil rail.
11. Remove case-to-head tube plug from the rear of the right side oil rail; install the ICP Sensor Adapter in this port. This will block air flow to the right oil rail and injectors.

    NOTE: Understand and comply with the following:
    - When case-to-head tube plug is removed, the case-to-head tube may be still attached. Remove tube from plug. Install ICP Leak Test Plug on tube.
    - If the wrong diagnostic tool is used, a misdiagnosis will result. Use ICP Adapter/Plug Kit (ZTSE4690).

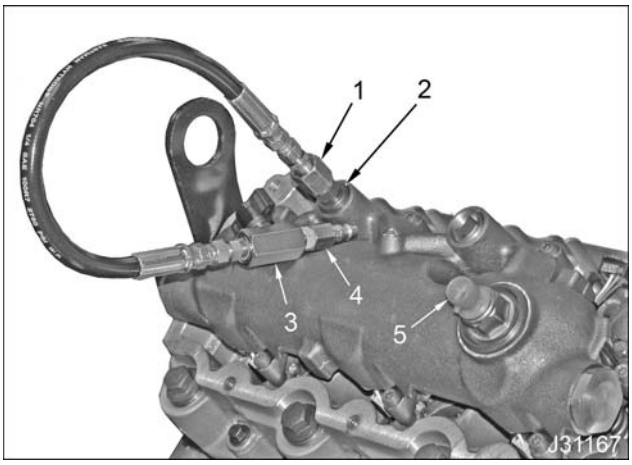


Figure 125 ICP Sensor Adapter with test hose

1. ICP System Test Adapter
2. ICP Sensor Adapter
3. In-line shutoff valve
4. Air chuck
5. ICP sensor

12. Connect test hose and ICP System Test Adapter to ICP Sensor Adapter. Close the in-line shutoff valve.
13. Remove the case-to-head tube plug from the rear of the left side oil rail; install the ICP leak test plug in this port. This will block air flow to the left oil rail and injectors.

NOTE: Understand and comply with the following:

- When case-to-head tube plug is removed, the case-to-head tube may be still attached. Remove tube from plug. Install ICP Leak Test Plug on tube.
- If the wrong diagnostic tool is used, a misdiagnosis will result. Use ICP Adapter/Plug Kit (ZTSE4690).

14. Connect shop air to test hose in right side.
15. Apply 690 kPa (100 psi) of pressure, open shutoff valve, and listen for air leaks.

    A faint air leak should be heard. Air should be passing through the IPR valve and returning to the crankcase when the IPR valve is not energized.
16. Use Actuator Breakout Harness to apply B+ and ground to the IPR valve.
17. Listen for air leaks:
    - If an air leak is heard coming from the crankcase, continue with step 18.
    - If an air leak is not heard, one or more injector O-rings or oil rail O-rings are leaking. If unable to tell which side is leaking, do Cylinder Head Isolation test (page 138).
18. Disconnect shop air from test hose.
19. Remove and replace questionable case-to-head tube or tubes, following procedures in the *Engine Service Manual*.

NOTE: If case-to-head tube is not attached to the ICP Leak Test Plug or ICP Sensor Adapter, use Case-to-head Tube Removal Tool to remove tube from crankcase.

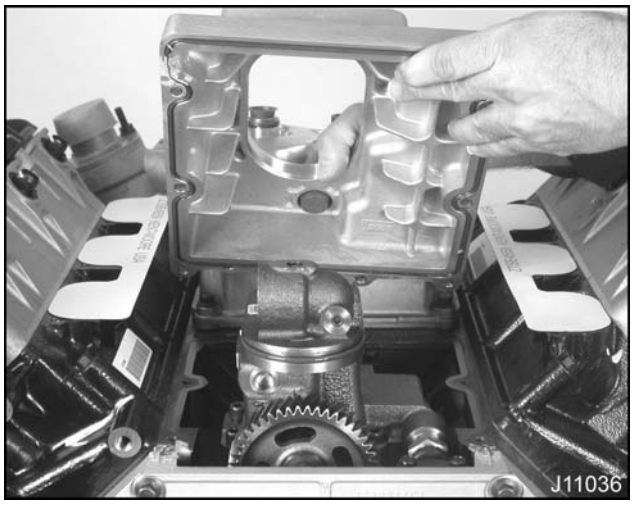


Figure 126 High-pressure pump cover

20. Remove the high-pressure pump cover. Reinstall IPR valve. Follow procedures in the *Engine Service Manual*.
21. Close in-line shutoff valve and connect shop air line to the ICP System Test Adapter.
    - Apply 690 kPa (100 psi) of pressure, open shutoff valve, and listen for an air leak.
    - A faint air leak should be heard. Air should be passing through the IPR valve and returning to the crankcase when the IPR valve is not energized.

CAUTION: To prevent engine damage, do not leave IPR valve energized longer than 120 seconds. This can damage the IPR valve.

22. Use the Actuator Breakout Harness to apply B+ and ground to the IPR valve.
23. Check for air leaks in the branch tube assembly connections, high-pressure oil pump and branch tube adapter.
24. Listen for air leaks in both O-ring areas under the high-pressure pump.

    If an air leak is not detected in the area under the high-pressure cover, but an air leak is heard, replace the branch tube assembly.

Cylinder Head Isolation

NOTE: Before doing this test, inspect ICP Sensor Adapter and ICP Leak Test Plug D-rings. Replace D-rings if worn, cracked or cut.

Depending on which rail is being tested, the complete test setup must be on the same side.

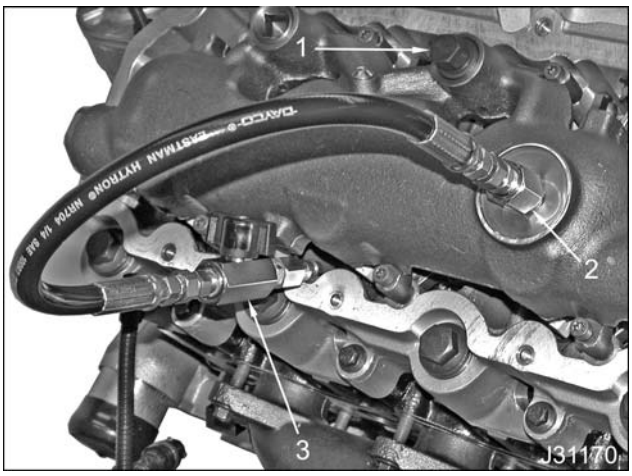


Figure 127 ICP Leak Test Plug and ICP System Test Adapter (left cylinder head)

1. ICP Leak Test Plug
2. ICP System Test Adapter
3. In-line shutoff valve

1. Remove the case-to-head tube plug from the rear of the oil rail being tested. Install the ICP Leak Test Plug in this port. This will isolate this high-pressure oil manifold and injectors.

   NOTE: Understand and comply with the following:

   - When case-to-head tube plug is removed, the case-to-head tube may still be attached. Remove tube from plug. Install ICP Leak Test Plug on tube.
   - If the wrong diagnostic tool is used, a misdiagnosis will result. Use ICP Adapter/Plug Kit (ZTSE4690).

2. Install ICP System Test Adapter into ICP sensor port on right high-pressure oil manifold.
3. Close in-line shutoff valve and connect shop air line to the ICP System Test Adapter.
4. Apply 690 kPa (100 psi) of pressure, open shutoff valve, and listen for air leaks.

   NOTE: When air pressure is applied for the first time, it may take up to 5 minutes before the leak can be heard. This allows air to displace engine oil in the ICP system.

5. If an air leak is not detected, the leak may be coming from the crankcase or opposite cylinder head. Verify previous test results and repeat procedure for opposite cylinder head.

High-pressure Pump

NOTE: Do this test only if the IPR Function test (page 134) did not have leaks and EST Data List test had low Injection Control Pressure (ICP).

NOTE: Before doing this test, inspect ICP Sensor Adapter and ICP Leak Test Plug D-rings. Replace D-rings if worn, cracked or cut.

1. Close test hose In-line shutoff valve before disconnecting shop air.
2. Remove test hose.
3. Remove the left and right valve covers, following procedures in the *Engine Service Manual*.

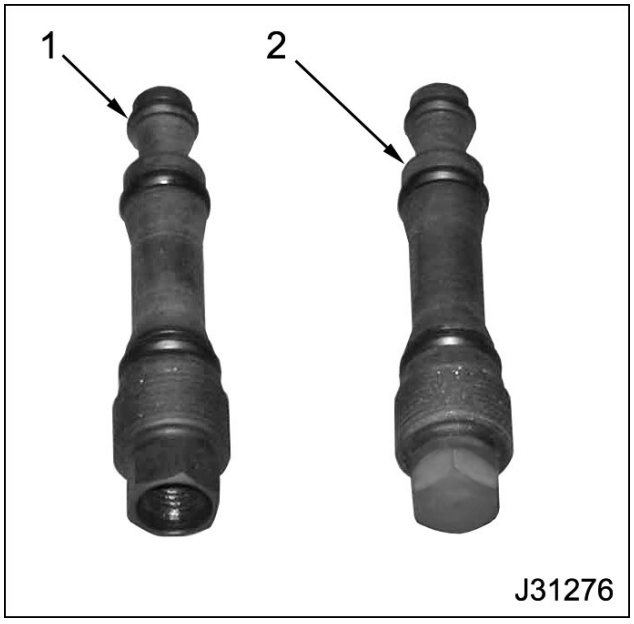


Figure 128 ICP Adapter/Plug Kit

1. ICP Sensor Adapter (Threaded hex head)
2. ICP Leak Test Plug (Solid hex head)

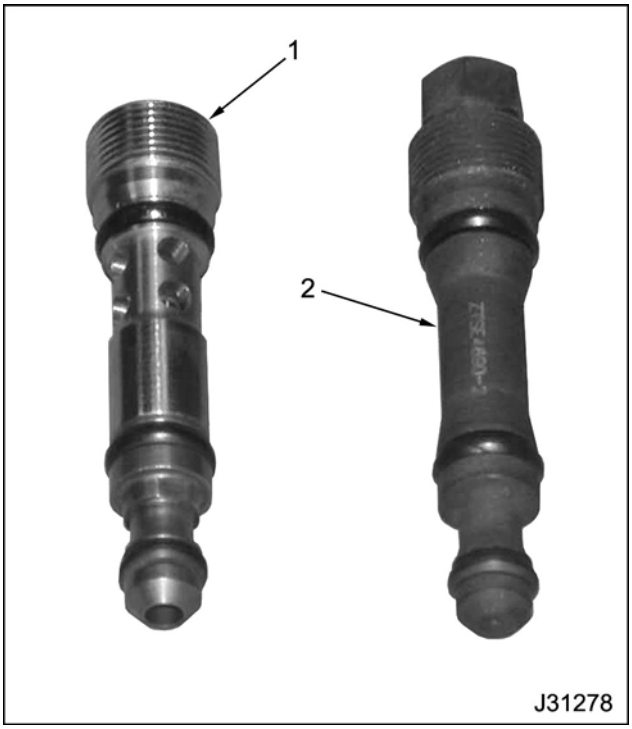


Figure 129 Case-to-head tube plug and ICP Leak Test Plug

1. Case-to-head tube plug
2. ICP Leak Test Plug

4. Remove the case-to-head tube plug from the rear of the right side oil rail; install the ICP Sensor Adapter in this port. This will block oil flow to the right oil rail and injectors.

   NOTE: Understand and comply with the following:

   - When case-to-head tube plug is removed, the case-to-head tube may be still attached. Remove tube from plug. Install ICP Leak Test Plug on tube.
   - If the wrong diagnostic tool is used, a misdiagnosis will result. Use ICP Adapter/Plug Kit (ZTSE4690).

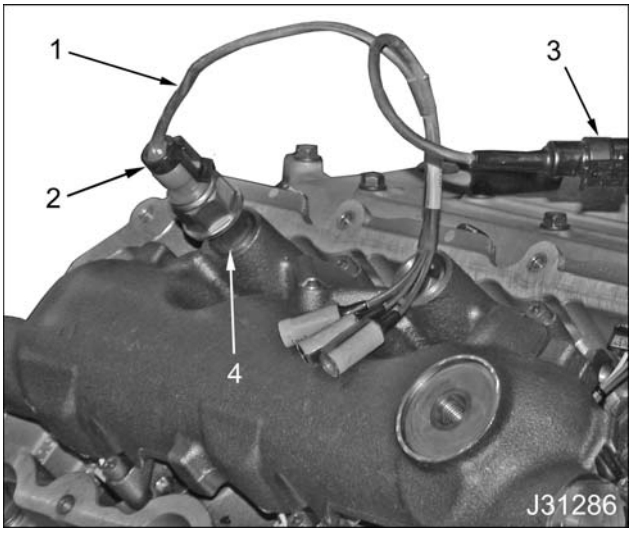


Figure 130 ICP sensor with ICP Sensor Adapter (right cylinder head)

1. Pressure Sensor Breakout Harness
2. ICP sensor
3. Engine harness
4. ICP Sensor Adapter

5. Install ICP sensor into ICP Sensor Adapter.
6. Connect the engine wiring harness to the ICP sensor. Use the Pressure Sensor Breakout Harness as an extension, if needed.
7. Remove the case-to-head tube plug from the rear of the left side oil rail. Install the ICP Leak Test Plug in this port. This will block oil flow to the left oil rail and injectors.

