DIAGNOSTIC/TROUBLESHOOTING MANUAL

EGES-270-1

August 2008

Read all safety instructions in the "Safety Information" section of this manual before doing any procedures.
Follow all warnings, cautions, and notes.

DIAGNOSTIC/TROUBLESHOOTING MANUAL

International® DT 466, DT 570, and HT 570

DIESEL ENGINE

EGES-270-1

Printed in the United States of America

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Foreword

International Truck and Engine Corporation 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.

Technical Service Literature

1171809R5	*DT 466, DT 570 and HT 570 Engine Operation and Maintenance Manual*
EGES-265-1	*DT 466, DT 570 and HT 570 Service Manual*
EGES-270	*DT 466, DT 570 and HT 570 Diagnostic Manual*
EGED-285	DT 466, DT 570 and HT 570 Electronic Control Systems Diagnostic Form (Pad of 50)
EGED-290-1	DT 466, DT 570 and HT 570 Diagnostic Form (Pad of 50)

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.

To order technical service literature, contact your International dealer.

Service Diagnosis

Service diagnosis is an investigative procedure that must be followed to find and correct an engine application problem or an engine problem.

If the problem is engine application, see specific vehicle manuals for further diagnostic information.

If the problem is the engine, see specific *Engine Diagnostic Manual* for further diagnostic information.

Prerequisites for Effective Diagnosis

- Availability of gauges and diagnostic test equipment
- Availability of current information for engine application and engine systems
- Knowledge of the 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

- *Engine Service Manual*
- *Engine Diagnostic Manual*
- Diagnostics Forms
- Electronic Control Systems Diagnostics Forms
- Service Bulletins

Safety Information

This manual provides general and specific maintenance 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.

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

Disregard for Safety Instructions, Warnings, Cautions, and Notes in this manual can lead to injury, death or damage to the engine or vehicle.

Safety Terminology

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

Warning: A warning describes actions necessary to prevent or eliminate conditions, hazards, and unsafe practices that can cause personal injury or death.

Caution: A caution describes actions necessary to prevent or eliminate conditions that can cause damage to the engine or vehicle.

Note: A note describes actions necessary for correct, efficient engine operation.

Safety Instructions

Work Area

- Keep work area clean, dry, and organized.
- Keep tools and parts off the floor.
- Make sure the 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 safety glasses and shoes.
- Wear correct hearing protection.
- Wear cotton work clothing.
- Wear sleeved heat protective gloves.
- Do not wear rings, watches or other jewelry.
- Restrain long hair.

Vehicle

- Make sure the vehicle is in neutral, the parking brake is set, and the wheels are blocked before servicing engine.
- Clear the area before starting the engine.

Engine

- The engine should be operated or serviced only by qualified individuals.
- Provide necessary ventilation when operating engine in a closed area.
- Keep combustible material away from engine exhaust system and exhaust manifolds.
- Install all shields, guards, and access covers before operating engine.
- Do not run engine with unprotected air inlets or exhaust openings. If unavoidable for service reasons, put protective screens over all openings before servicing engine.
- Shut engine off and relieve all pressure in the system before removing panels, housing covers, and caps.
- If an engine is not safe to operate, tag the engine and ignition key.

Fire Prevention

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

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

1. Type A — Wood, paper, textiles, and rubbish
2. Type B — Flammable liquids
3. Type C — Electrical equipment

Batteries

- 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 open 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 the 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 the 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

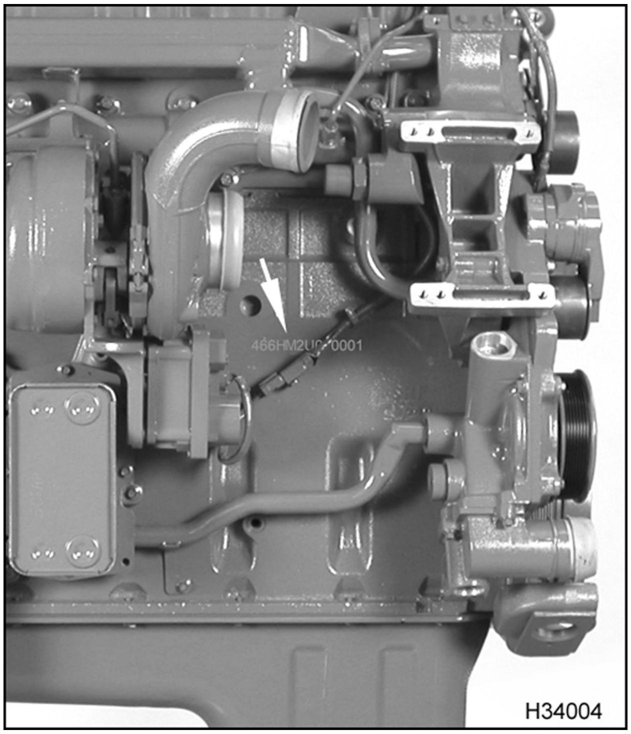


Figure 1 Engine serial number

The engine serial number is in two locations:

- Stamped on a crankcase pad on the right side of the crankcase below the cylinder head
- On the engine emission label on the valve cover

Engine Serial Number Examples

DT 466 engine: 466HM2U2000001

DT 570 engine: 570HM2U2000001

Engine Serial Number Codes

466 – Engine displacement
570 – Engine displacement
H – Diesel, turbocharged, Charge Air Cooler (CAC), and electronically controlled
M2 – Motor truck
A2 – Unknown (Stripped and service engines)
U – United States
7 digit suffix – Engine serial number sequence beginning with 2

Engine Emission Label

A common emission label is issued for the International® DT 466 and DT 570 diesel engines.

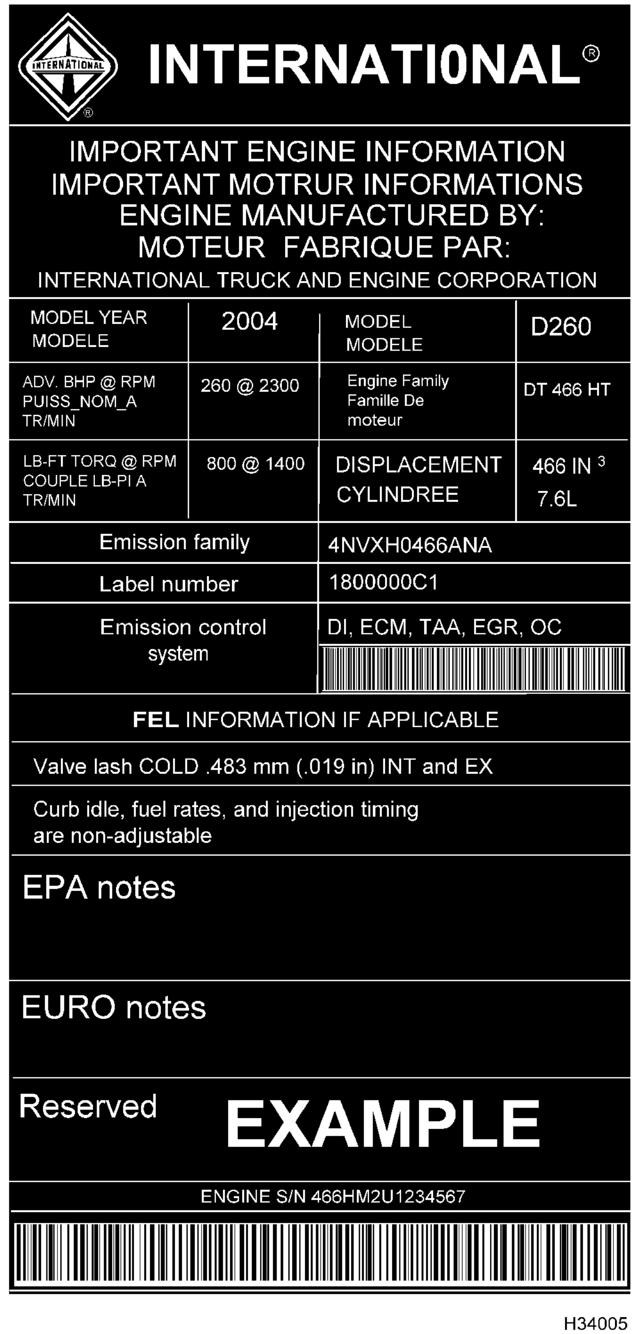


Figure 2 Engine emission label (Example)

The Environmental Protection Agency (EPA) emission label is on top of the valve cover. The engine label includes the following:

- Model year
- Engine family, model, and displacement
- Advertised brake horsepower and torque rating
- Emission family and control systems
- U.S. Family Emission Limits (FEL), if applicable
- Valve lash specifications
- Engine serial number
- EPA, EURO, and reserved fields for specific applications

Engine Accessories

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

- Air compressor (for brake or suspension system)
- Air conditioning compressor
- Alternator
- Cooling fan clutch
- EVRT® electronically controlled turbocharger – International's version of a Variable Geometry Turbocharger (VGT)
- Power steering pump
- Starter motor

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

Engine Description

International® DT 466 , DT 570, and HT 570 Features and Specifications	
Engine	4 stroke, inline six cylinder diesel
Configuration	Four valves per cylinder
Displacement	7.6 L (466 in^3)
Displacement	9.3 L (570 in^3)
Bore (sleeve diameter)	116.6 mm (4.59 in)
Stroke	
• DT 466	119 mm (4.68 in)
• DT 570 and HT 570	146 mm (5.75 in)
Compression ratio	
• DT 466	16.5 : 1
• DT 570 and HT 570	17.5 : 1
Aspiration	VGT turbocharged and Charge Air Cooled (CAC)
Rated power @ rpm[1]	
• DT 466	210 bhp @ 2600 rpm
• DT 570	285 bhp @ 2200 rpm
Peak torque @ rpm[1]	
• DT 466	520 lbf•ft @ 1400 rpm
• DT 570	800 lbf•ft @ 1200 rpm
Engine rotation (facing flywheel)	Counterclockwise
Combustion system	Direct injection turbocharged
Fuel system	International® electro-hydraulic generation 2 injection
Total engine weight (dry without accessories)	
• DT 466	671 kg (1,480 lbs)
• DT 570 and HT 570	708 kg (1,560 lbs)
Cooling system capacity (engine only)	12.8 L (13.5 qts US)
Lube system capacity (including filter)	28 L (30 qts US)
Lube system capacity (overhaul only, with filter)	34 L (36 qts US)
Firing order	1-5-3-6-2-4

1 Base rating shown. See Appendix A or B in this manual for additional ratings.

Engine Features

Standard Features	Optional Features
Four valves per cylinder	Air compressor
Dual timing sensors	Power steering pump
Replaceable piston and sleeve configuration	Front cover PTO access
Gerotor lube oil pump	Engine Fuel Pressure (EFP) sensor
International® electro-hydraulic generation 2 injection system	Diamond Logic® engine brake
Variable Geometry Turbocharger (VGT)	Diamond Logic® exhaust brake
Exhaust Gas Recirculation (EGR)	Fuel heater
Water supply housing (Freon® compressor bracket)	Oil pan heater
Alternator bracket	Coolant heater assembly
Control modules	
Water In Fuel (WIF) separation	
Water In Fuel (WIF) sensor	
Inlet Air Heater (IAH)	

Standard Features

DT 466, DT 570, and HT 570 are inline six cylinder engines (medium range). Engine displacements are 7.6 liters (466 cubic inches) for the DT 466 and 9.3 liters (570 cubic inches) for the DT 570, and HT 570. The firing order of the cylinders is 1–5–3–6–2–4.