   NOTE: Understand and comply with the following:

   - When case-to-head tube plug is removed, the case-to-head tube may be still attached. Remove tube from plug. Install ICP Leak Test Plug on tube.
   - If the wrong diagnostic tool is used, a misdiagnosis will result. Use ICP Adapter/Plug Kit (ZTSE4690).

NOTE: This blocks oil flow to both rails and all injectors; only the branch tube assembly, case-to-head tube, and the high-pressure pump will be tested.

CAUTION: To prevent engine damage, do not leave IPR valve energized longer than 120 seconds. This can damage the IPR valve.

8. Use the Actuator Breakout Harness to apply B+ and ground to the IPR valve.
9. Crank the engine and monitor ICP pressure.
10. Evaluate test results:

    - If unable to build the ICP pressure above 3.45 MPa (500 psi) (0.71 volts) check branch tube, case-to-head tubes, use of proper diagnostic tools or faulty high-pressure oil pump.
    - If able to build ICP pressure above 3.45 MPa (500 psi) (0.71 volts) check previous test results. Remove the ICP Leak Test Plug from the left side oil rail and reinstall case-to-head tube plug. Continue to step 11.

CAUTION: To prevent engine damage, we recommend replacing case-to-head tubes each time they are removed. D-rings are not replaceable. Inspect each D-ring carefully for cuts, abrasion, and twisting; do not reuse a case-to-head tube having any of these conditions

11. Crank the engine and monitor ICP pressure (right side isolation):

    If unable to build ICP pressure above 3.45 MPa (500 psi) (0.71 volts) the problem is on the left side. Do Cylinder Head Isolation (page 138) and check for leaks.

    Remove ICP test adapter from the right side oil rail and reinstall case-to-head tube plug. Reinstall ICP sensor. Reconnect ICP sensor to engine wiring harness. Continue to step 12.

12. Crank the engine and monitor ICP pressure.

    - If unable to build the ICP pressure above 3.45 MPa (500 psi) (0.82 volts), the problem is on the right side. Do Cylinder Head Isolation and check for leaks.
    - If able to build pressure the engine should start and run.

EGR Valve Operation

NOTE: See “Diagnostic Software Operation” section in this manual for specific Electronic Service Tool (EST) software procedures to do this test.

Purpose

Inspect for Exhaust Gas Recirculation (EGR) valve malfunctions.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)

Possible Causes

- Valve motion interference
- Failed electrical circuits or components

Procedure

1. Turn ignition switch to ON.
2. Open COM device.
3. Select Key On Engine Off Tests. From the drop down menu, select Output State Tests, then select Output State Low Test.
4. Record EGR valve positions on Diagnostic Form.
5. Select Key On Engine Off Tests. From the drop down menu, select Output State Tests, then select Output State High Test.
6. Record EGR valve positions on Diagnostic Form. See “Appendix A: Performance Specifications” (page 427).

   If readings are not in specification, repair problem. Test again to verify repair.

Main Power Relay Voltage to ECM

Purpose

Determine if correct power is supplied to operate the Electronic Control Module (ECM). ECM requires 7 volts minimum for correct operation.

Tools

- Main Power Relay Breakout Harness (page 391)
- Digital Multimeter (DMM) (page 388)

Voltage at ECM Main Power Relay with Main Power Relay Breakout Harness

Possible Causes

Low battery voltage

- Failed batteries
- High resistance at battery cable connections
- Wiring problem to the ECM

Low or no battery voltage to the ECM

- High resistance or OPEN power feed circuit to the ECM or ECM relay.
- ECM power circuit fuse in battery box OPEN.
- ECM relay failed.
- VIGN circuit problem
- Failed ECM

NOTE: Batteries must be fully charged before doing the following procedure.

Procedure

1. Turn ignition switch OFF and ensure all accessories are turned off.
2. Connect Main Power Relay Breakout Harness between the ECM main power relay and power distribution center or chassis harness. Depending on application, the relay could be one of two kinds. Check power distribution center or cab cowl.
3. Connect DMM POS lead to pin 87 and NEG to ground terminal on cowl.
4. Crank engine for 20 seconds and measure voltage.
   - If the voltage is below 7 volts, the ECM relay may be resetting, due to low voltage and current from the batteries, or problems in the ignition circuit and power feed circuits. See ECM PWR (Electronic Control Module Power) (page 252).
   - If the voltage is above 7 volts, continue with “Hard Start and No Start Diagnostic” tests.

   NOTE: Results can be above 7 volts, but there may be a problem between the ECM relay and the ECM. If a Hard Start and No Start problem remains after Main Power Relay check, do Voltage Measurement at ECM with Breakout Box procedure (page 143).

Voltage Measurement at ECM with Breakout Box

NOTE: Use the following procedure when any of the following situations exist:

- A Main Power Relay Breakout Harness is not available.
- Expected voltages were not in specification when using the Main Power Relay Breakout Harness.
- Voltages were in specification using the Main Power Relay Breakout Harness and “Hard Start and No Start Diagnostics” sequence is complete, but a concern remains.

Tools

- 180 Pin Breakout Box (page 385)
- Digital Multimeter (DMM) (page 388)

Possible Causes

Low battery voltage

- Failed batteries
- High resistance at battery cable connections

Low or no battery voltage to the ECM

- High resistance or an OPEN power feed circuit to the ECM or ECM relay.
- The ECM power circuit fuse in battery box OPEN.
- ECM relay failed.
- VIGN circuit problem
- Failed ECM

NOTE: Batteries must be fully charged before doing the following steps.

Procedure

1. Turn ignition switch OFF and ensure all accessories are turned off.
2. Remove 76-pin chassis connector from the ECM.
3. Connect 76-pin chassis breakout box connector to the chassis connection on the ECM.
4. Connect chassis harness connectors to breakout box chassis header.
5. Connect leads of the DMM to the following test points on the breakout box:
   - POS C-31 to NEG C-2, 4, or 6 (VIGN)
   - POS C-1, 3, or 5 to NEG C-2, 4, or 6 (ECM PWR)
6. Crank engine for 20 seconds and measure voltage.
   - If voltage is below 7 volts, the ECM relay may be resetting, resulting from low voltage and current from the batteries, or problems in the ignition circuit and power feed circuits. See ECM PWR (Electronic Control Module Power) (page 252).
   - If voltage is above 7 volts, continue with “Hard Start and No Start diagnostics” tests.

Glow Plug System

Purpose

Determine if the glow plug system is operating correctly to start the engine.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)
- Digital Multimeter (DMM) (page 388)
- Amp Clamp (page 387)
- Glow Plug Sensor Harness (page 390)

Possible Causes

- Poor wiring harness connection
- Poor ground connection
- Failed glow plug relay
- Failed glow plugs
- Failed ECM

Glow Plug System Amperage

1. Install Amp Clamp around the feed wire loom for glow plugs in the left side.
2. Turn ignition switch to ON. (Do not start engine).
3. Select D_OutputStateTest.ssn in the Open Session File window, select Open to detect possible DTCs.
4. Select Diagnostics from the menu bar.
5. Select Key On Engine Off Tests from the drop down menu.

NOTE: When using the EST for KOEO or KOER diagnostic tests, Standard Test is always selected and run first. If the ignition switch is not cycled, the Standard Test does not have to be run again.

6. From Key On Engine Off Diagnostics menu, select Glow Plug/Inlet Air Heater Output State Test and click run to start the test.

   NOTE: The Glow Plug/Inlet Air Heater Output State Test will command the glow plugs on for 120 seconds. Both sides can be tested during this time. The Glow Plug/Inlet Air Heater Output State Test is limited to two requests per key cycle.
7. After 9 seconds, measure amperage.
8. Install Amp Clamp around the feed wire loom for glow plugs in the right side and test amperage.
9. Evaluate test results:
   - If right and left amperage is in specification and DTC 1375 is set, the glow plug system is working correctly, but the GPD circuit is open.
   - If right or left amperage is not in specification, do Glow Plug Harness to Ground test.
   - If right and left amperage is zero, do Relay Operation test (page 145).
10. When finished with this test, select Session from menu bar, then Close.

Glow Plug Harness to Ground

1. Select the feed wiring loom for the glow plug side that failed.
2. Disconnect glow plug 3-pin connector.
3. Use DMM to measure resistance between glow plug 3-pin harness and alternator ground.

   NOTE: This checks glow plug harness and glow plugs.
4. Evaluate test results:
   - If any reading is not within 0.1 to 6 ohms, do Glow Plug to Ground test (page 145).
   - If all readings are within 0.1 to 6 ohms, do Engine Harness 3-pin to Relay test (page 145).

Glow Plug to Ground

1. Disconnect glow plug harness from suspect glow plug.
2. Connect glow plug test lead.
3. Use DMM to measure glow plug resistance to ground.
4. Evaluate test results:
   - If resistance is greater than 5 ohms, replace glow plug.
   - If resistance is less than 5 ohms, replace glow plug harness.

Engine Harness 3-pin to Relay

1. Use DMM to measure resistance of wire between the glow plug relay and all three circuits in the 3-pin connector.

   NOTE: Engines could be wired differently, having wiring harness connectors secured to different relay terminals. Trace wiring harness from 3-pin connector to the glow plug relay to be sure the correct relay terminal is tested.
2. Use DMM to measure resistance. Evaluate resistance measurement:
   - If wiring resistance is greater than 5 ohms, check for loose connections and terminals. Repair or replace wire between element and relay.
   - If wiring resistance is less than 5 ohms, check for corroded wires and loose connections on relay terminals. If wires are not corroded and connections are tight do Relay Operation procedure.

Relay Operation

1. Connect DMM positive lead to battery supply terminal (battery to glow plug relay).

   NOTE: Engines could be wired differently, having wiring harness connectors secured to different relay terminals. Trace wiring harness from battery to the glow plug relay to be sure the correct relay terminal is tested.
2. Connect DMM negative lead to alternator ground.
3. Use DMM to measure voltage.
4. Evaluate voltage measurement results:
   - If voltage at relay supply terminal is B+, continue to step 5
   - If voltage at relay supply terminal is less than B+, repair or replace wire from battery to glow plug relay.
5. Connect DMM positive lead to glow plug relay output terminal.
6. Turn ignition switch to ON, do not start engine.
7. Select D_OutputStateTest.ssn in the Open Session File window, select Open to detect possible DTCs.
8. Select Diagnostics from the menu bar.
9. Select Key On Engine Off Tests from the drop down menu.

NOTE: When using the EST to do the KOEO or KOER diagnostic tests, Standard Test is always selected and run first. If the ignition switch is not cycled, the Standard Test does not have to be run again.

10. From the KOEO Diagnostics menu, select Glow Plug/Inlet Air Heater, then select Run to start the test.

    NOTE: KOEO Standard Test will enable the relay for 2 to 4 seconds every time the test is run. The GPC/IAH test only enables the relay twice for 30 seconds to prevent element overheating.
11. Use DMM to measure voltage.
12. If voltage was not detected, check for corroded wires and loose connections on relay terminals. If terminals are clean and connections were tight, replace the relay.
13. When finished with this test, select Session from menu bar, then Close.

Inlet Air Heater System

Purpose

Determine if the Inlet Air Heater (IAH) system is operating correctly.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)
- Digital Multimeter (DMM) (page 388)
- Amp Clamp (page 387)

Possible Causes

- Poor wiring harness connection
- Poor ground connection
- Failed relay
- Failed heater element
- Failed ECM

Amperage Draw

NOTE: Inspect for corroded, loose or damaged terminals. Repair if necessary.

1. Install Amp Clamp around feed wire next to heater element.
2. Turn ignition switch to ON, do not start engine.
3. Select D_OutputStateTest.ssn in the Open Session File window, select Open to detect possible DTCs.
4. Select Diagnostics from the menu bar.
5. Select Key On Engine Off Tests from the drop down menu.

NOTE: When using the EST for KOEO or KOER diagnostic tests, Standard Test is always selected and run first. If the ignition switch is not cycled, the Standard Test does not have to be run again.

6. From the KOEO Diagnostics menu, select Glow Plug/Inlet Air Heater, then select Run to start the test.

   NOTE: Voltage should be present for 30 seconds after a 3 second delay. The Glow Plug/Inlet Air Heater Output State Test is limited to two requests per key cycle.