The cylinder head has four valves per cylinder for improved air flow. Each fuel Injector is centrally located between the four valves and directs fuel over the piston bowl for improved performance and reduced emissions. The overhead valve train includes mechanical roller lifters, push rods, rocker arms, and dual valves that open using a valve bridge.

A one piece crankcase withstands high-pressure loads during diesel operation.

The lower end of the DT 570 and HT 570 engines (for ratings above 300 hp) includes a crankcase ladder designed to absorb additional loads generated by increased horsepower. Seven main bearings support the crankshaft for DT 466, DT 570, and HT 570 engines. Fore and aft thrust are controlled at the rear bearing. Four insert bushings support the camshaft. The rear oil seal carrier is part of the flywheel housing. The open crankcase breather assembly uses a road draft tube to vent crankcase pressure and an oil separator that returns oil to the crankcase.

The crankshaft (CKP) and camshaft (CMP) sensors are used by the ECM and IDM to calculate rpm, fuel timing, fuel quantity, and duration of fuel injection.

Two different types of pistons are used in the inline engines:

- The DT 466 engine has one piece aluminum alloy pistons.
- The DT 570 and HT 570 engines have two piece articulated pistons with a steel crown.

All pistons are mated to fractured cap joint connecting rods. Replaceable wet cylinder sleeves are used with the pistons.

A gerotor lube oil pump, mounted to the front cover, is driven directly by the crankshaft. All engines use an oil cooler and spin-on oil filter.

A low-pressure fuel supply pump draws fuel from the fuel tank through a fuel filter assembly that includes a strainer, filter element, primer pump, drain valves, and Water In Fuel (WIF) sensor. After filtering, fuel is pumped to the cylinder head fuel rail.

The International® electro-hydraulic generation 2 injection system includes a cast iron oil manifold, fuel injectors, and a high-pressure oil pump.

The VGT has actuated vanes in the turbine housing. The vanes modify flow characteristics of exhaust gases through the turbine housing. The benefit is the ability to control boost pressure for various engine speeds and load conditions. An additional benefit is lower emissions.

An EGR control valve regulates cooled exhaust gases entering the inlet air stream. Cool exhaust gas increases engine tolerance for EGR, while reducing smoke formed by gas dilution in the mixture. Three EGR coolers are available depending on applications.

The water supply housing, which includes auxiliary water connections, serves the dual function as the Freon® compressor bracket.

Three control modules monitor and control the electronic engine systems:

- Diamond Logic® engine controller – Electronic Control Module (ECM)
- Injector Drive Module (IDM)
- Exhaust Gas Recirculation (EGR) drive module

Water In Fuel (WIF) separation occurs when the filter element repels water molecules and water collects at the bottom of the element cavity in the fuel filter housing.

A Water In Fuel (WIF) sensor in the element cavity of the fuel filter housing detects water. When enough water accumulates in the element cavity, the WIF sensor signal changes to the Electronic Control Module (ECM). The ECM sends a message to illuminate the amber water and fuel lamp, alerting the operator. A fuel drain valve handle on the housing can be opened to drain water from the fuel filter housing.

Optional Features

An air compressor is available for applications requiring air brakes or air suspension.

A hydraulic power steering pump can be used with or without an air compressor.

The front cover includes a mounting flange for Power Take Off (PTO) accessories. The air compressor drive gear train, used with a spline adapter, provides power for front mounted PTO accessories.

An optional Engine Fuel Pressure (EFP) sensor detects low pressure caused by high fuel filter restriction and sends a signal to the ECM; the ECM illuminates the amber FUEL FILTER lamp on the instrument panel.

The Diamond Logic® exhaust brake system uses only the VGT to restrict exhaust flow for additional braking. The operator controls the exhaust brake for different operating conditions.

The Diamond Logic® engine brake is new for medium range diesel engines. This compression braking system uses a high-pressure rail assembly and the VGT for additional braking. The operator controls the engine brake for different operating conditions.

The Inlet Air Heater (IAH) warms intake air entering the cylinder head.

Options for vehicles and applications used in cold climates include the following:

- **Oil pan heater**

  The oil pan heater warms engine oil in the pan and ensures oil flow to the injectors.

- **Coolant heater**

  The coolant heater raises the temperature of coolant surrounding the cylinders for improved performance and fuel economy during start-up.

- **Fuel heater**

  The fuel heater (a 300 watt element) in the base of the fuel filter assembly heats the fuel for improved performance.

Engine Component Locations

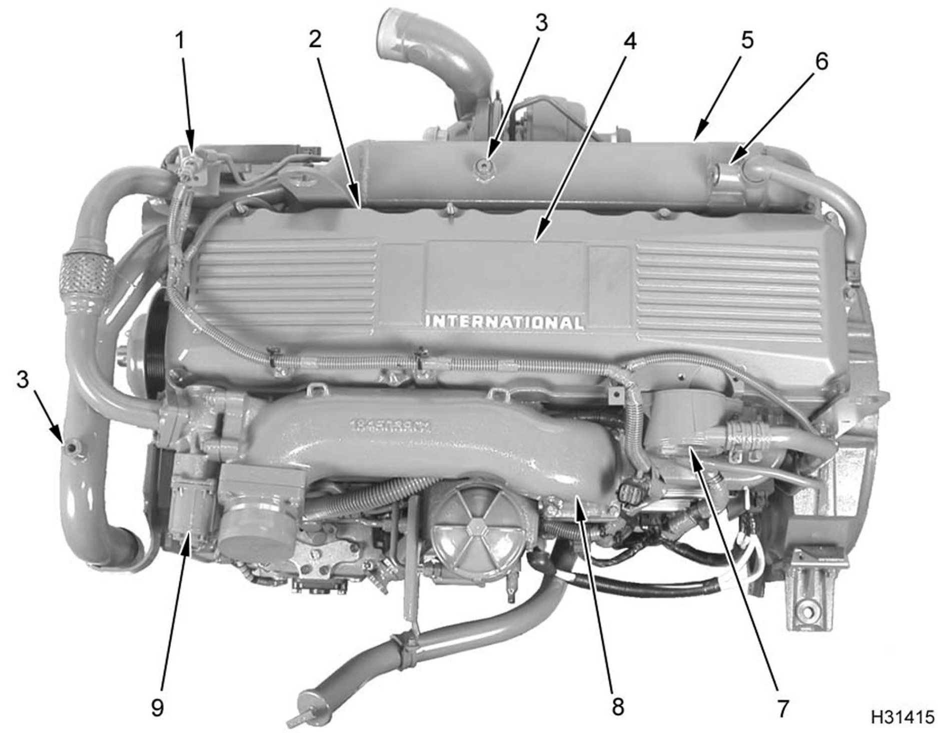


Figure 3 Component location – top

1. Exhaust Back Pressure (EBP) sensor
2. Valve cover
3. Dearation port
4. Exhaust emission label (location)
5. EGR cooler assembly
6. Secondary air heater supply
7. Breather assembly
8. Inlet and EGR mixer duct
9. EGR control valve

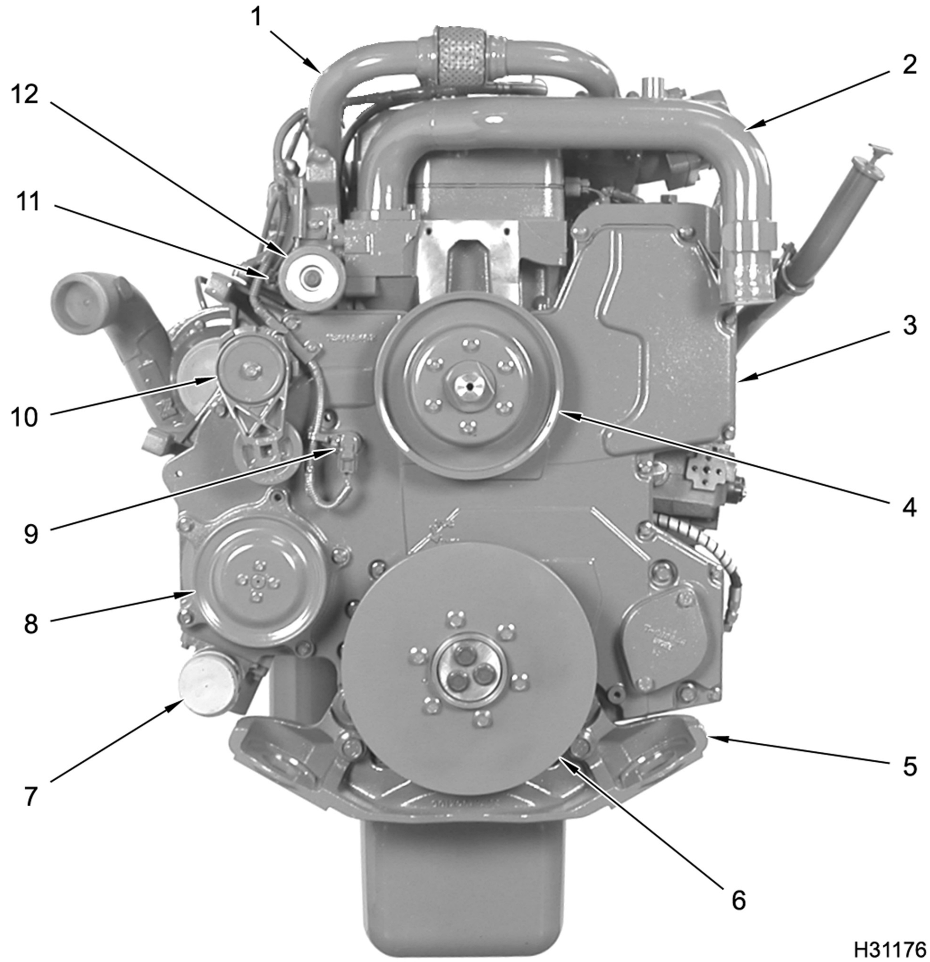


Figure 4 Component location – front

1. Exhaust gas crossover (EGR cooler to EGR valve)
2. Water outlet tube assembly (thermostat outlet)
3. Front cover (front half)
4. Fan drive pulley
5. Engine mounting bracket (front)
6. Vibration damper
7. Water inlet elbow
8. Water pump pulley
9. Camshaft Position (CMP) sensor
10. Auto tensioner assembly (belt)
11. ECT sensor (location)
12. Flat idler pulley assembly

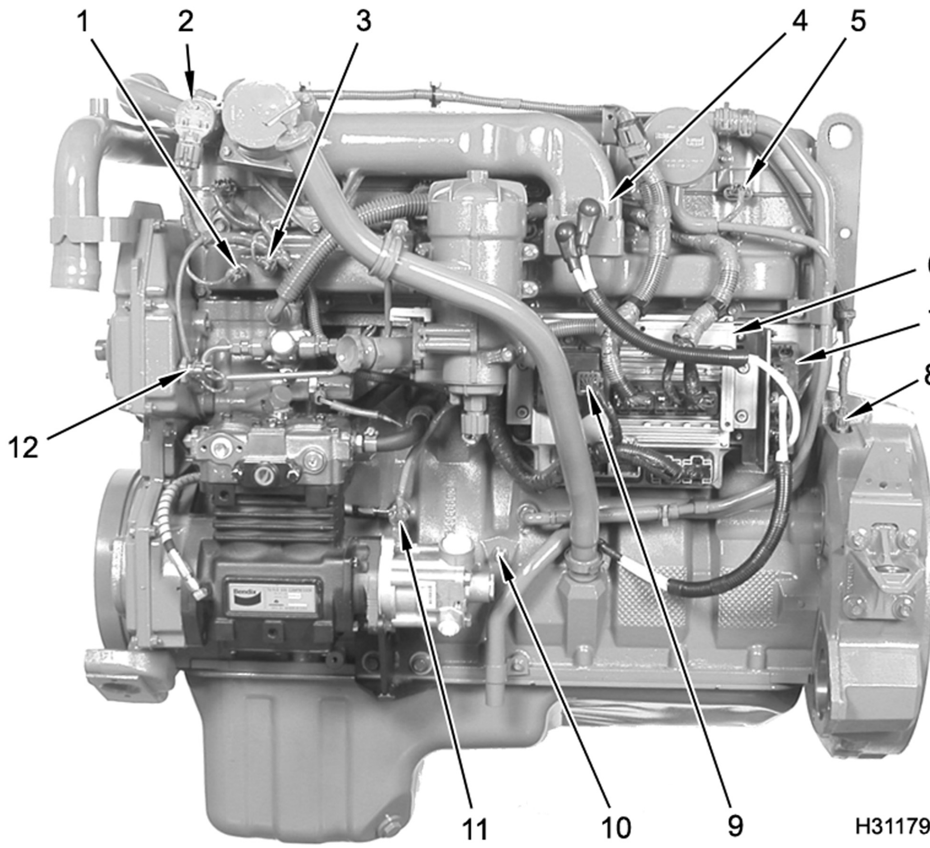


Figure 5 Component location, electrical– left

1. Manifold Absolute Pressure (MAP) sensor
2. EGR control valve
3. Manifold Air Temperature (MAT) sensor
4. Inlet Air Heater (IAH) assembly
5. Valve cover gasket pass-through connector
    a. (Six) four wire connectors for fuel injectors
    b. (One) three wire connector for ICP sensor
    c. Engine brake application – (one) three wire connector for the BCP sensor and (one) three wire connector for the brake shut-off valve.
6. ECM and IDM module assembly
7. IAH relay
8. Crankshaft Position (CKP) sensor
9. EGR drive module
10. Ground stud
11. Engine Oil Pressure (EOP) sensor
12. Engine Oil Temperature (EOT) sensor

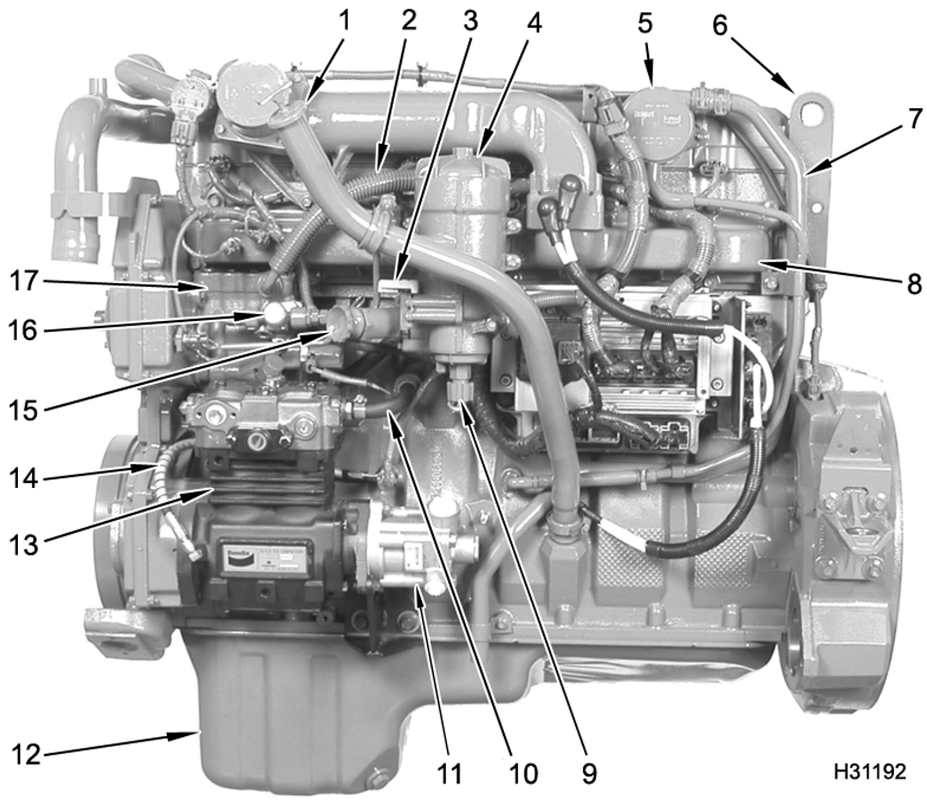


Figure 6 Component location, mechanical – left

1. Oil level gauge tube
2. High-pressure oil hose
3. Water drain valve (fuel)
4. Fuel filter header assembly
5. Breather assembly
6. Lifting eye
7. Vent and drain tube assembly
8. Intake manifold
9. Drain valve (fuel strainer)
10. Coolant hose (supply)
11. Power steering pump
12. Oil pan assembly
13. Air compressor
14. Oil supply line
15. Fuel primer pump assembly
16. Low-pressure fuel supply pump
17. High-pressure oil pump assembly

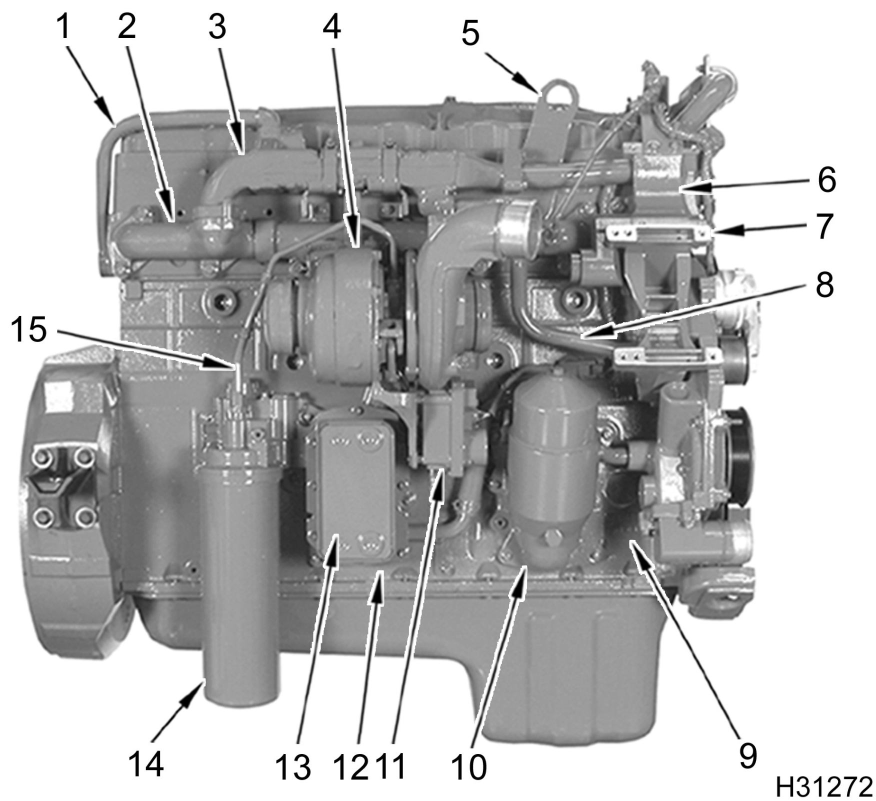


Figure 7 Component location – right

1. EGR cooler return tube assembly
2. Exhaust manifold assembly
3. EGR cooler assembly
4. Variable Geometry Turbocharger (VGT)
5. Lifting eye
6. Water supply housing (Freon® compressor bracket)
7. Alternator bracket
8. EGR cooler supply tube assembly
9. Crankcase
10. Secondary filtration filter (early engines only)
11. Turbocharger control module
12. Coolant drain plug (underneath location)
13. Oil cooler
14. Oil filter
15. Turbo oil inlet tube (supply)