7. After 4 seconds, measure amperage.
8. Evaluate amperage measurements:
   - If amperage is 45 to 70 Amps and DTCs were not set the IAH system is working correctly and is not the starting problem.
   - If amperage is in specification and DTC 1374 was set check for open IAHD circuit.
   - If amperage is not in specification do Voltage at IAH Element procedure (page 147).
9. When finished with this test, select Session from menu bar, then Close.

Voltage at IAH Element

1. Connect DMM positive lead to IAH element terminal.
2. Connect DMM negative lead to ground.
3. Turn ignition switch to ON, do not start engine.
4. Select Diagnostics from the menu bar.
5. Select Key On Engine Off Tests from the drop down menu.

NOTE: When using the EST to do the KOEO or KOER diagnostic tests, Standard Test is always selected and run first. If the ignition switch is not cycled, the Standard Test does not have to be run again.

6. Run KOEO standard test.

   NOTE: KOEO Standard Test will enable the relay for 2 to 4 seconds every time the test is run. The GPC/IAH test only enables the relay twice for 30 seconds to prevent element overheating.

7. Use DMM to measure voltage.
8. Evaluate voltage measurement:
   - If voltage is B+, do Resistance of Element (page 147) test.
   - If voltage is not B+, do Wiring Harness Continuity and Resistance (page 147) test.

Resistance of Element

1. Turn ignition switch OFF
2. Connect DMM positive lead to IAH element terminal.
3. Connect DMM negative lead to ground.
4. Use the DMM to measure resistance.
5. Evaluate resistance measurement:
   - If element resistance is greater than 5 ohms, replace the IAH element, following procedure in the *Engine Service Manual* and retest.
   - If element resistance is less than 5 ohms, verify Voltage at Element and do Wiring Harness Continuity and Resistance (page 147) test to check for corrosion and loose connections.

Wiring Harness Continuity and Resistance

1. Turn ignition switch OFF.
2. Connect DMM positive lead to IAH element terminal.
3. Connect DMM negative lead to IAH relay terminal.

   NOTE: Engines could be wired differently, having wiring harness connectors secured to different relay terminals. Trace wiring harness from element to the IAH relay, to be sure the correct relay terminal is tested.

4. Use DMM to measure resistance. Evaluate resistance measurement:
   - If the wiring resistance is greater than 5 ohms, check for loose or corroded connections and terminals. Repair or replace wire between element and relay.
   - If wires are not corroded and connections are tight, do Relay Operation test (page 148).

Relay Operation

1. Connect DMM positive lead to battery supply terminal (battery to IAH relay).

   NOTE: Engines could be wired differently, having wiring harness connectors secured to different relay terminals. Trace wiring harness from battery to IAH relay, to be sure the correct relay terminal is tested.

2. Connect DMM negative lead to ground.
3. Use DMM to measure voltage.
4. Evaluate voltage measurement:
   - If voltage at relay supply terminal is B+, continue to next step.
   - If voltage at relay supply terminal is less than B+, repair or replace wire from battery to IAH relay.
5. Connect DMM positive lead to the IAH relay output terminal.
6. Turn ignition switch to ON, do not start engine.
7. Select D_OutputStateTest.ssn in Open Session File window, select Open to detect possible DTCs.
8. Select Diagnostics from the menu bar.
9. Select Key On Engine Off Tests from the drop down menu.
10. Run KOEO Standard Test.

    NOTE: KOEO Standard Test will enable the relay for 2 seconds every time the test is run. The GPC/IAH test only enables the relay twice for 30 seconds to prevent element overheating.

11. Use DMM to measure voltage.
12. If voltage was not detected, check for corroded wires and loose connections on relay terminals. If terminals are clean and connections were tight, replace the relay.
13. When finished with this test, select Session from menu bar, then Close.

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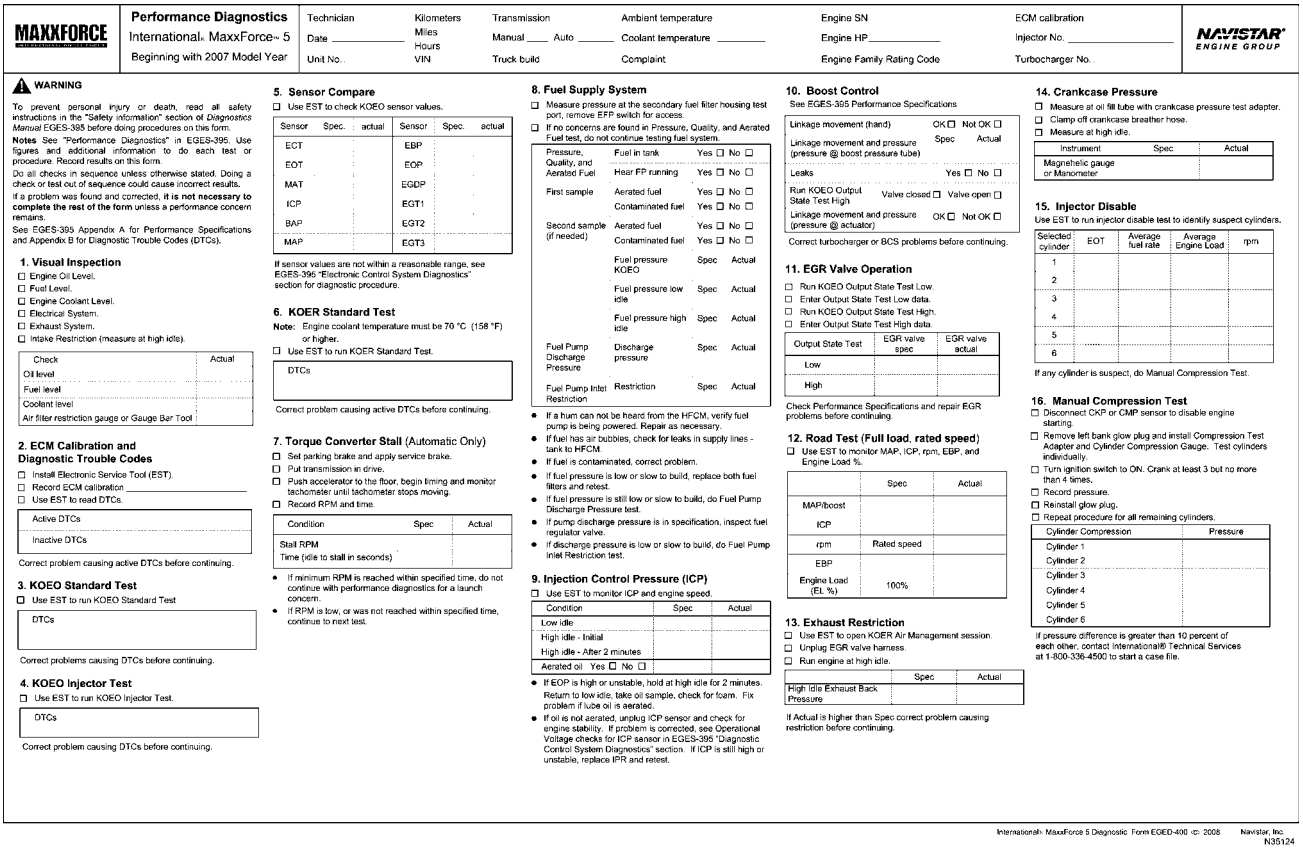
Diagnostic Form EGED-400



MAXXFORCE

Performance Diagnostics
International® MaxxForce™ 5
Beginning with 2007 Model Year

Technician | Kilometers | Transmission | Ambient temperature | Engine SN | ECM calibration
Date _____ | Miles | Manual ____ Auto _____ | Coolant temperature _____ | Engine HP_____ | Injector No. _____
Unit No. | Hours | Truck build | Complaint | Engine Family Rating Code | Turbocharger No.
VIN

NAVISTAR ENGINE GROUP

WARNING

To prevent personal injury or death, read all safety instructions in the "Safety Information" section of *Diagnostics Manual* EGES-395 before doing procedures on this form.

Notes See "Performance Diagnostics" in EGES-395. Use figures and additional information to do each test or procedure. Record results on this form.

Do all checks in sequence unless otherwise stated. Doing a check or test out of sequence could cause incorrect results.

If a problem was found and corrected, **it is not necessary to complete the rest of the form** unless a performance concern remains.

See EGES-395 Appendix A for Performance Specifications and Appendix B for Diagnostic Trouble Codes (DTCs).

1. Visual Inspection

- ☐ Engine Oil Level.
- ☐ Fuel Level.
- ☐ Engine Coolant Level.
- ☐ Electrical System.
- ☐ Exhaust System.
- ☐ Intake Restriction (measure at high idle).

Check	Actual
Oil level	
Fuel level	
Coolant level	
Air filter restriction gauge or Gauge Bar Tool	

2. ECM Calibration and Diagnostic Trouble Codes

- ☐ Install Electronic Service Tool (EST).
- ☐ Record ECM calibration _____
- ☐ Use EST to read DTCs.

Active DTCs
Inactive DTCs

Correct problem causing active DTCs before continuing.

3. KOEO Standard Test

- ☐ Use EST to run KOEO Standard Test

DTCs

Correct problems causing DTCs before continuing.

4. KOEO Injector Test

- ☐ Use EST to run KOEO Injector Test.

DTCs

Correct problem causing DTCs before continuing.

5. Sensor Compare

- ☐ Use EST to check KOEO sensor values.

Sensor	Spec.	actual	Sensor	Spec.	actual
ECT			EBP		
EOT			EOP		
MAT			EGDP		
ICP			EGT1		
BAP			EGT2		
MAP			EGT3		

If sensor values are not within a reasonable range, see EGES-395 "Electronic Control System Diagnostics" section for diagnostic procedure.

6. KOER Standard Test

Note: Engine coolant temperature must be 70 °C (158 °F) or higher.

- ☐ Use EST to run KOER Standard Test.

DTCs

Correct problem causing active DTCs before continuing.

7. Torque Converter Stall (Automatic Only)

- ☐ Set parking brake and apply service brake.
- ☐ Put transmission in drive.
- ☐ Push accelerator to the floor, begin timing and monitor tachometer until tachometer stops moving.
- ☐ Record RPM and time.

Condition	Spec	Actual
Stall RPM		
Time (idle to stall in seconds)		

- If minimum RPM is reached within specified time, do not continue with performance diagnostics for a launch concern.
- If RPM is low, or was not reached within specified time, continue to next test.

8. Fuel Supply System

- ☐ Measure pressure at the secondary fuel filter housing test port, remove EFP switch for access.
- ☐ If no concerns are found in Pressure, Quality, and Aerated Fuel test, do not continue testing fuel system.

Pressure, Quality, and Aerated Fuel	Fuel in tank	Yes ☐ No ☐	
	Hear FP running	Yes ☐ No ☐	
First sample	Aerated fuel	Yes ☐ No ☐	
	Contaminated fuel	Yes ☐ No ☐	
Second sample (if needed)	Aerated fuel	Yes ☐ No ☐	
	Contaminated fuel	Yes ☐ No ☐	
	Fuel pressure KOEO	Spec	Actual
	Fuel pressure low idle	Spec	Actual
	Fuel pressure high idle	Spec	Actual
Fuel Pump Discharge Pressure	Discharge pressure	Spec	Actual
Fuel Pump Inlet Restriction	Restriction	Spec	Actual

- If a hum can not be heard from the HFCM, verify fuel pump is being powered. Repair as necessary.
- If fuel has air bubbles, check for leaks in supply lines - tank to HFCM.
- If fuel is contaminated, correct problem.
- If fuel pressure is low or slow to build, replace both fuel filters and retest.
- If fuel pressure is still low or slow to build, do Fuel Pump Discharge Pressure test.
- If pump discharge pressure is in specification, inspect fuel regulator valve.
- If discharge pressure is low or slow to build, do Fuel Pump Inlet Restriction test.

9. Injection Control Pressure (ICP)

- ☐ Use EST to monitor ICP and engine speed.

Condition	Spec	Actual
Low idle		
High idle - Initial		
High idle - After 2 minutes		
Aerated oil Yes ☐ No ☐		

- If EOP is high or unstable, hold at high idle for 2 minutes. Return to low idle, take oil sample, check for foam. Fix problem if lube oil is aerated.
- If oil is not aerated, unplug ICP sensor and check for engine stability. If problem is corrected, see Operational Voltage checks for ICP sensor in EGES-395 "Diagnostic Control System Diagnostics" section. If ICP is still high or unstable, replace IPR and retest.