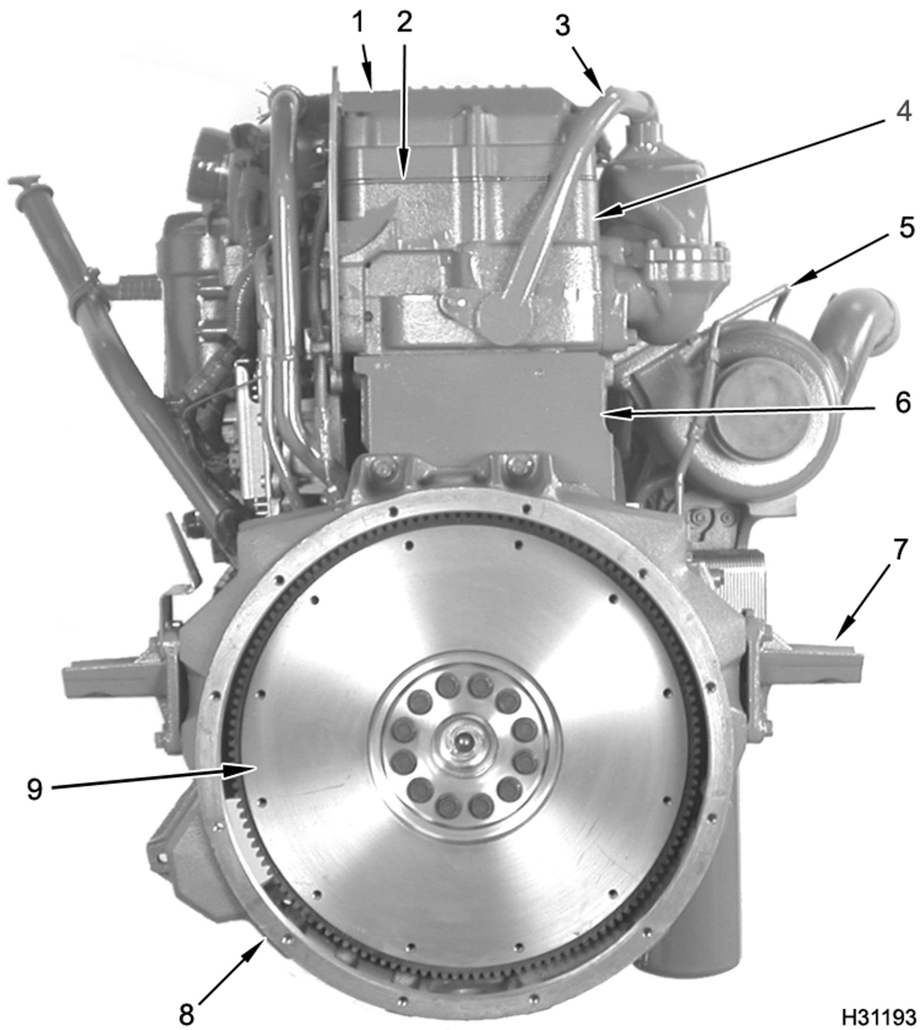


Figure 8 Component location – rear

1. Valve cover
2. Valve cover gasket with pass-through connectors
3. EGR cooler return tube assembly
4. Cylinder head assembly
5. Turbo oil inlet tube (supply)
6. Crankcase
7. Rear engine mount bracket (2)
8. Flywheel housing
9. Flywheel or flexplate assembly

Engine Systems

Engine System Diagram

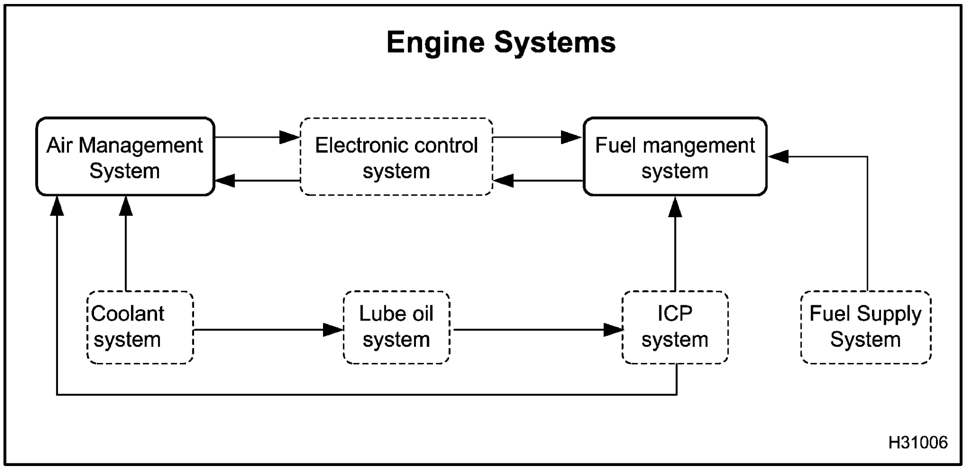


Figure 9 Engine systems

The primary engine 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 sleeves, cylinder head, EGR gases, and lubrication oil.
- The Lube Oil System provides lubrication and heat transfer for engine components.
- The ICP system uses lube oil for hydraulic fluid to actuate the fuel injectors and the optional engine brake.
- The Fuel Supply System pressurizes fuel for transfer to the fuel injectors.

Air Management System

Air Management Components and Air Flow

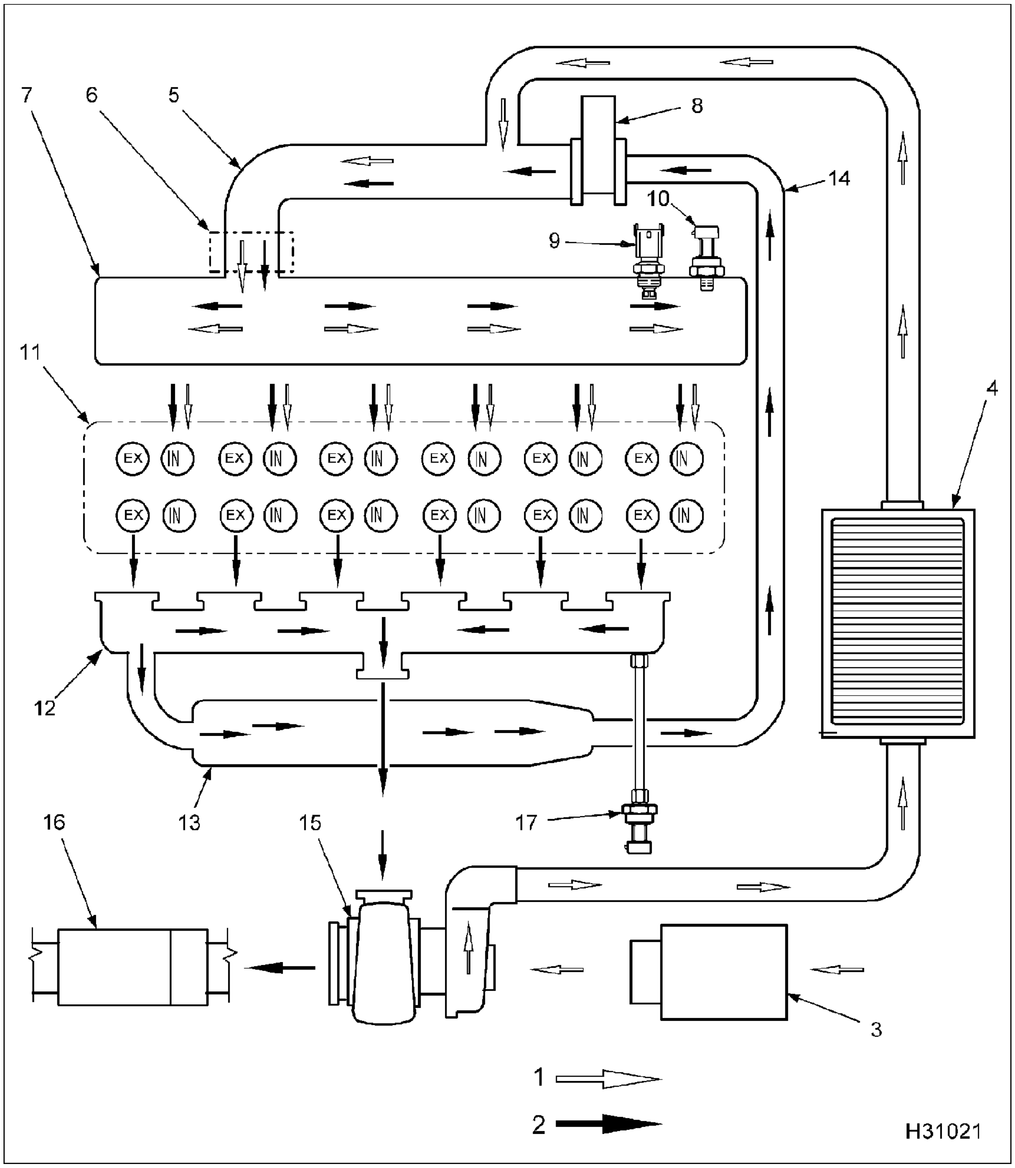


Figure 10 Air Management System (AMS)

1. Intake air
2. Exhaust gas
3. Air filter assembly
4. Charge Air Cooler (CAC)
5. Inlet and EGR mixer duct
6. Inlet Air Heater (IAH) assembly
7. Intake manifold
8. EGR valve
9. Manifold Air Temperature (MAT) sensor
10. Manifold Absolute Pressure (MAP) sensor
11. Cylinder head
12. Exhaust manifold
13. EGR cooler
14. Exhaust gas crossover
15. Variable Geometry Turbocharger (VGT)
16. Muffler
17. Exhaust Back Pressure (EBP) sensor

The Air Management system includes the following:

- Air filter assembly
- Chassis mounted Charged Air Cooler (CAC)
- Variable Geometry Turbocharger (VGT)
- Inlet Air Heater (IAH) assembly
- Intake manifold
- Exhaust Gas Recirculation (EGR) system
- Exhaust system
- Intake and EGR mixer duct
- Diamond Logic® engine brake
- Catalytic converter– dependent on application
- Catalyzed Diesel Particulate Filter (CDPF) – dependent on application

Air Flow

Air flows through the air filter assembly and enters the Variable Geometry Turbocharger (VGT). The compressor in the VGT increases the pressure, temperature, and density of the intake air before it enters the Charge Air Cooler (CAC). Cooled compressed air flows from the CAC into the EGR mixer duct.

- If the EGR control valve is open, exhaust gas will mix with filtered intake air and flow into the intake manifold.
- If the EGR control valve is closed, only filtered air will flow into the intake manifold.

After combustion, exhaust gas is forced through the exhaust manifold to the EGR cooler and VGT.

- Some exhaust gas is cooled in the EGR cooler and flows through the EGR control valve to the EGR mixer duct. When exhaust gas mixes with filtered air, Nitrogen Oxide (NOx) emissions and noise are reduced.
- The rest of the exhaust gas flows to the VGT, spins and expands through the turbine wheel, varying boost pressure.
- The VGT compressor wheel, on the same shaft as the turbine wheel, compresses the mixture of filtered air.

The VGT responds directly to engine loads. During heavy load, an increased flow of exhaust gases turns the turbine wheel faster. This increased speed turns the compressor impeller faster and supplies more air or greater boost to the intake manifold. Conversely, when engine load is light, the flow of exhaust gas decreases and less air is directed into the intake manifold.

Charge Air Cooler (CAC)

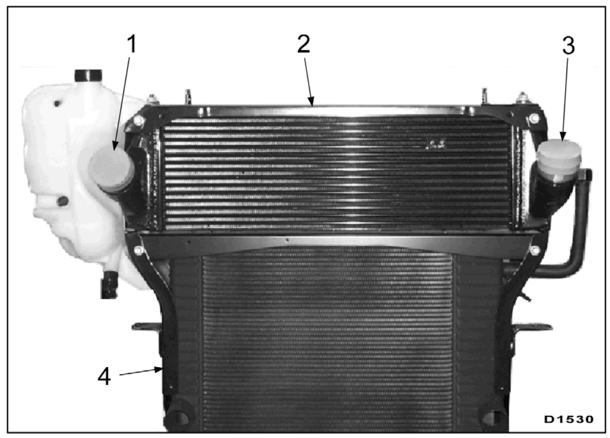


Figure 11 Charge Air Cooler (typical)

1. Air outlet
2. Charge Air Cooler (CAC)
3. Air inlet
4. Radiator

The CAC is mounted on top of the radiator. Air from the turbocharger passes through a network of heat exchanger tubes before entering the EGR mixer duct. Outside air flowing over the tubes and fins cools the charged air. Charged air is cooler and denser than the uncooled air; cooler and denser air improves the fuel-to-air ratio during combustion, resulting in improved emission control and power output.