10. Boost Control

See EGES-395 Performance Specifications

Linkage movement (hand)	OK ☐	Not OK ☐
Linkage movement and pressure (pressure @ boost pressure tube)	Spec	Actual
Leaks	Yes ☐	No ☐
Run KOEO Output State Test High	Valve closed ☐	Valve open ☐
Linkage movement and pressure (pressure @ actuator)	OK ☐	Not OK ☐

Correct turbocharger or BCS problems before continuing.

11. EGR Valve Operation

- ☐ Run KOEO Output State Test Low.
- ☐ Enter Output State Test Low data.
- ☐ Run KOEO Output State Test High.
- ☐ Enter Output State Test High data.

Output State Test	EGR valve spec	EGR valve actual
Low		
High		

Check Performance Specifications and repair EGR problems before continuing.

12. Road Test (Full load, rated speed)

- ☐ Use EST to monitor MAP, ICP, rpm, EBP, and Engine Load %.

	Spec	Actual
MAP/boost		
ICP		
rpm	Rated speed	
EBP		
Engine Load (EL %)	100%	

13. Exhaust Restriction

- ☐ Use EST to open KOER Air Management session.
- ☐ Unplug EGR valve harness.
- ☐ Run engine at high idle.

	Spec	Actual
High Idle Exhaust Back Pressure		

If Actual is higher than Spec correct problem causing restriction before continuing.

14. Crankcase Pressure

- ☐ Measure at oil fill tube with crankcase pressure test adapter.
- ☐ Clamp off crankcase breather hose.
- ☐ Measure at high idle.

Instrument	Spec	Actual
Magnehelic gauge or Manometer		

15. Injector Disable

Use EST to run injector disable test to identify suspect cylinders.

Selected cylinder	EOT	Average fuel rate	Average Engine Load	rpm
1				
2				
3				
4				
5				
6				

If any cylinder is suspect, do Manual Compression Test.

16. Manual Compression Test

- ☐ Disconnect CKP or CMP sensor to disable engine starting.
- ☐ Remove left bank glow plug and install Compression Test Adapter and Cylinder Compression Gauge. Test cylinders individually.
- ☐ Turn ignition switch to ON. Crank at least 3 but no more than 4 times.
- ☐ Record pressure.
- ☐ Reinstall glow plug.
- ☐ Repeat procedure for all remaining cylinders.

Cylinder Compression	Pressure
Cylinder 1	
Cylinder 2	
Cylinder 3	
Cylinder 4	
Cylinder 5	
Cylinder 6	

If pressure difference is greater than 10 percent of each other, contact International® Technical Services at 1-800-336-4500 to start a case file.

International® MaxxForce 5 Diagnostic Form EGED-400 © 2008 Navistar, Inc.
N35124

Engine diagnostic forms assist technicians in troubleshooting International® diesel engines. The diagnostic tests help technicians find problems and avoid unnecessary repairs.

This section gives detailed instructions of the tests on the Diagnostic Form. This section should be used with the form and referenced for supplemental test information. Use the form as a worksheet to record data and test results.

Do all tests in sequence, unless otherwise stated. Doing a test out of sequence can cause incorrect results. If the problem is found and corrected, it is not necessary to complete the remaining tests.

See appendices for Diagnostic Trouble Codes (DTCs) and Performance Specifications.

Header Information

Technician _____	Kilometers _____	Transmission	Ambient temperature _____	Engine SN _____	ECM calibration _____
Date _____	Miles _____ Hours _____	Manual ____ Auto ____	Coolant temperature _____	Engine HP _____	Injector No.
Unit No. _____	VIN _____	Truck build _____	Complaint _____	Engine Family Rating Code _____	Turbocharger No. _____

N35108

Enter Header Information

1. Technician
2. Date
3. Unit No. (dealer's quick reference number)
4. Customer complaint

Enter Vehicle Information

The Vehicle Identification Number (VIN) is required to complete steps 5 through 9. The VIN can be obtained in ISIS.

5. VIN – the last 8 digits (verify to VIN plate)
6. Truck Build date (verify to VIN plate)
7. Engine hp
8. ECM calibration
9. Transmission type
10. Engine SN

Note: The engine Serial Number (SN) is located on the rear of the crankcase, below the left cylinder head.

Enter Performance Specification Information

11. See "Performance Specifications" (page 427) appendix in this manual or Technical Service Information (TSI) bulletin to obtain the following header information:

NOTE: Performance specifications are periodically published in TSI format to support new model year products. Check service bulletin listing on ISIS® for appropriate model year application.

- Engine Family Rating Code (EFRC)
- ECM calibration
- Injector No.
- Turbocharger No.

Verify ECM Calibration with Vehicle Specifications

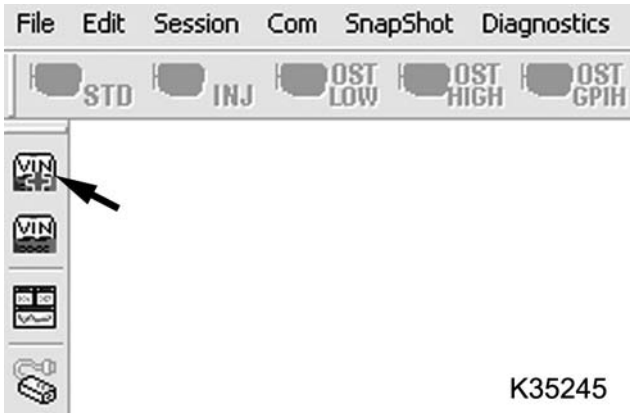


Figure 133 Selecting VIN+ icon

12. Using the EST with MasterDiagnostics®, open the VIN+ session by selecting the VIN+ icon.

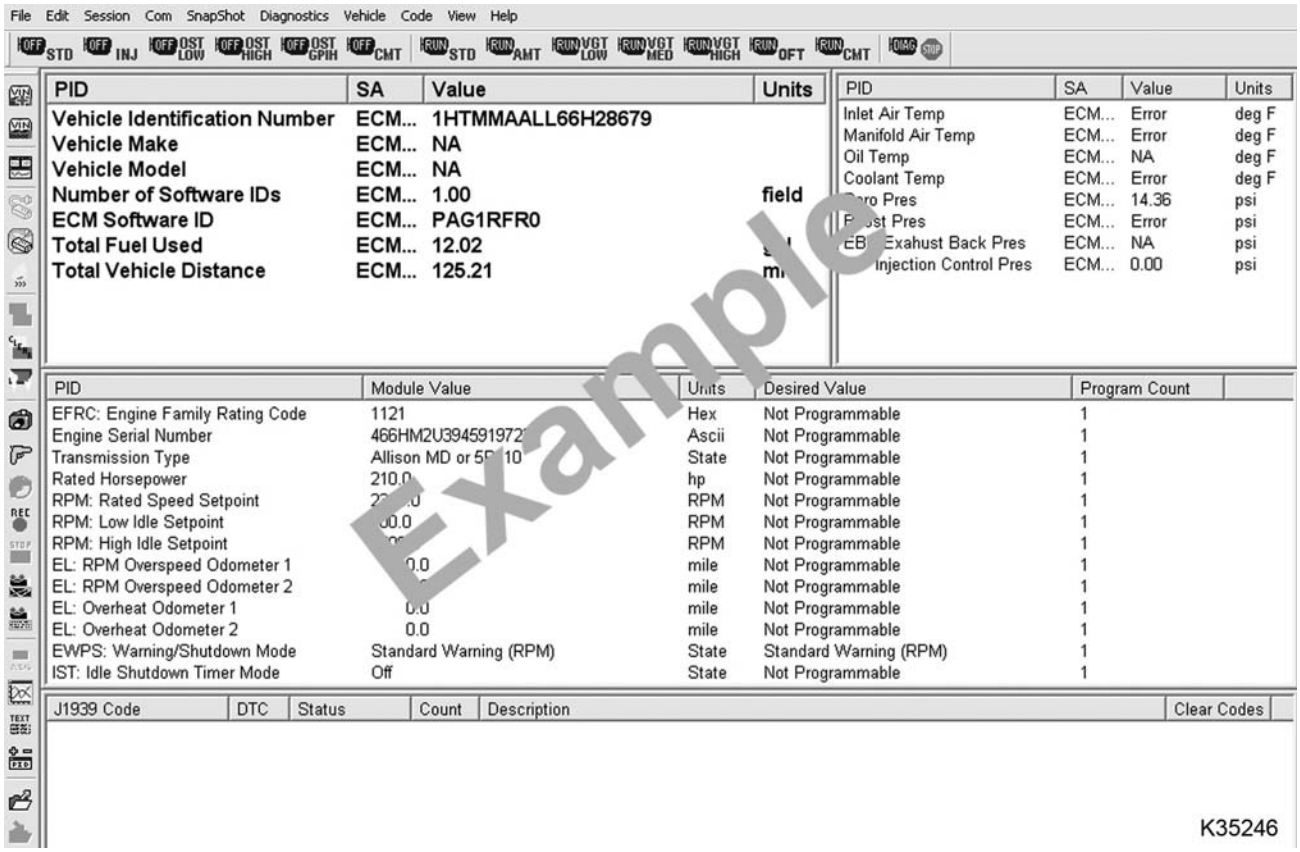


Figure 134 VIN+ session (example)

13. Verify the following match vehicle specification:
    - VIN
    - ECM calibration
    - Rated hp
    - EFRC
    - Engine SN
    - Transmission
14. Enter the following information:
    - Odometer (miles)
    - Engine hours
    - Ambient Temperature
    - Coolant temperature

Test Procedures

GOVERNMENT REGULATION: Engine fluids (oil, fuel, and coolant) may be a hazard to human health and the environment. Handle all fluids and other contaminated materials (e.g. filters, rags) in accordance with applicable regulations. Recycle or dispose of engine fluids, filters, and other contaminated materials according to applicable regulations.

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

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

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

WARNING: To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked DIESEL FUEL.

WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

WARNING: To prevent personal injury or death, provide proper ventilation when operating an engine in a closed area. Inhalation of exhaust gas can be fatal.

WARNING: To prevent personal injury or death, be careful of edge of driver's door, when the cab is tilted and the door is open.

1. Visual Inspection

Purpose

Check fluid levels, look for intake and exhaust restrictions, and electrical problems.

Tools

- Inspection lamp
- Flash light

Engine Oil

1. Park vehicle on level ground. Turn engine off. Wait 15 minutes for oil level to stabilize.
2. Use oil level gauge (dip stick) to verify engine oil level. Record results on Diagnostic Form.
   - If oil level is below specification, inspect for leaks, oil consumption, or improper servicing.
   - If oil level is above specification, inspect for fuel dilution, coolant contamination, or improper servicing.

Fuel Level

1. Park vehicle on level ground. Turn engine off.
2. Use dash gauge to check fuel level. Inspect fuel tank fill ports to verify.
3. Record results on Diagnostic Form.
   - If fuel tank is empty, put the correct grade of diesel fuel in the fuel tank.
   - If fuel level is low or below dash gauge reading, inspect for leaks, or fuel gauge problems.
   - If fuel level is above empty, and no tank contamination is evident, no repair is required.

Engine Coolant Level

1. Park vehicle on level ground.

   NOTE: Turn engine off. Wait 15 minutes or more for engine to cool.

2. Check coolant level on surge tank level window. Record results on Diagnostic Form.
   - If coolant level is low, inspect for leaks, coolant in the oil, coolant in the exhaust, improper servicing, or problems causing engine overheating.
   - If coolant level is full, and no tank contamination or leaks are evident, no repair is required.

Electrical System

1. Inspect batteries and electrical system (engine and vehicle) for loose or disconnected connections, corroded terminals, or broken and damaged wires.
2. Repair electrical problems as required.

Exhaust System

1. Inspect exhaust system (engine and vehicle) for restrictions, damage, and leaks.
2. Repair exhaust system problems as required.

Intake Restriction

1. Inspect Charge Air Cooler (CAC) system, including intercooler and all intake piping and ducts for leaks and damage.

   Inspect the following parts for restriction, damage or incorrect installation:
   - Air inlet hoses and ducts
   - Air filter housing, filter element, and gaskets
   - CAC and piping
   - Air filter inlet and duct - look inside duct and remove any restrictions.
2. Inspect all CAC and intake air connections and clamps.
3. If a CAC or intake air system problem is found, repair as required.
4. See “Performance Specifications” (page 427) for air cleaner restriction specification.

Figure 135 Air filter restriction gauge

5. Locate the air filter restriction gauge or install a Gauge Bar Tool to the air filter housing.
6. Start engine and run at high idle.
7. Record intake restriction on Diagnostic Form.
8. If restriction is detected, repair as required. Test again to validate repair.

2. ECM Calibration and Diagnostic Trouble Codes

Purpose

Verify ECM information matches the vehicle and identify Diagnostic Trouble Codes (DTCs).

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)

ECM Calibration Verification

1. Turn ignition Key ON, Engine OFF (KOEO).
2. Connect EST, open the VIN+ session. Select the VIN+ icon.
3. Verify the vehicle information on the ECM matches the vehicle. See Enter Vehicle Information (page 152).
4. Record ECM calibration level on Diagnostic Form.

Diagnostic Trouble Codes (DTCs)

CAN code: Codes associated with a Suspect Parameter Number (SPN) and Failure Mode Indicator (FMI)

Status: Indicates active or inactive DTCs

- **Active**: With the ignition switch ON; Active indicates a DTC for a condition currently in the system. When the ignition switch is turned Off, an Active DTC becomes Inactive. (If a problem remains, the DTC will be Active on the next ignition switch cycle and the EST will display Active/Inactive.)
- **Inactive**: With the ignition switch On, Inactive indicates a DTC for a condition during a previous key cycle. When the ignition switch is turned to OFF, Inactive DTCs from a previous ignition switch cycle remain in the ECM memory until cleared.
- **Active/Inactive:** With the ignition switch On, Active/Inactive indicates a DTC for a condition currently in the system and was present in previous key cycles, if the codes were not cleared.

Description: Defines each DTC

1. Record all Active and Inactive DTCs on the Diagnostic Form.
   - If no DTCs are set, continue to next test.
   - Correct any active DTCs, related to performance. See “Electronic Control Systems Diagnostics” section of this manual.
   - Investigate any inactive DTCs that affect performance.

3. KOEO Standard Test

NOTE: See “Diagnostic Software Operation” section in this manual for specific EST software procedures to do this test.

Purpose

Inspect for electrical malfunctions detected by the ECM self-test and Output Circuit Check (OCC).

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4-USB Interface Cable (page 390)

Possible Causes

- Failed electrical components or circuitry
- OCC faults detected by ECM.

Procedure

1. Turn ignition switch to ON. Do not start engine.
2. Open COM device.
3. Select Key On Engine Off Tests. Select Standard Test from the drop down menu.
4. Follow the on-screen instructions.
5. Record DTCs on the Diagnostic Form. See “Diagnostic Trouble Code (DTC) Index” (page 435) appendix in this manual.
6. If DTCs are detected, fix problems causing DTCs. See “Electronic Control System Diagnostics” section in this manual.
7. Clear DTCs.
8. Run the KOEO Standard Test again to verify repairs.

4. KOEO Injector Test

NOTE: See “Diagnostic Software Operation” section in this manual for specific EST software procedures to do this test.

NOTE: When using the EST for KOEO or KOER diagnostic tests, Standard Test is always selected and run first. If the ignition switch is not cycled, the Standard Test does not have to be run again.

Purpose

Inspect for electrical faults in injector solenoids.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)

Possible Causes

- OPEN or short in injector circuits
- Poor ECM power or ground
- Failed injector coil
- Failed ECM

Procedure

1. Turn ignition switch to ON. Do not start engine.
2. Open COM device.
3. Select Key On Engine Off Tests and Injector Test from the drop down menu.
4. Listen for injectors to pre-cycle (clicking), then cycle in order of cylinder position.
5. Listen again for injectors to pre-cycle, then cycle in reverse order of cylinder position.
6. Record DTCs on Diagnostic Form. See “Diagnostic Trouble Code Index” (page 435) in this manual.
7. If DTCs are detected, fix problems causing DTCs. See “Electronic Control System Diagnostics” section in this manual.
8. Clear DTCs.
9. Run the KOEO Injector Test again to verify repair.

5. Sensor Compare

NOTE: See “Diagnostic Software Operation” section in this manual for specific EST software procedures to do this test.

Purpose

Check for sensor malfunctions while running KOEO Continuous Monitor test.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)

Possible Causes

- Failed sensor circuits.
- Biased sensor

Procedure

1. Turn ignition switch to ON. Do not start engine.
2. Open COM device.
3. Open Sensor Compare session
4. Select Key On Engine Off (KOEO) Tests and Continuous Monitor Test from the drop down menu.
5. Check for normal KOEO sensor values.
6. Record results on Diagnostic Form. See “Performance Specifications” (page 427).
   - If engine has not been run for 8 hours or more, the Engine Coolant Temperature (ECT), Engine Oil Temperature (EOT), and Manifold Air Temperature (MAT) should be within about 2 °C (5 °F) of each other.
   - The Injection Control Pressure (ICP) values may fluctuate and affect performance. Electromagnetic Interference (EMI) or ground shift can cause an small voltage shift that does not indicate a problem.

     If voltage shift causes the signal to exceed 690 kPa (100 psi), see ICP Sensor (page 325).
   - Engine Oil Pressure (EOP), Manifold Air Pressure (MAP), and Exhaust Back Pressure (EBP) values may fluctuate by about 7 kPa (1 psi). Electromagnetic Interference (EMI) or ground shift can cause a small voltage shift that does not indicate a problem.
7. Verify sensor values are normal. Sensor readings will vary depending on engine temperature, ambient temperature, engine speed, etc.
   - If out of specification, see “Electronic Control Systems Diagnostics” section of this manual.
   - If sensors are in specification, continue to next test.

6. KOER Standard Test

NOTE: See “Diagnostic Software Operation” section in this manual for specific Electronic Service Tool (EST) software procedures to do this test.

Purpose

Inspect for engine sensor and IPR malfunctions within specified operating ranges.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)

Possible Causes

- ICP oil leak
- Sensor and actuator circuit problems
- Failed engine sensors or actuators
- Low oil supply to high-pressure pump reservoir
- High-pressure pump failure
- Injector problem

Procedure

1. Turn ignition switch to ON.
2. Open session and select D_KOER_Standard session from menu.
3. Start engine and run until minimum engine coolant temperature of 70 °C (158 °F) is reached.
4. Select Key On Engine Running (KOER) Tests and Standard Test from the drop down menu.
5. Follow the on-screen instructions.
    - The Electronic Control Module (ECM) will start the KOER Standard Test by commanding engine rpm to rise to a predetermined level.
    - When the test is finished, the ECM will return engine rpm to low idle.
6. Record DTCs on Diagnostic Form. See “Diagnostic Trouble Code Index” (page 435) in this manual.
7. If DTCs are detected, fix problems causing DTCs. See “Electronic Control System Diagnostics” section in this manual.
8. Clear DTCs.
9. Run KOER Standard Test again to verify repair.

7. Torque Converter Stall (Automatic only)

Purpose

Check engines ability to meet specified stall rpm within specified time.

Possible Causes

- Intake or exhaust restriction
- Boost or exhaust system leak
- Biased engine sensors
- Low supply fuel pressure
- Low injection control pressure
- EGR control valve issue
- Turbocharger issue
- Fuel injector issue
- Power cylinder or valve train issue

Procedure

WARNING: To prevent personal injury or death, make sure brakes are correctly adjusted and in good condition. Ensure parking brake is set before doing the Torque Converter Stall Test. This test should be done in an open lot.

CAUTION: To prevent drive train damage, do not do this test for more than 10 seconds at a time or more than twice back to back. If doing twice – wait 2 minutes between tests.

1. See “Performance Specifications” (page 427) appendix for automatic transmission torque converter stall specification.
2. Set parking brake.
3. Start the engine.
4. Apply service brake.
5. Put transmission in drive.
6. Press accelerator pedal to the floor and begin timing until TACH stops moving.
7. Record stall rpm and time to reach stall rpm on Diagnostic Form.
   - If stall rpm is below specification, or stall time is above specification, continue to next test.
   - If minimum RPM is reached within specified time, do not continue with Performance Diagnostics for a launch concern.

8. Fuel Supply System

Purpose

Check for correct fuel pressure and aerated fuel. Do the following:

- Determine if the amber WATER IN FUEL lamp was on during vehicle operation.
- Determine if the Check Engine light was on during vehicle operation. If Diagnostic Trouble Code (DTC) 2372 is set, change both fuel filters and retest for poor engine performance.
- If fuel pressure is pulsating see Air or Combustion Leaks to Fuel test (page 108) in the “Engine Symptoms Diagnostics” (page 93) section of this manual .

Tools

- 0-160 psi gauge (on Gauge Bar Tool)
- Fuel Pressure Gauge (page 393)
- ICP System Test Adapter (page 395)
- In-line shut off valve
- 3/8 inch clear sample line
- Clear container with a wide opening (approximately 1 liter or 1 quart US)

Possible Causes

Contaminated Fuel

- Water or contaminants in fuel tank
- Ice in fuel lines
- Debris in fuel tank
- Fuel colored, cloudy, or colored
- Fuel is waxy or gelled
- Off road fuel red colored or blue colored

Aeration

- Low or no fuel level in fuel tank(s).
- Failed seals for fuel lines between fuel tank(s) and the Horizontal Fuel Conditioning Module (HFCM), fuel supply line broken or crimped.
- A cracked or restricted pickup tube screen or pickup tube.
- HFCM fuel filter cap seal damaged, HFCM drain plug loose, or HFCM drain plug O-ring broken or missing
- A loose fuel line or fuel line connector on the suction side of the fuel pump

No Fuel

- Low or no fuel level in fuel tank(s).
- Inoperative fuel tank transfer pump
- A restricted, kinked, bent, loose, cracked, or broken fuel pickup tube or screen.
- Failed seals for fuel lines between fuel tanks, ice in fuel lines, fuel supply line broken or crimped, or restriction in the fuel line from the fuel tank to the HFCM.

Low fuel pressure

- Debris in tank
- Restriction from the fuel tank to the HFCM
- A kinked or bent fuel supply line or a blocked pickup tube screen
- A loose fuel line or fuel line connector on the suction side of the fuel system
- Dirty, plugged, or missing fuel filters
- Inoperative fuel pump
- Inoperative, stuck, or debris in the fuel pressure regulator valve.

Fuel Restriction

- Debris in fuel
- A kinked or bent fuel supply line or a blocked pickup tube strainer
- Dirty or plugged filter element
- Waxed or gelled fuel in the fuel filter
- Ice in fuel lines

High fuel pressure

- Debris in the fuel regulator valve
- Inoperative fuel pressure regulator valve.
- Restriction in the fuel return to the HFCM

WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

WARNING: To prevent personal injury or death, store diesel fuel properly in an approved container designed for and clearly marked DIESEL FUEL.

Pressure, Quality, and Aerated Fuel

1. See “Appendix A: Performance Specifications” (page 427).
2. Verify there is fuel in the fuel tank(s). Check fuel in fuel tank(s) for odors other than diesel fuel, for example: kerosene, alcohol, or gasoline.

   NOTE: Low biodiesel blends (up to 5% B5) that meet all ASTM D975-08a standard requirements should not cause engine or fuel system problems. Biodiesel blends higher than 5% and lower than or equal to 20% (B6 to B20) can be used if bought from a BQ9000 certified fuel supplier and meet ASTM D7467-08 standard specifications. If biodiesel blends are used, the odor in the fuel tank(s) or exhaust may not match typical diesel fuel.
3. Turn ignition switch to ON, listen for a hum coming from the fuel pump. The ECM turns the fuel pump on, it should run for 60 seconds. After 60 seconds the ECM turns the fuel pump off unless the engine is running.

   NOTE: Engine may run without the fuel pump, but damage to the injectors could occur.

   - If the fuel pump can be heard running, continue to next step.
   - If the fuel pump cannot be heard running, turn ignition switch OFF.
     a. Disconnect the fuel pump harness connector and measure voltage between the power and ground circuits.
     b. Turn ignition switch to ON, battery voltage should be present for 60 seconds.
     c. If battery voltage is not present, see FPC (Fuel Pump Control) in the “Electronic Control Systems Diagnostics” section of this manual. See *Chassis Electrical Circuit Diagram Manual* and *Electrical System Troubleshooting Guide* for circuit numbers, connector and fuse locations.
4. Turn ignition switch OFF.

CAUTION: To prevent damage to the engine, take precautions to prevent foreign materials from entering the air intake system when the air inlet duct is removed.