Variable Geometry Turbocharger (VGT)

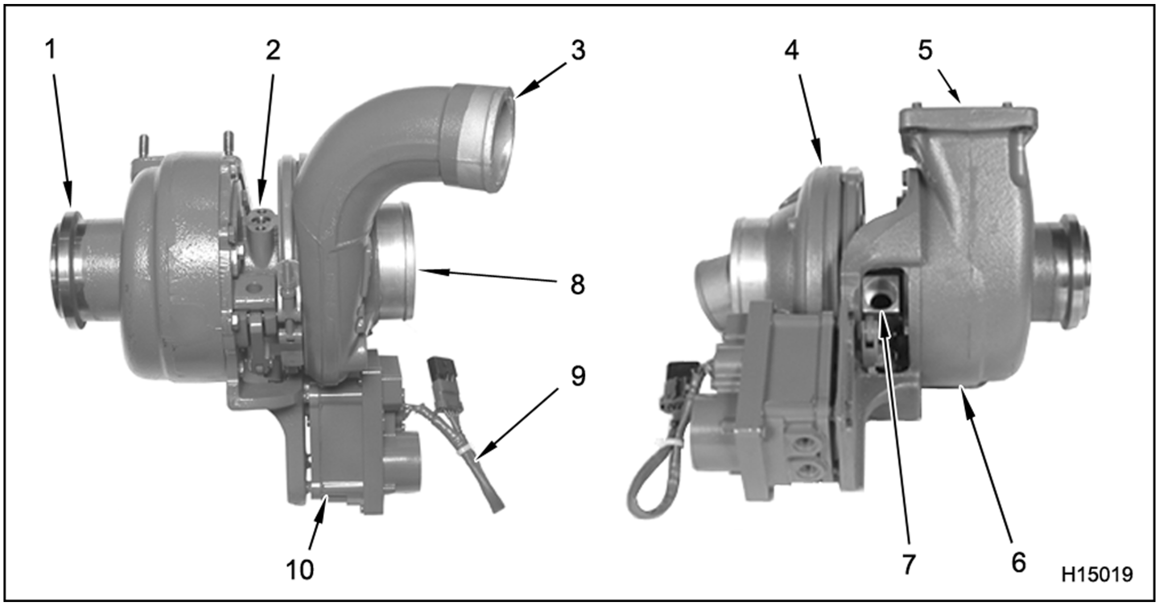


Figure 12 Variable Geometry Turbocharger (VGT)

1. Turbine outlet
2. Oil supply port
3. Compressor outlet
4. Compressor housing
5. Turbine inlet
6. Turbine housing
7. Oil drain port
8. Compressor inlet
9. Electrical connector and wire
10. Turbocharger control module

The Variable Geometry Turbocharger (VGT) has actuated vanes in the turbine housing. The vanes modify flow characteristics of exhaust gases through the turbine housing. The benefit is the ability to control boost pressure for various engine speeds and load conditions. An additional benefit is lower emissions.

VGT Closed Loop System

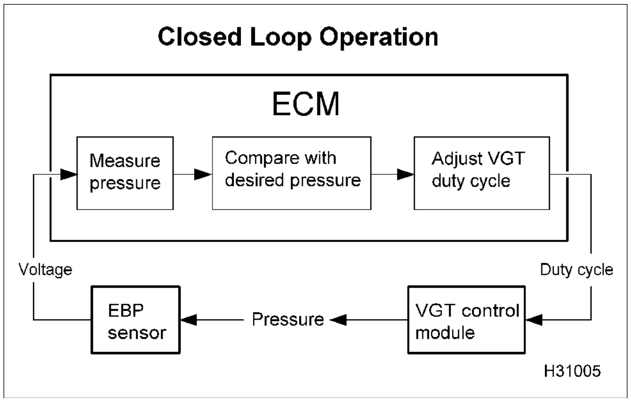


Figure 13 VGT closed loop system

The Variable Geometry Turbocharger (VGT) is a closed loop system that uses the Exhaust Back Pressure (EBP) sensor to provide feedback to the ECM. The ECM uses the EBP sensor to continuously monitor EBP and adjust the duty cycle to the VGT to match engine requirements.

VGT Control

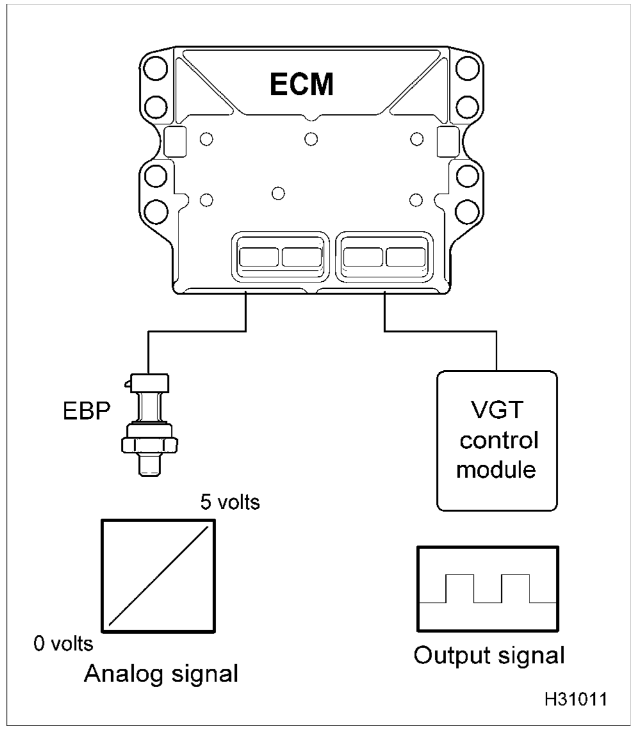


Figure 14 VGT control

The VGT actuator is a control module that contains a microchip and a DC motor. The VGT actuator is located below the turbocharger. The microchip operates a DC motor which rotates a crank lever controlling the vane position in the turbine housing. The position of the vanes is based off the pulse-width modulated signal sent from the ECM.

Actuated vanes are mounted around the inside circumference of the turbine housing. A unison ring links all the vanes. When the unison ring moves, all vanes move to the same position. Unison ring movement occurs when the crank lever in the control module moves.

Exhaust gas flow can be regulated depending on required exhaust back pressure for engine speed and load. As demand for EBP increases, the ECM increases the pulse-width modulation to the VGT control module. When EBP demand decreases, the ECM decreases the duty cycle to the control module.

Exhaust Gas Recirculation (EGR) System

The EGR system includes the following:

- EGR control valve
- EGR cooler
- Air intake manifold
- Inlet and EGR mixer duct
- Exhaust manifold
- Exhaust gas crossover

The Exhaust Gas Recirculation (EGR) system reduces Nitrogen Oxide (NOx) emissions.

NO_x forms during a reaction between nitrogen and oxygen at high temperature during combustion. Combustion starts when fuel is injected into the cylinder before or slightly after the piston reaches top-dead-center.

EGR Flow

Some exhaust from the exhaust manifold flows into the EGR cooler. Exhaust from the EGR cooler flows through the exhaust gas crossover to the EGR valve.

When EGR is commanded, the EGR control valve opens allowing cooled exhaust gases to enter the EGR mixer duct to be mixed with filtered intake air.

EGR Control Valve

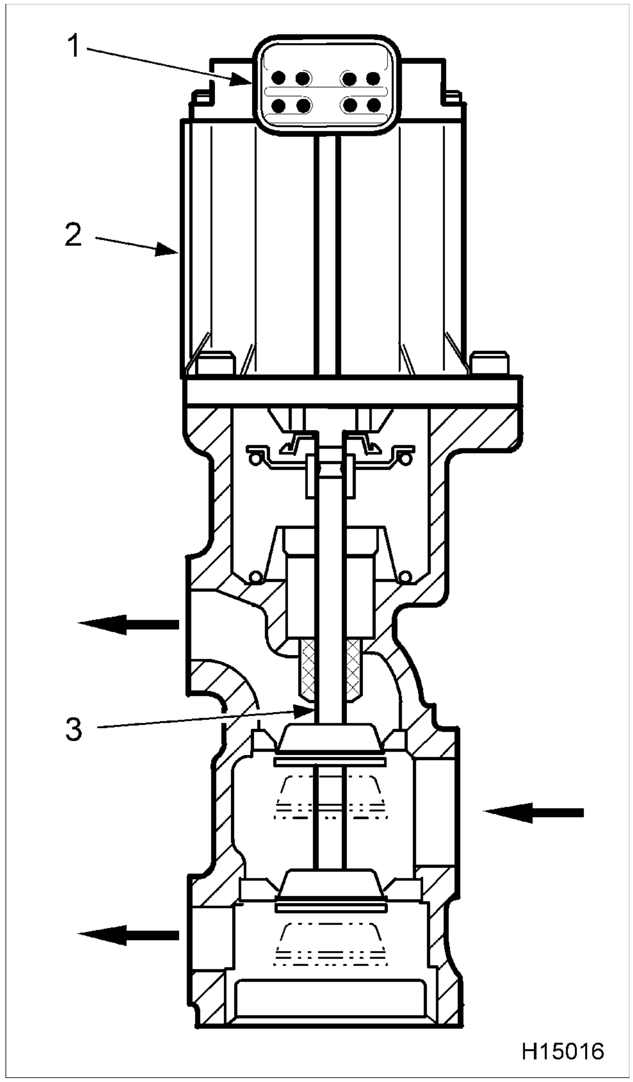


Figure 15 EGR control valve

1. Connector
2. DC motor with position sensor
3. Valve assembly

The EGR valve uses a DC motor to control the position of the valve assembly. The motor pushes directly on the valve assembly. The valve assembly has two valve heads on a common shaft.

The EGR actuator consists of three major components, a valve, an actuator motor, and Integrated Circuit (IC). The IC has three Hall effect position sensors to monitor valve movement. The

EGR actuator is located at the front of the engine on the intake manifold.