5. Remove the air inlet duct from the engine to aid in Engine Fuel Pressure (EFP) switch removal and system testing.

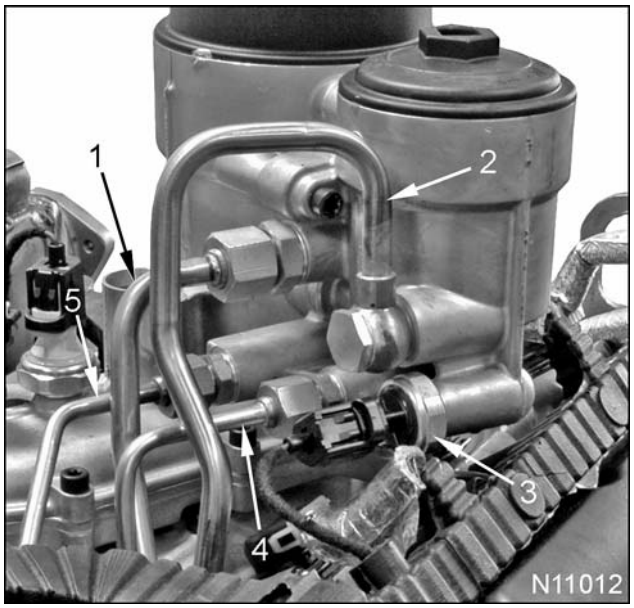


Figure 136 Secondary fuel filter tubes and housing

1. Fuel return to HFCM tube
2. Fuel supply to secondary filter tube
3. Engine Fuel Pressure (EFP) switch
4. Fuel filter to left cylinder head tube
5. Fuel filter to right cylinder head tube

WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

6. Place a suitable container under the secondary fuel filter housing to catch draining fuel.
7. Remove the EFP switch, installed in the bottom of secondary fuel filter housing.

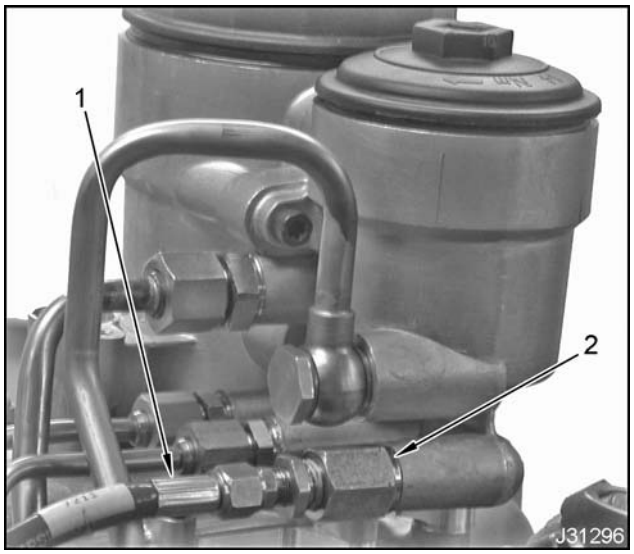


Figure 137 ICP System Test Adapter installed with Fuel Pressure Gauge

1. Test line
2. ICP System Test Adapter

8. Install the ICP System Test Adapter and assemble and attach Fuel Pressure Gauge.
9. Run the clear test line to a clear container.
10. Turn ignition switch to ON (do not crank the engine).
11. Open the in-line shut off valve, drain sample in the clear container. As filling, observe the clear test line for air bubbles.
12. Close in-line shut off valve.
13. Check for contamination.

    Sample should be clear, free of debris, water and other contaminates. Sample should not be cloudy or dyed (blue or red).

    - If air bubbles stop with sample flowing, the fuel is not aerated and if there is no contamination, continue with step 16.
    - If the air bubbles do not clear before the sample container is almost full, take a second sample to determine if air bubbles have cleared, continue with step 14.
    - If fuel is contaminated with water, debris or other contaminates, take a second sample. Some sediment and water may be present in the fuel sample if the fuel filter has not been replaced for a long time or if the sediment and water have not been drained recently, continue with step 14.
    - If the fuel sample is cloudy in cold temperatures, this indicates fuel waxing or gelling. Summer fuels are not suitable in cold temperatures. Change to the recommended fuel grade. See the *Engine Operation and Maintenance Manual*.
    - If the fuel sample is dyed, either blue or red, this indicates off-road use fuel and could cause a performance problem. Change to a recommended fuel grade. See the *Engine Operation and Maintenance Manual*.

14. If a second sample is needed, cycle the ignition switch to restart the fuel pump, drain sample and check for air bubbles and contamination in the fuel.

15. Evaluate sample results:
    - If air bubbles did not clear, check the fuel supply system from the fuel tank(s) to the HFCM inlet for leaks. Fix problem and retest. The check should include wiggling all fuel line connections, checking the primary fuel filter cover and the HFCM drain plug for leaks with the fuel pump turned off. With the fuel pump off, the primary fuel filter cover and the drain plug may show a slow drip of fuel indicating cover or plug is loose or seals are worn, cracked, or broken.
    - Excessive water or contaminants indicate the tank and fuel system may need to be flushed and cleaned. Take a sample from the HFCM drain plug for verification. See Drain Water from HFCM procedure (page 109).
    - If fuel doesn't clear up, the system may need to be flushed. Replace the primary and secondary fuel filters and verify fuel is clean and the recommended grade.

    NOTE: Any residue or microbial growth in the tank(s) will compound with the use of biodiesel. This can cause plugging of filters and deposits in the fuel system. Fuel tanks should be thoroughly cleaned and dried before operating with any biodiesel blends. Adding biocides will help minimize growth.
16. Cycle the ignition switch OFF and back to ON. Check fuel pressure on the gauge when the pump starts. Pressure should increase to specification quickly.
17. Turn ignition switch OFF.
18. Evaluate fuel pump pressures.
    - If fuel pressure is within specification, continue with the next step.
    - If fuel pressure is below specification or slow to build, replace both the primary and secondary fuel filters and retest.
    - If fuel pressure is still below specification or slow to build, after replacing both primary and secondary fuel filters, measure fuel pump discharge pressure. Do Fuel Pump Discharge Pressure (page 165) test.
19. Start the engine.

NOTE: See Air or Combustion Leaks to Fuel test in the "Engine Symptoms Diagnostics" section of this manual, if all of the following conditions are noted:

- If the fuel system develops air bubbles with the engine running.
- Pulsating fuel pressure

20. Run the engine at low idle, check the low idle pressure indication on the test gauge.
21. Run the engine at high idle, check the high idle pressure indication on the test gauge.
22. Evaluate fuel pressure results:
    - If fuel pressure is low or is slow to build, replace both the primary and secondary fuel filters and retest.
    - If all pressures are in specification, do Injection Control Pressure (ICP) test in this section.
23. Clear low fuel pressure DTC.

Fuel Pump Discharge Pressure

NOTE: This procedure should only be done when directed by Pressure, Quality, and Aerated Fuel test (page 161) when fuel pressure is still below specification or slow to build, after replacing both primary and secondary fuel filters.

Purpose

Measure fuel pump discharge pressure.

NOTE: Breaking any fuel system joints will induce air in the fuel system. Cycle ignition switch to On for 60 seconds, two times, to prime fuel system.

Tools

- 0-160 psi gauge (on Gauge Bar Tool)
- Fuel Pressure Gauge (page 393)
- Fuel Pressure Test Adapter (page 397)

NOTE: When removing the banjo bolt, fuel will leak out. Use a suitable container to collect fuel. Collect and dispose of fuel according to applicable regulations.

WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

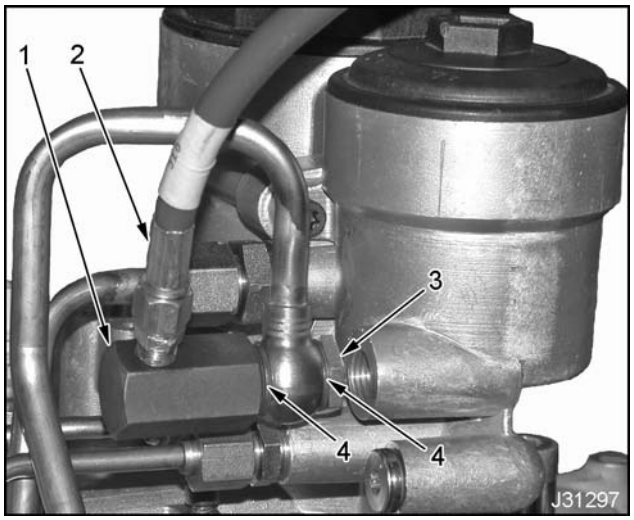


Figure 138 Fuel Pressure Test Adapter

1. Fuel Pressure Test Adapter
2. Test line
3. Banjo bolt
4. Copper gaskets

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

Procedure

1. Remove banjo bolt from fuel supply to filter tube at the bottom of the secondary fuel filter housing.

NOTE: Use existing copper gaskets for testing. Replace the copper gaskets on the banjo bolt when testing is finished.

2. Connect the Fuel Pressure Test Adapter to the fuel supply, using the banjo bolt and used copper gaskets.
3. Connect the Fuel Pressure Gauge to the Fuel Pressure Test Adapter.
4. Turn ignition switch to ON (do not crank the engine). Check fuel pressure on the test gauge when the pump starts. The fuel pressure should increase to specification quickly.

CAUTION: To prevent engine damage, replace the two copper gaskets when reattaching fuel supply from the HFCM to the secondary fuel filter housing.

5. Evaluate fuel pump discharge pressure.
   - If discharge pressure is within specification, turn ignition switch OFF, continue to next step.
   - If discharge pressure is not within specification or slow to build, turn ignition switch OFF. Reconnect the fuel line and banjo bolt to secondary fuel filter housing, do Fuel Inlet Restriction (page 166).
6. Remove the Fuel Pressure Test Adapter.
7. Remove, clean, and inspect the fuel pressure regulator, see the *Engine Service Manual*.
8. After reinstallation of the secondary fuel filter housing and all fuel lines. Attach the Fuel Pressure Gauge to the secondary fuel filter test port and retest fuel pressure.

Fuel Inlet Restriction

NOTE: This procedure should only be done when directed by Fuel Pump Discharge Pressure test (page 165) when discharge pressure is not within specification or slow to build.

Purpose

Measure fuel pump inlet restriction.

NOTE: Breaking any fuel system joints will induce air in the fuel system.

Tools

- 0-30 in Hg gauge (on Gauge Bar Tool)
- Fuel Inlet Restriction Adapter (page 397)
- In-line shut off valve

Procedure

1. Put a clean drain pan under the HFCM drain plug
2. Wipe down the frame around and under the drain plug. Wipe down the HFCM area around the drain plug also.

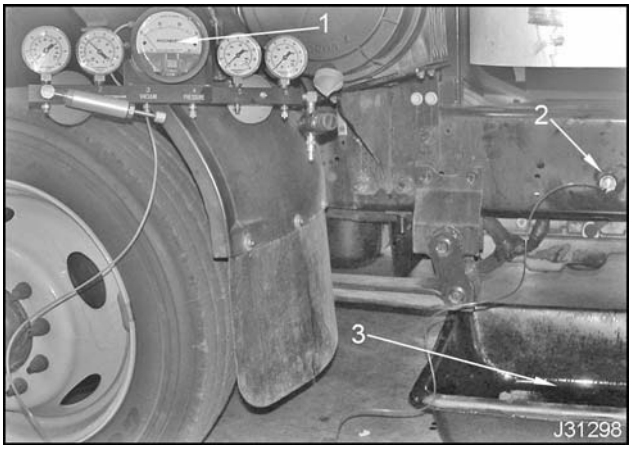


Figure 139 Fuel inlet restriction test setup (typical)

1. Gauge Bar Tool
2. Fuel Inlet Restriction Adapter
3. Drain pan

WARNING: To prevent personal injury or death, do not smoke and keep fuel away from flames and sparks.

3. Open the drain plug and drain the HFCM into drain pan.
4. Remove the HFCM drain plug, install the Fuel Inlet Restriction Adapter, hand tight.

NOTE: Inspect the drain plug O-ring for damage. Care must be taken when installing drain plug to prevent damaging the O-ring.

5. Connect to 0-30 in Hg gauge on the Gauge Bar Tool through an in-line shut off valve. Make sure the shut off valve is in the closed position.

NOTE: The fuel pump runs for 60 seconds when ignition switch is turned on. The in-line shut off valve must be closed before the fuel pump shuts off. This will prevent the gauge from filling with fuel.

6. Turn ignition switch to ON. Open the in-line shut off valve and check for restriction indication on the test gauge. Close the in-line shut off valve. Turn ignition switch OFF.
7. Evaluate restriction indication:
   - If vacuum indication is above specification, check for restrictions in the fuel supply lines from the fuel pickup tube in the fuel tank to the HFCM. Visually inspect for bent, crimped, or damaged fuel supply lines and connections from the fuel tank(s) to the HFCM. Repair any restrictions and retest fuel pressure at the secondary fuel filter housing test port.
   - If vacuum indication is below specification and fuel pump discharge pressure is low, replace the fuel pump and retest fuel pressure at the secondary fuel filter housing test port.

9. Injection Control Pressure (ICP)

Purpose

Determine if the ICP system is providing enough hydraulic pressure to operate the injectors.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)
- Fuel Pressure Test Fitting (page 395)
- Fuel/Oil Pressure Test Coupler (page 395)
- Gauge Bar Tool (page 393)
- Oil sample line with in-line shut off valve
- Container (for oil sample)

Monitoring ICP Using EST

Possible causes

- Poor quality oil, oil not to API specifications, oil not serviced correctly
- ICP system leakage
- Failed ICP sensor circuit
- Failed ICP sensor
- Failed IPR valve
- Failed high-pressure oil pump
- Failed lube oil pump
- Failed oil pick up tube
- Missing or failed gasket for oil pick up tube

If the Electronic Control Module (ECM) detects low boost pressure, an incorrect feedback signal from APS or the ICP sensor, the ECM will command the IPR valve to reduce ICP.

Procedure

1. See “Appendix A: Performance Specifications” (page 427) for ICP specifications.
2. Select D_RoadPerformance_V6.ssn in the Open Session File window, select Open to monitor engine operation.
3. Run engine at low idle, monitor ICP, and record results on Diagnostic Form.
4. Run engine at high idle, monitor ICP, and record initial results on Diagnostic Form. Continue to run engine at high idle for 2 minutes, monitor ICP, and record 2 minute results on Diagnostic Form. Compare the two ICP readings. ICP that rises above specification at any point during the two minutes, indicates oil aeration.
   - If ICP is high or unstable during low or high idle, continue with step 5.
   - If ICP is in specification during low and high idle, select Session from menu bar, then Close. Continue with next test.
5. Turn off engine.

WARNING: To prevent personal injury or death, comply with the following when taking oil sample:

- **Do not route oil line too close to moving parts.**
- **Do not let oil line touch hot engine surfaces.**
- **Use caution not to burn hands.**

6. Check lube oil supply for aeration. Connect fitting on test line with Fuel/Oil Pressure Test Coupler to the 0 - 160 psi gauge on the Gauge Bar Tool.

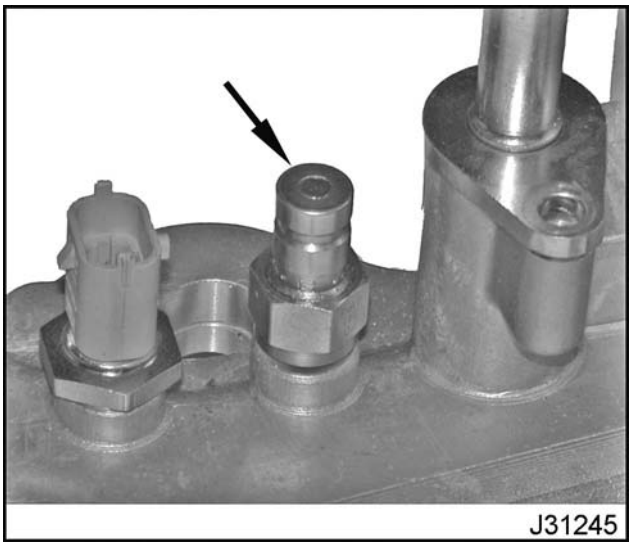


Figure 140 Fuel Pressure Test Fitting installed in EOP switch port

7. Remove EOP switch and install Fuel Pressure Test Fitting.
8. Connect Fuel/Oil Pressure Test Coupler to Fuel Pressure Test Fitting.
9. Start and run engine at high idle for two minutes. Record EOP initially as high idle is set, then again after two minutes.
10. Return engine to low idle, take oil sample, and check for foam (aerated).
    - If oil is aerated, a large quantity of air bubbles will be mixed throughout the oil, or foam build up on top of the oil sample will be seen. Fix problem and retest.
    - If oil is not aerated, unplug ICP sensor and check engine stability. If problem is corrected, see ICP (Injection Control Pressure) Sensor test in the “Electronic Control Systems Diagnostics” section of this manual.
    - If ICP is still high or unstable, replace the Injection Pressure Regulator (IPR) valve following procedures in the *Engine Service Manual*. Retest to verify repair.
11. When finished with this test, select Session from menu bar, then Close.

10. Boost Control

Purpose

Verify turbocharger bypass control is operating correctly.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)
- Gauge Bar Tool (page 393)
- Hose and adapters from vacuum pump kit

Possible Causes

- Failed Boost Control Solenoid (BCS)
- Electrical failure to BCS
- Broken, cracked, or disconnected tubing
- Failed or damaged pneumatic actuator
- Actuator linkage disconnected or damaged
- Failed turbocharger bypass valve

Linkage Inspection

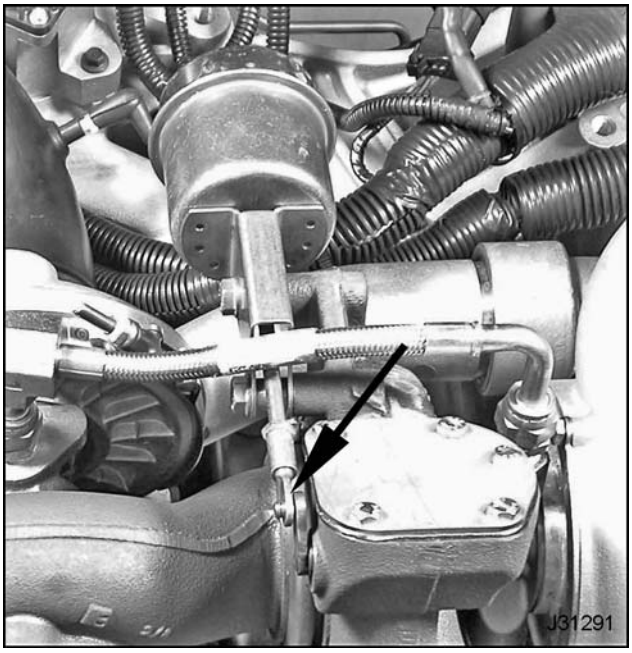


Figure 141 Turbocharger pneumatic actuator linkage connection to bypass valve lever

1. Inspect turbocharger pneumatic actuator linkage and check for freedom of movement by hand.
   - If linkage moves freely, do Actuator and Bypass Valve Operation (page 170).
   - If bypass valve lever is hard to move. Remove the bypass valve cover, inspect the internal components for damage. Clean bypass valve if possible or replace turbocharger, and retest. When installing the bypass valve cover, replace the cover gasket and tighten fasteners to 13.6 N·m (120 lbf·in).

Actuator and Bypass Valve Operation

1. Disconnect the boost pressure tube from the intake manifold inlet elbow. Inspect all boost pressure tube connectors for cracks.

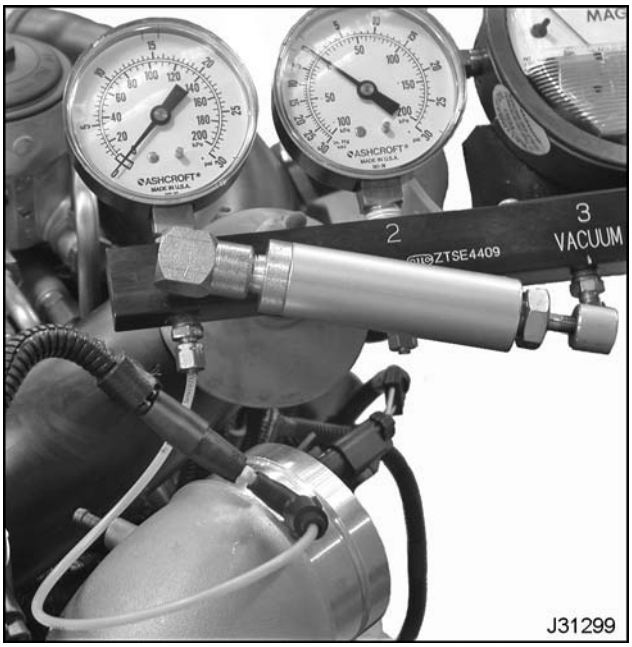


Figure 142 Actuator and bypass valve operational test

2. Attach pressure tubing from the Gauge Bar Tool hand pump and 0-30 psi gauge to the boost pressure tube.

   NOTE: Use adapters from a vacuum pump kit to make test hose connections.

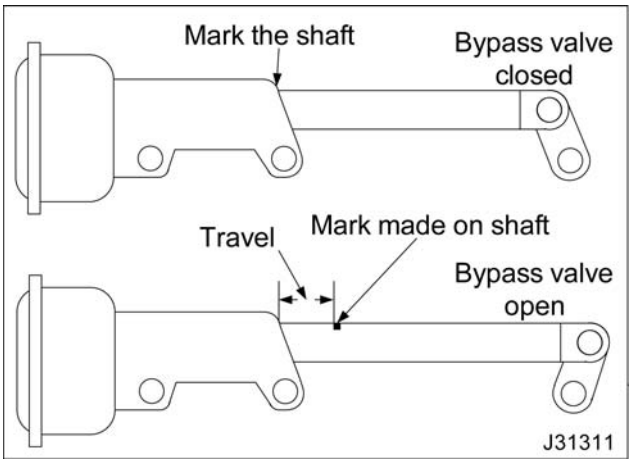


Figure 143 Bypass valve linkage movement

3. Mark a reference spot on the linkage shaft.
4. See “Appendix A: Performance Specifications” (page 427) Turbocharger Actuator.
5. Using the Gauge Bar Tool hand pump, apply pressure to the pneumatic actuator. As pressure starts to build, linkage movement (indicated by mark on the linkage) should begin to move at specified pressure.

   NOTE: If unable to build pressure with the hand pump, attach shop air to the regulator and 0-30 psi gauge on the Gauge Bar Tool to supply air pressure. Gradually increase air pressure (do not exceed 30 psi) to check linkage movement and test for leaks.
6. Evaluate actuator linkage movement:
   - If the pneumatic actuator linkage moves and test pressure is within specification, continue with BCS Control test (page 171).
   - If the pneumatic actuator linkage does not move, or initial movement is not at specified pressure, continue to next step.
7. With pressure applied spray leak detector or soap solution on the boost pressure tubes and pneumatic actuator housing. Also leak test all boost pressure tubes, BCS, and rubber connectors.
   - If boost pressure tubes are leaking, replace and retest.
   - If the BCS is leaking, replace and retest.
   - If pneumatic actuator is leaking do Pneumatic Actuator Operation (page 172) test to verify pneumatic actuator leakage.
   - If the pneumatic actuator linkage does not move, or initial movement is not at specified pressure, and there are no leaks, do Pneumatic Actuator Operation test (page 172).

BCS Control

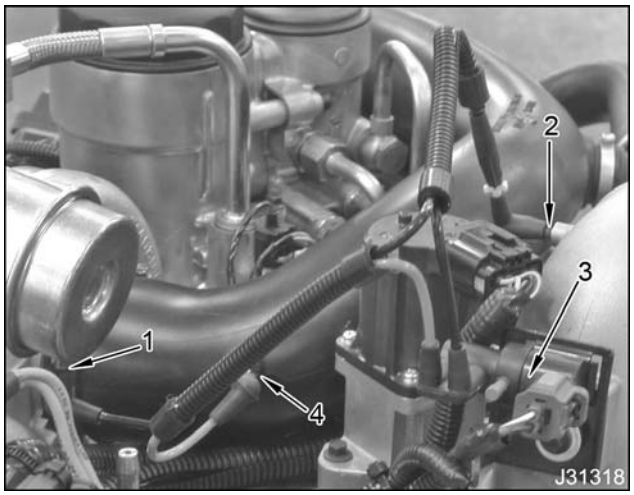


Figure 144 BCS Control system

1. Air supply to pneumatic actuator
2. Supply air inlet elbow
3. Boost Control Solenoid (BCS)
4. Vent inlet to low-pressure compressor

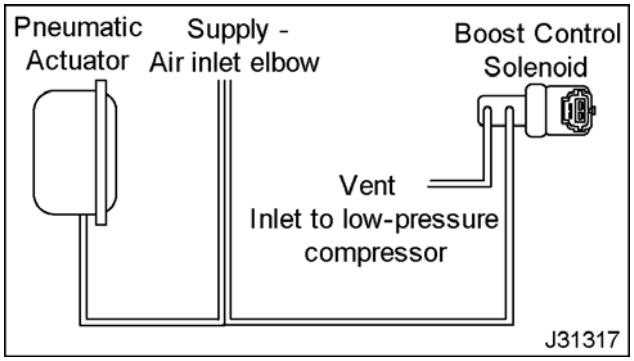


Figure 145 BCS Control system functional diagram

1. Connect the IC4–USB Interface Cable to the EST.
2. Turn ignition switch to ON, do not crank engine.
3. Select D_OutputStateTest.ssn from the Open Session File window, select Open to open the session.

⚠ WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

4. Apply pressure to the pneumatic actuator through the supply tube and fully open the bypass valve. Using the Gauge Bar Tool hand pump apply pressure of 172 kPa (25 psi), do not exceed 206 kPa (30 psi).