EGR Closed Loop System and Control

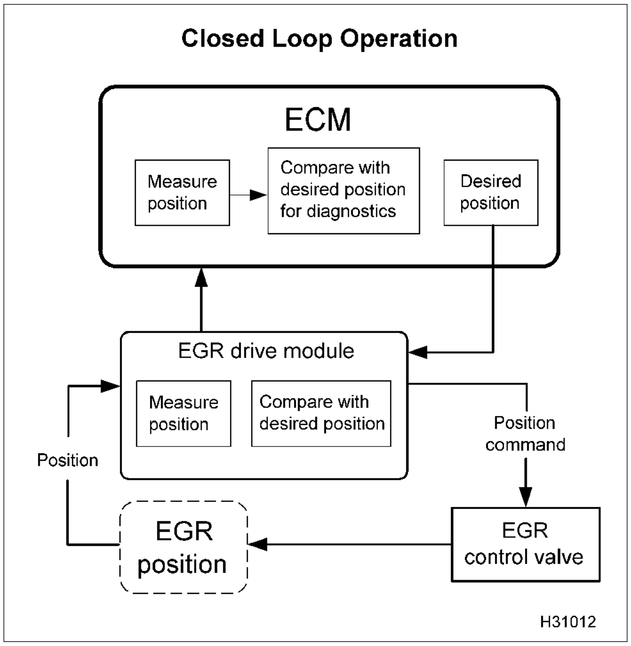


Figure 16 EGR closed loop operation with fault management

The EGR drive module controls the EGR actuator and is located on the left side of the engine on the ECM and Injector Driver Module (IDM).

The EGR drive module receives the desired EGR actuator position from the ECM across the CAN 2 datalink to activate the valve for exhaust gas recirculation. The EGR drive module provides feedback to the ECM on the valve position. The EGR drive module interprets the ECM command and sends the command using three pulse-width modulated signals to the valve actuator.

The system is closed loop control using the EGR position signals.

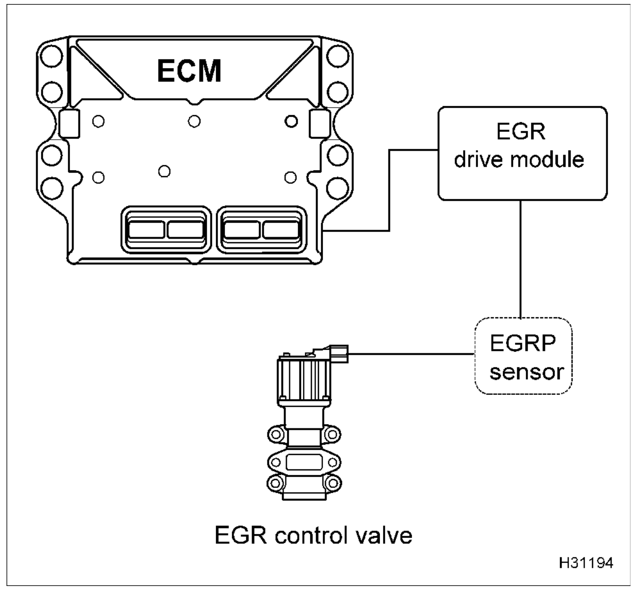


Figure 17 EGR control

Exhaust System

The exhaust system includes the following:

- Exhaust valves
- Exhaust manifold
- Diamond Logic® engine brake
- Variable Geometry Turbocharger (VGT)
- Exhaust piping
- Muffler and catalytic converter – dependent on application
- Catalyzed Diesel Particulate Filter (CDPF) – dependent on application

The exhaust system removes exhaust gases from the engine. Exhaust gases exit from exhaust valves, through exhaust ports, and flow into the exhaust manifold. Expanding exhaust gases are directed through the exhaust manifold. The exhaust manifold directs some exhaust gases into the Exhaust Gas Recirculation (EGR) cooler. Exhaust gases flowing into the turbocharger drive the turbine wheel. Exhaust gases exit the turbocharger and flow into the exhaust piping, through the muffler and catalytic converter or CDPF, depending on application, and out the discharge pipe to the atmosphere.

Fuel Management System

Fuel Management Components

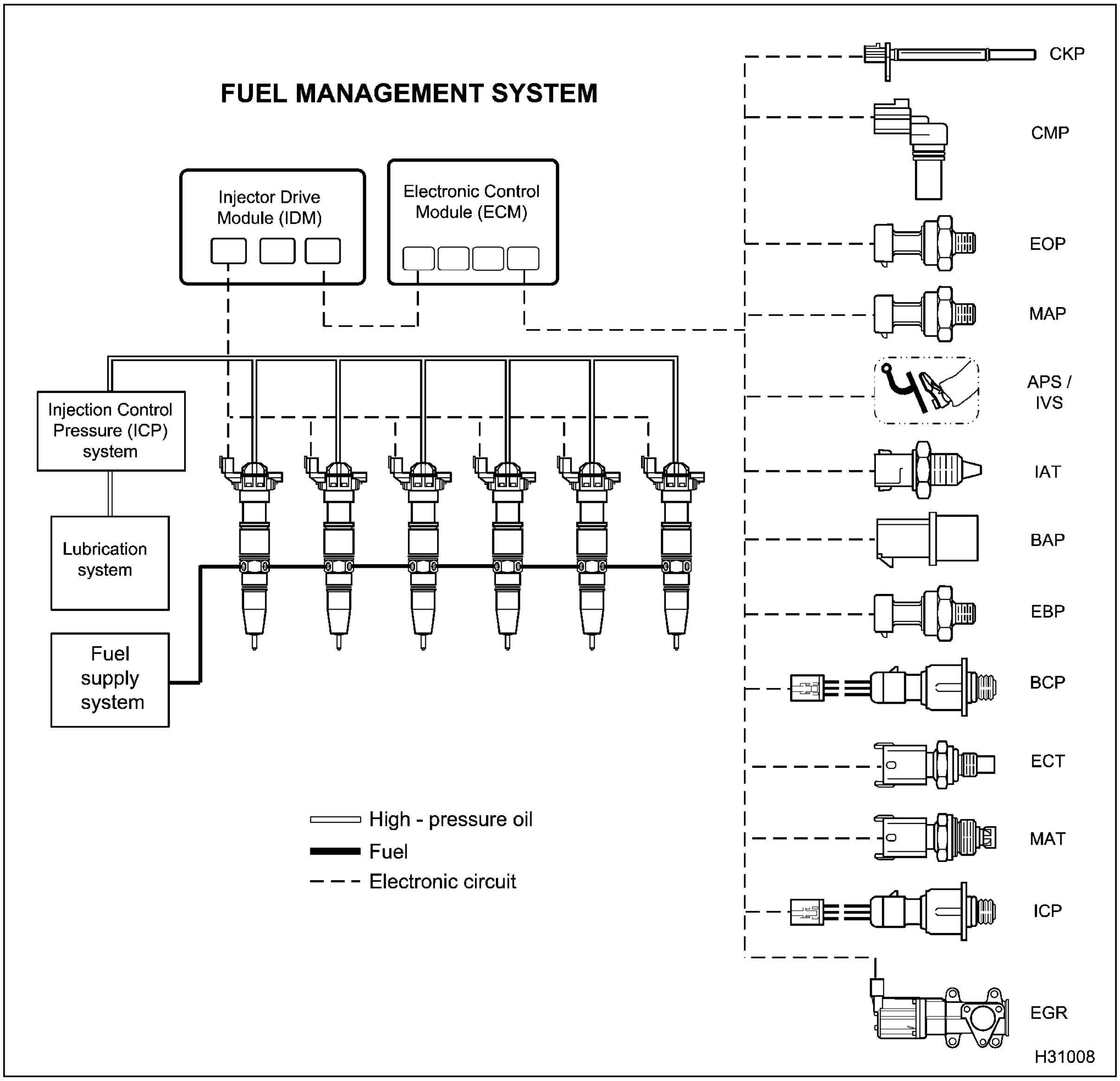


Figure 18 Fuel management system

The fuel management system includes the following:

- Injection Control Pressure (ICP) system
- Fuel supply system
- Fuel injectors
- Lubrication system
- Electronic control system

Injection Control Pressure (ICP) System Components and High-Pressure Oil Flow

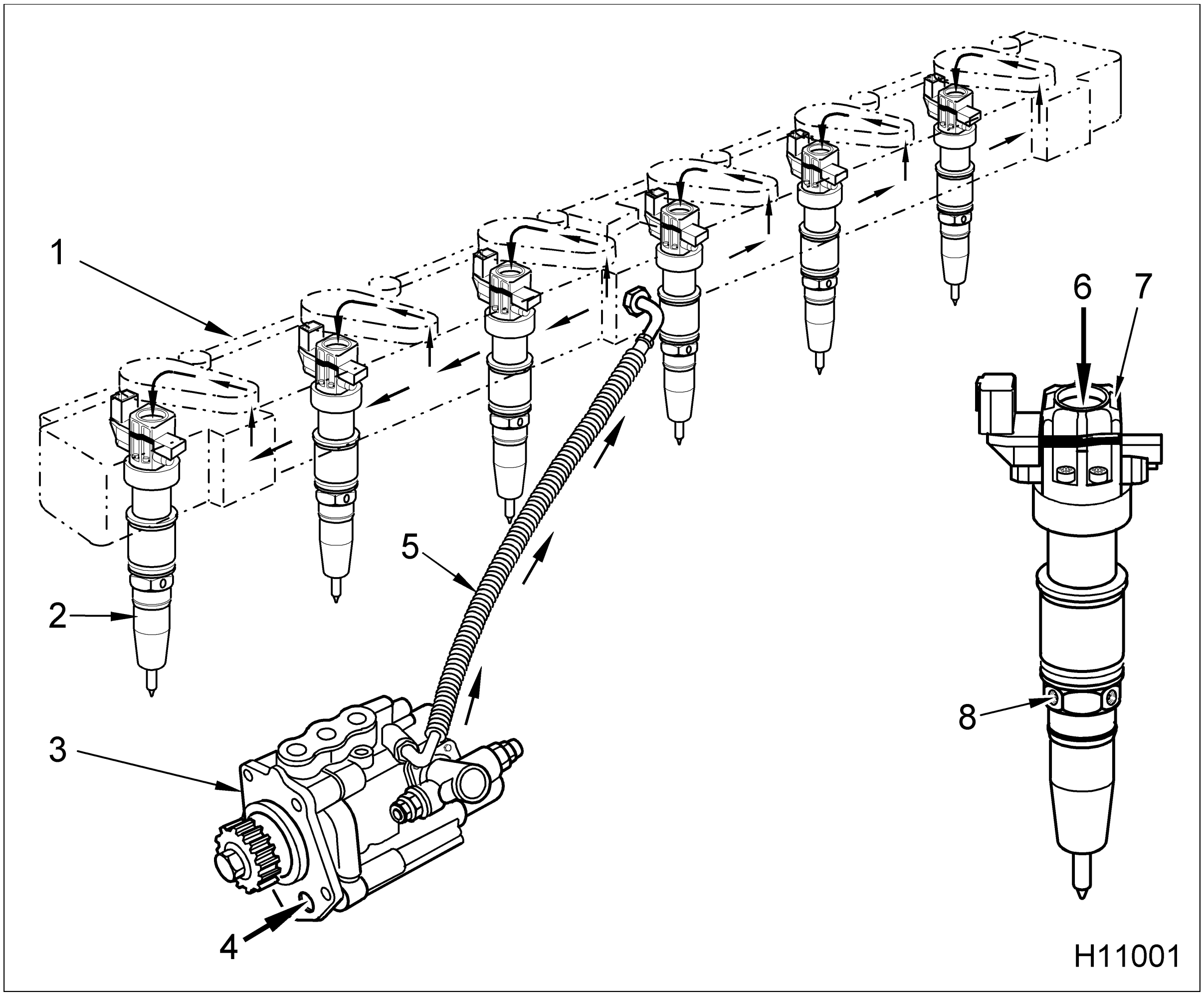


Figure 19 Injection Control Pressure (ICP) system

1. High-pressure oil manifold assembly
2. Fuel injector
3. High-pressure pump assembly
4. Oil inlet (lube oil)
5. High-pressure oil hose
6. High-pressure oil inlet (injector)
7. Oil exhaust port (2)
8. Fuel inlet (4)

High-Pressure Oil Flow

The oil reservoir in the front cover provides a constant supply of oil to a high-pressure oil pump mounted to the backside of the front cover. Oil drawn from the oil reservoir is constantly refilled by the engine lubrication system.

The gear-driven, high-pressure oil pump delivers oil through a high-pressure oil hose, through a cylinder head passage into the high-pressure oil manifold beneath the valve cover. The manifold distributes to the top of each fuel injector.

When the OPEN coil for each injector is energized, the injectors use high-pressure oil to inject and atomize fuel in the combustion chambers. To end injection, the CLOSE coils are energized. Exhaust oil exits through two ports in the top of the fuel injectors, then drains back to sump.

Injection Control Pressure (ICP) Closed Loop System

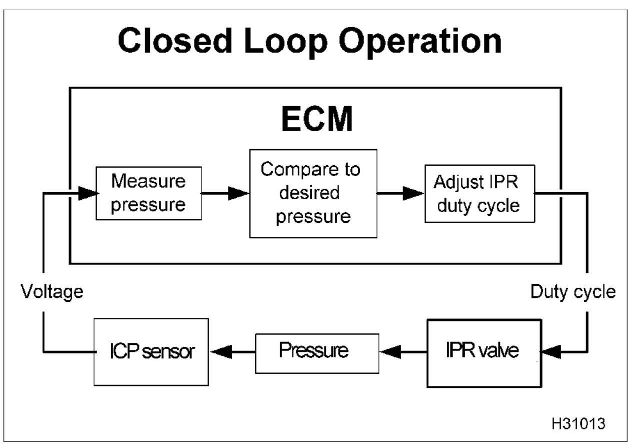


Figure 20 ICP closed loop system

The ICP is a closed loop system that uses the ICP sensor to provide feedback to the ECM. The ECM uses the ICP sensor to continuously monitor injection control pressure and adjust the duty cycle of the IPR valve to match engine requirements.

ICP System Control

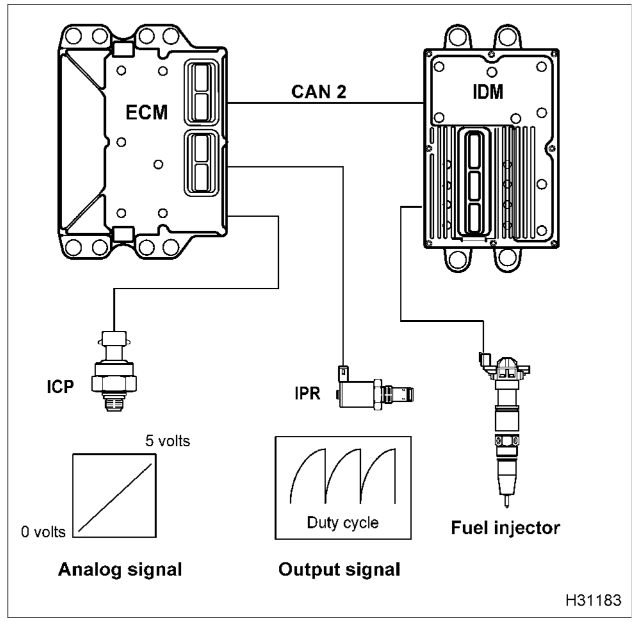


Figure 21 ICP control

ICP Operation

The IPR solenoid receives a pulse-width modulated signal from the ECM that indicates the on and off time the control valve is energized. The pulse is calibrated to control ICP pressure in a range from 5 MPa (725 psi) up to 28 MPa (4,075 psi). Maximum pressure relief occurs at about 32 MPa (4,600 psi).

The IPR valve is mounted in the body of the high-pressure pump. The IPR valve maintains the desired ICP by dumping excess oil back to the crankcase sump.

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.

The ECM sets Diagnostic Trouble Codes (DTCs), if the ICP electrical signal is out-of-range. DTCs are also set if an ICP signal corresponds to an out-of-range value for injection control pressure for a given operating condition.

The ECM will ignore ICP signals that are out-of-range and the IPR valve will operate from programmed default values. This is called Open Loop operation.

The ICP sensor is installed under the valve cover, forward of the No. 6 fuel injector in the high-pressure oil rail.

Fuel Injectors

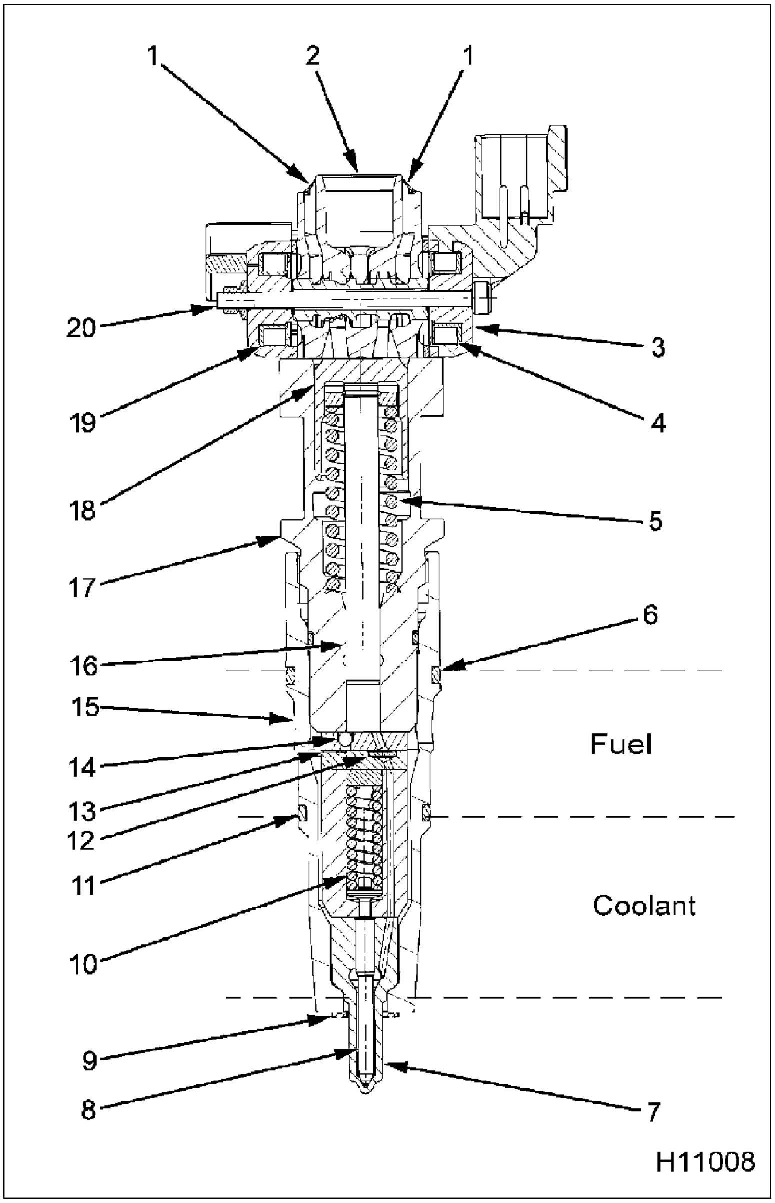


Figure 22 Fuel injector assembly

1. Exhaust port (oil) (2)
2. Inlet port (oil)
3. Control valve body
4. OPEN coil
5. Intensifier piston spring
6. Upper O-ring
7. Nozzle assembly
8. Needle
9. Nozzle gasket
10. Valve Opening Pressure (VOP) spring
11. Lower O-ring
12. Reverse flow check
13. Edge filter
14. Fuel inlet check ball
15. Fuel inlet (4)
16. Plunger
17. Barrel
18. Intensifier piston
19. CLOSE coil
20. Spool valve (control valve)

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 or millionths of a second). Each injector has a single four pin connector that couples to the valve cover gasket assembly.

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:

- When the spool valve is open, oil flows into the injector from the high-pressure oil rail.
- When the spool valve is closed oil exhausts from the top of the fuel injector and drains back to the crankcase.

Intensifier Piston and Plunger

When the spool valve is open, high-pressure oil enters the injector pushing down the intensifier piston and plunger. Since the intensifier piston is 7.1 times greater in surface area than the plunger, the injection pressure is also 7.1 times greater than ICP pressure on the plunger.

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 ICP. The plunger has a diamond-like coating to resist scuffing.

Injector Needle

The injector needle opens inward, off its seat when fuel pressure overcomes the Valve Opening Pressure (VOP) of 28 mPa (4,075 psi). Fuel is atomized at high pressure through the nozzle tip.