   NOTE: Shop air may be used to supply air pressure. Attach shop air to the regulator and 0-30 psi gauge on the Gauge Bar Tool to supply air pressure. Gradually increase air pressure, do not exceed 206 kPa (30 psi) to open bypass valve.

5. Select Diagnostics from the menu bar.
6. Select Key On Engine Off (KOEO) Tests from the drop down menu.

NOTE: When using the EST to do KOEO or KOER diagnostic tests, the Standard Test is always selected and run first. If the ignition switch is not cycled, the Standard test does not have to be run again.

7. From the KOEO Diagnostics menu, select Output State Test High and select Run to start the test.
   - If the bypass valve linkage moves to the closed position, the boost control system is working correctly, continue to EGR Valve and ITV Operation test.
   - If the bypass valve linkage does not move to the closed position, see BCS (Boost Control Solenoid) test in the “Electronic Control Systems Diagnostics” section of this manual.
8. When finished with this test, select Session from menu bar, then Close.

Pneumatic Actuator Operation

Figure 146 Pressure control connector on pneumatic actuator

1. Disconnect pressure tube connector from the bottom of the pneumatic actuator.

Figure 147 Pneumatic actuator operational test

2. Attach pressure tubing from the Gauge Bar Tool hand pump and 0-30 psi gauge to the bottom of the pneumatic actuator.

   NOTE: Use adapters from a vacuum pump kit to make test tube connections.

WARNING: To prevent personal injury or death, wear safety glasses with side shields. Limit compressed air pressure to 207 kPa (30 psi).

3. Using the Gauge Bar Tool hand pump, apply pressure to the pneumatic actuator. As pressure starts to build up, linkage movement (indicated by mark on the linkage) should begin to move at specified pressure.

   NOTE: If unable to build pressure with the hand pump, attach shop air to the regulator and 0-30 psi gauge on the Gauge Bar Tool to supply air pressure. Gradually increase air pressure, do not exceed 206 kPa (30 psi) to check linkage movement and test for leaks.

4. Evaluate linkage movement, operating pressures, and leak tests.

   - If the pneumatic actuator linkage moves, test pressure is within specifications, and there is no leak, continue to next step.
   - If the pneumatic actuator linkage does not move, or initial movement is not at specified pressure, repair or replace turbocharger.

5. Check BCS assembly electrical circuits, see BCS (Boost Control Solenoid) test in the “Electronic Control Systems Diagnostics” section of this manual.

   - If electrical control is operating properly, check BCS assembly. It could be stuck in the vent position. If BCS assembly is stuck, replace and retest.
   - If electrical control circuits are not operating properly, repair as needed and retest.

11. EGR Valve Operation

NOTE: See “Diagnostic Software Operation” section in this manual for specific EST software procedures to do this test.

Purpose

Check for correct Exhaust Gas Recirculation (EGR) valve operation.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)

Possible Causes

- Valve motion interference
- Failed electrical circuits or components

Procedure

1. Turn ignition switch to ON.
2. Open COM device.
3. Select Key On Engine Off Tests. From the drop down menu, select Output State Tests, then select Output State Low Test.
4. Record EGR valve position on Diagnostic Form.
5. Select Key On Engine Off Tests. From the drop down menu, select Output State Tests, then select Output State High Test.
6. Verify EGR valve position. See “Performance Specifications” (page 427).
    - If Output State Low and High tests are in specification, no repair is required.
    - If Output State Low and High tests are not in specification, fix problem. Test again to verify repair.

12. Road Test (Full load, rated speed)

NOTE: See “Diagnostic Software Operation” section in this manual for specific Electronic Service Tool (EST) software procedures to do this test.

Purpose

Check engine performance at full load and rated speeds by means of maximum boost, minimum fuel pressure, and minimum injection control pressure.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)

Unacceptable Boost Possible Causes

- Boost leaks
- Restricted intake or exhaust
- Control system faults
- Biased BAP, EBP, ICP, or MAP sensors
- Power cylinder condition
- Low fuel pressure
- Low Injection Control Pressure
- Failed EGR valve
- Failed turbocharger
- Failed fuel injectors

Unacceptable Injection Control Pressure Possible Causes

- Low pressure or aeration of lube oil
- Incorrect feedback from APS or ICP sensor
- High-pressure system leaks
- Fuel injector oil leaks
- IPR failure
- Circuit faults (ICP, IPR)
- Failed high-pressure pump
- Failed fuel injectors

Unacceptable Fuel Pressure Possible Causes

- Primary or secondary filter blockage
- Incorrect fuel grade for cold climate
- Debris, water, or ice in fuel system
- Oil, gasoline, or kerosene present in fuel system
- Combustion gases entering fuel system
- Fuel supply line leak, damage, or blockage
- Air leak in suction side fuel line or filter assembly
- Failed fuel regulator valve
- Failed fuel pump

Unacceptable Exhaust Back Pressure Possible Causes

- Restricted exhaust
- Restricted Diesel Particulate Filter (DPF)
- Restricted Diesel Oxidation Catalyst (DOC)
- Biased Exhaust Back Pressure (EBP) sensor or plugged EBP tube

Procedure

1. See “Performance Specifications” (page 427) appendix.
2. Start engine and run until engine coolant temperature is above 70 °C (158 °F).
3. Open COM device.
4. Open Road Performance session.
5. Set the Road Performance snapshot to record at 0.2 second interval for the following PIDs:
   - Boost pressure / (MAP)
   - Injection Control Pressure (ICP)
   - Engine speed / (rpm)
   - Exhaust Back Pressure (EBP)
   - Engine load (EL %)
6. Find an open stretch of road. Start snapshot recording. When driving conditions are safe, select a suitable gear, press accelerator pedal to the floor, and accelerate to rated speed at 100% Engine Load. See “Performance Specifications” Engine rating for rated speed.
7. When road test is complete, stop snapshot recording.
8. Save snapshot for review and future reference.
9. Review snapshot in text form, scroll down to Rated speed at 100% Engine Load.
   - If boost pressure is below specification, diagnose low performance problem.
   - If EBP is above specification, diagnose high exhaust back pressure problem.
   - If ICP is not in specification, diagnose ICP problem.
   - If results are within specification, there is no acceleration performance problem.

13. Exhaust Restriction

Purpose

Check for exhaust system restrictions causing hard start, no start, or engine performance problems.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)

Possible Causes

- Turbocharger problem
- Damaged or biased Exhaust Back Pressure (EBP) sensor or plugged EBP tube
- Restricted or damaged exhaust piping or components
- Clogged Diesel Oxidation Catalyst (DOC)
- Clogged Diesel Particulate Filter (DPF)

Procedure

1. See “Performance Specifications” (page 427) for High Idle Exhaust Back Pressure (EBP) specification and record on Diagnostic Form.
2. Turn ignition switch to ON.
3. Open COM device.
4. Open KOER_AirManagement session.
5. Unplug EGR valve harness connection during the test. Ignore DTC that will set.
6. Start and run engine at high idle, no load.

WARNING: To prevent personal injury or death, make sure engine has cooled before removing components.

7. Record exhaust back pressure on Diagnostic Form.
   - If exhaust back pressure is in specification, reconnect EGR valve and clear DTCs. No repair is required.
   - If exhaust back pressure is above specification, continue to next step.
8. Remove exhaust down pipe from turbocharger outlet and test again.
   - If exhaust back pressure is in specification, reconnect EGR valve, clear DTCs, and repair problem between turbocharger outlet and tailpipe.
   - If exhaust back pressure is above specification, reconnect exhaust pipe, reconnect EGR valve, clear DTCs, and repair problem with turbocharger.

14. Crankcase Pressure

Purpose

Measure the condition of the power cylinders.

Tools

- Magnehelic gauge on gauge bar or Water Manometer
- Oil Fill Extension (page 399)
- Crankcase Pressure Test Adapter (page 398)
- Heater hose pliers

Possible Causes

High oil consumption and excessive crankcase pressure may indicate the following:

- Dirt in air induction system
- Badly worn or broken piston rings
- Cylinder walls badly worn or scored
- Leaking valve seals or worn valve guides
- A restricted orifice in the Crankcase Pressure Test Adapter
- Failed turbocharger

Normal oil consumption and excessive crankcase pressure may indicate the following:

A restricted orifice in the Crankcase Pressure Test Adapter

Procedure

1. See “Appendix A: Performance Specifications” (page 427).
2. Park vehicle on level ground.
3. Make sure engine oil level is not above operating range and the oil level gauge is secured.

   Make sure crankcase breather hose is clean and secure in crankcase breather assembly, and the crankcase breather assembly and the valve cover are tight.
4. Make sure all hoses are secure and not leaking.
5. Clamp off crankcase breather hose with heater hose pliers.
6. Remove oil fill cap.
7. Install Oil Fill Extension in the oil fill cap opening
8. Install the Crankcase Pressure Test Adapter on the Oil Fill Extension.

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

WARNING: To prevent personal injury or death, when routing test line, do not crimp line, run line too close to moving parts, or let line touch hot engine. Secure the gauge and test line to not obstruct vehicle operation.

9. Connect a test line from the Crankcase Pressure Test Adapter to the magnehelic gauge on the gauge bar or to a water manometer.
10. Start engine and run until engine coolant temperature is above 70 °C (158 °F) before measuring crankcase pressure.
11. Run engine at high idle. Allow the gauge reading to stabilize before taking crankcase pressure reading.
    - If crankcase pressure is in specification, continue to Injector Disable test (page 177)
    - If pressure is above specification, continue to next step.
12. Do Manual Compression test to identify suspect cylinders.
13. Do Injector Disable test (page 177) to further identify suspect cylinders.

15. Injector Disable

NOTE: See “Diagnostic Software Operation” section in this manual for specific Electronic Control Module (EST) software procedures to do this test.

Purpose

To help determine the cause of uneven cylinder power and rough idle.

NOTE: The Injector Disable test is used in conjunction with the Relative Compression test to distinguish between an injector problem or a mechanical problem.

Tools

- EZ-Tech® Electronic Service Tool (EST) (page 389) with MasterDiagnostics® software
- IC4–USB Interface Cable (page 390)

Possible Causes

- OPEN or short injector wiring
- Failed injector
- Failed ECM
- Power cylinder issue

Procedure

NOTE: Before doing this test, all preceding tests must be completed.

1. Start engine and connect EST to vehicle.
2. Open COM device.
3. Select Diagnostics from menu bar.
4. Select V6 Injector Disable test from drop down menu.

   NOTE: Run Injector Disable test only when engine temperature reaches 70 °C (158 °F) or higher. The EOT indicator will change from red to green when engine temperature reaches 70 °C (158 °F).
5. Select cylinder number and select Run. (Injector selected will be disabled and engine idle should change.)
6. Record results on Diagnostic Form.
7. Select Normal Operation. Injector will be enabled and engine noise should return to previous state of operation.
8. Repeat steps 6 and 7 for the remaining cylinders.

   NOTE: Listen for tone changes from cylinder to cylinder.

   - If test does not identify a suspect cylinder, do Manual Compression Test.
   - If test identifies a suspect cylinder do not repair injectors without completing both the Injector Disable and Manual Compression tests.

16. Manual Compression Test

Purpose

To measure the condition of the power cylinders

Tools

- Cylinder Compression Gauge (page 399)
- Compression Test Adapter (page 399)
- Glow Plug Socket

Possible Causes

- Loose fuel injector
- Valve train damage
- Power cylinder damage

Procedure

WARNING: To prevent personal injury or death, ensure engine starting capability is disabled before doing Compression Test procedures.

1. Disconnect CMP or CKP sensor connector to disable engine starting.
2. Remove glow plug from cylinder 2 following the procedure in *Engine Service Manual*. It is not necessary to remove the valve covers.

   NOTE: Left bank cylinders include 2, 4, 6, and 8. Right bank cylinders include 1, 3, 5, and 7.
3. Inspect Compression Test Adapter O-ring. Ensure O-ring is intact and seated correctly.
4. Install and hand tighten Compression Test Adapter.
5. Connect Cylinder Compression Gauge to adapter.
6. Turn ignition switch to ON. Crank engine at least 3 but no more than 4 revolutions.

   NOTE: If more than 4 revolutions occur, bleed air from Cylinder Compression Gauge. Repeat cranking procedure.
7. Record pressure on Diagnostic Form.
8. Bleed pressure from gauge, then disconnect Cylinder Compression Gauge from adapter. Remove Compression Test Adapter.
9. Reinstall glow plug using Glow Plug Installer Sleeve and Glow Plug Socket. Follow the procedure in *Engine Service Manual*.
10. Repeat Steps 2 through 9 for all remaining individual glow plugs.
    - If pressure difference is within 10 percent of each other, there is no mechanical cylinder balance problem.
    - If pressure difference is greater than 10 percent of each other, contact International® Technical Services at 1-800-336-4500 to start a case file.