Fuel Injector Operation

The injection operation has three stages:

- Fill stage
- Main injection
- End of main injection

Fill Stage

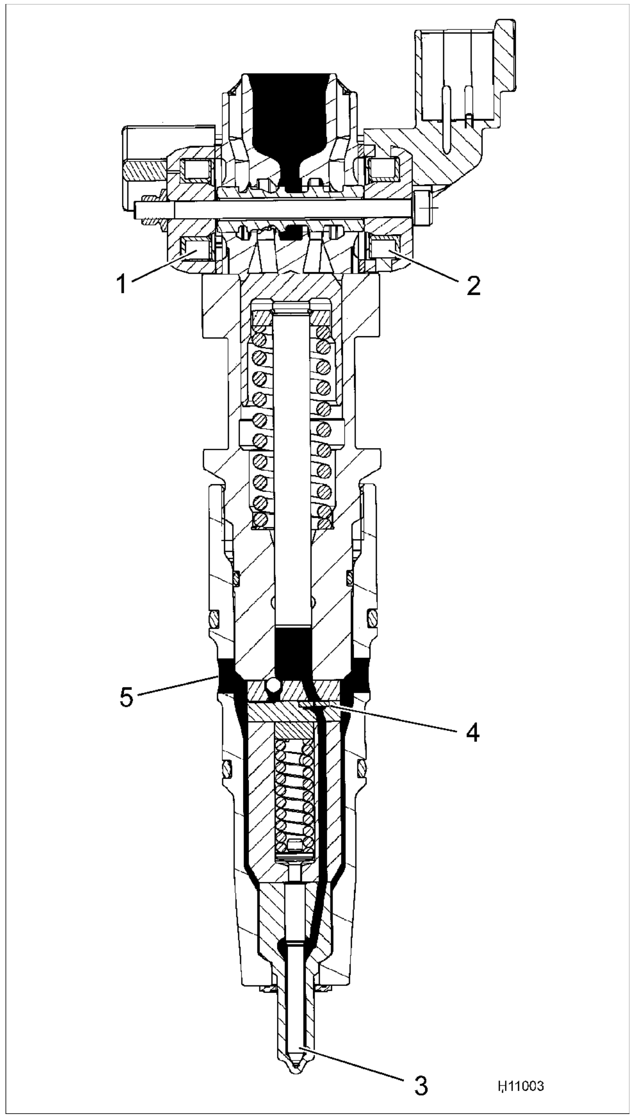


Figure 23 Fill stage

1. CLOSE coil (off)
2. OPEN coil (off)
3. Needle (seated)
4. Disk check (seated)
5. Fuel inlet (4)

During the fill stage both coils are de-energized and the spool valve is closed. High-pressure oil from the high-pressure oil rail is deadheaded at the spool valve.

Low-pressure fuel fills the four ports and enters through the edge filter 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.

Main Injection (Step 1)

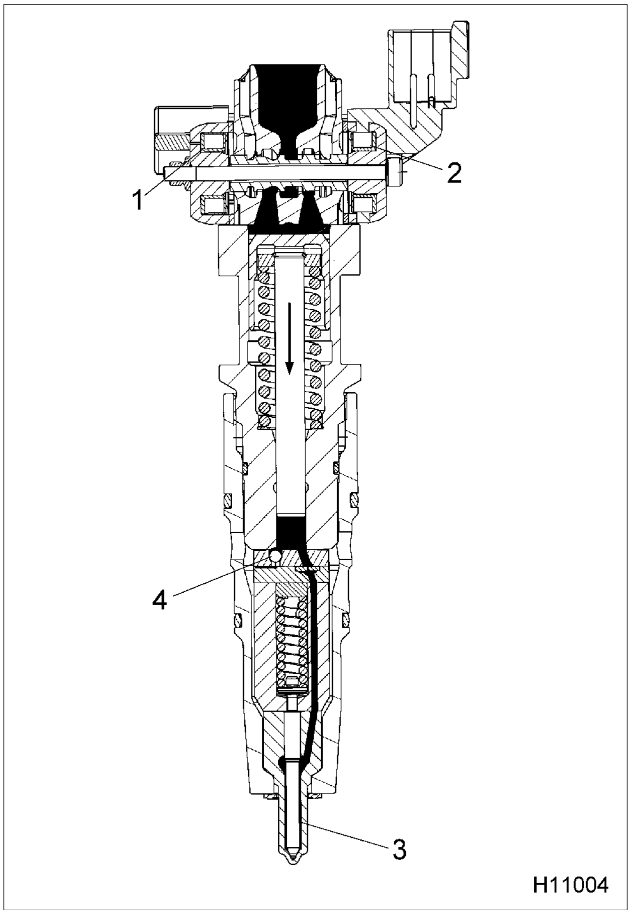


Figure 24 Main injection (Step 1)

1. CLOSE coil (off)
2. OPEN coil (on)
3. Needle (seated)
4. Fuel inlet check ball (seated)

A pulse-width controlled current energizes the OPEN coil. Magnetic force 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.

Main Injection (Step 2)

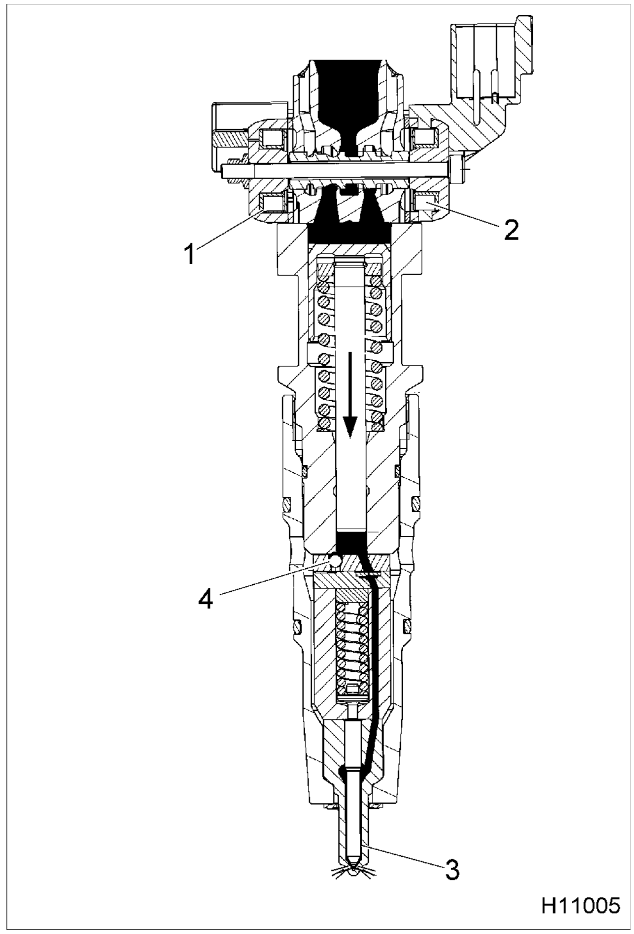


Figure 25 Main injection (Step 2)

1. CLOSE coil (off)
2. OPEN coil (off)
3. Needle (unseated – VOP)
4. Fuel inlet check ball (seated)

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 rail 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 the VOP - about 28 MPa (4,075 psi) - the needle lifts of its seat and injection begins.

End of Main Injection (Step 1)

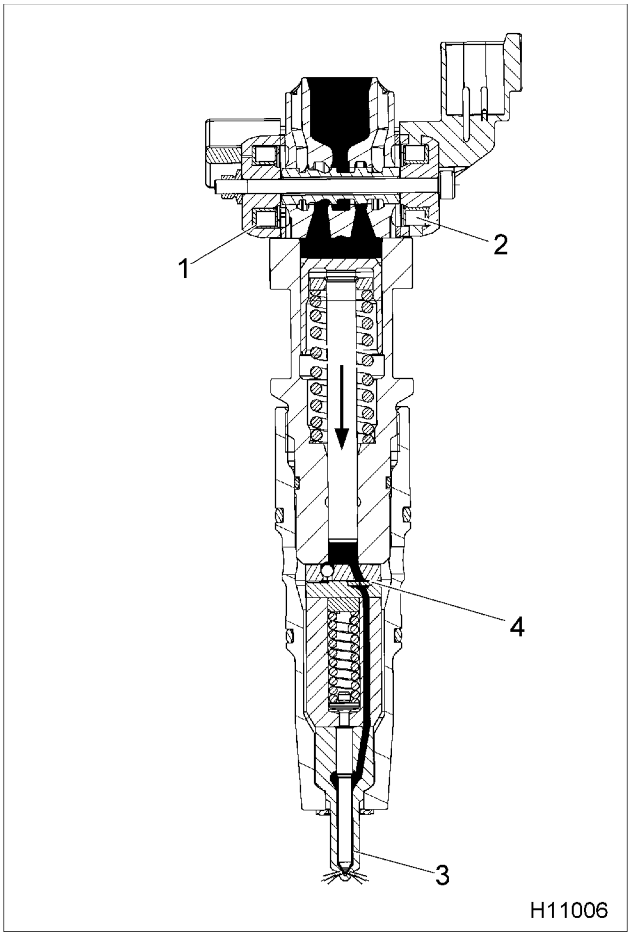


Figure 26 End of main injection (Step 1)

1. CLOSE coil (on)
2. OPEN coil (off)
3. Needle (unseated / closing)
4. Check disk (seated)

When the Injector Drive Module (IDM) determines that the correct injector on-time has been reached (the correct amount of fuel has been delivered), the IDM sends a pulse-width controlled current to the CLOSE coil of the injector. The current energizes the CLOSE coil and magnetic force closes the spool valve. High-pressure oil is deadheaded against the spool valve.

End of Main Injection (Step 2)

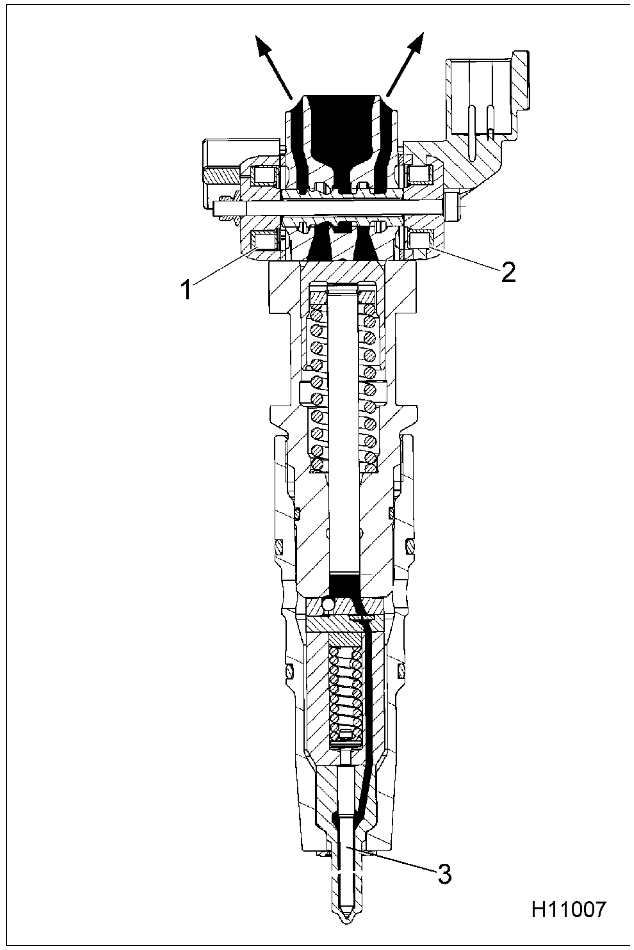


Figure 27 End of main injection (Step 2)

1. CLOSE coil (off)
2. OPEN coil (off)
3. Needle (seated)

The pulse-width controlled current to close the coil is shut off, but the spool valve remains closed. The intensifier piston and plunger return to their initial positions. Oil above the intensifier piston flows past the spool valve through the exhaust ports. Fuel pressure decreases until the needle control spring forces the needle back onto its seat.

Fuel Supply System

Fuel System Components and Fuel Flow

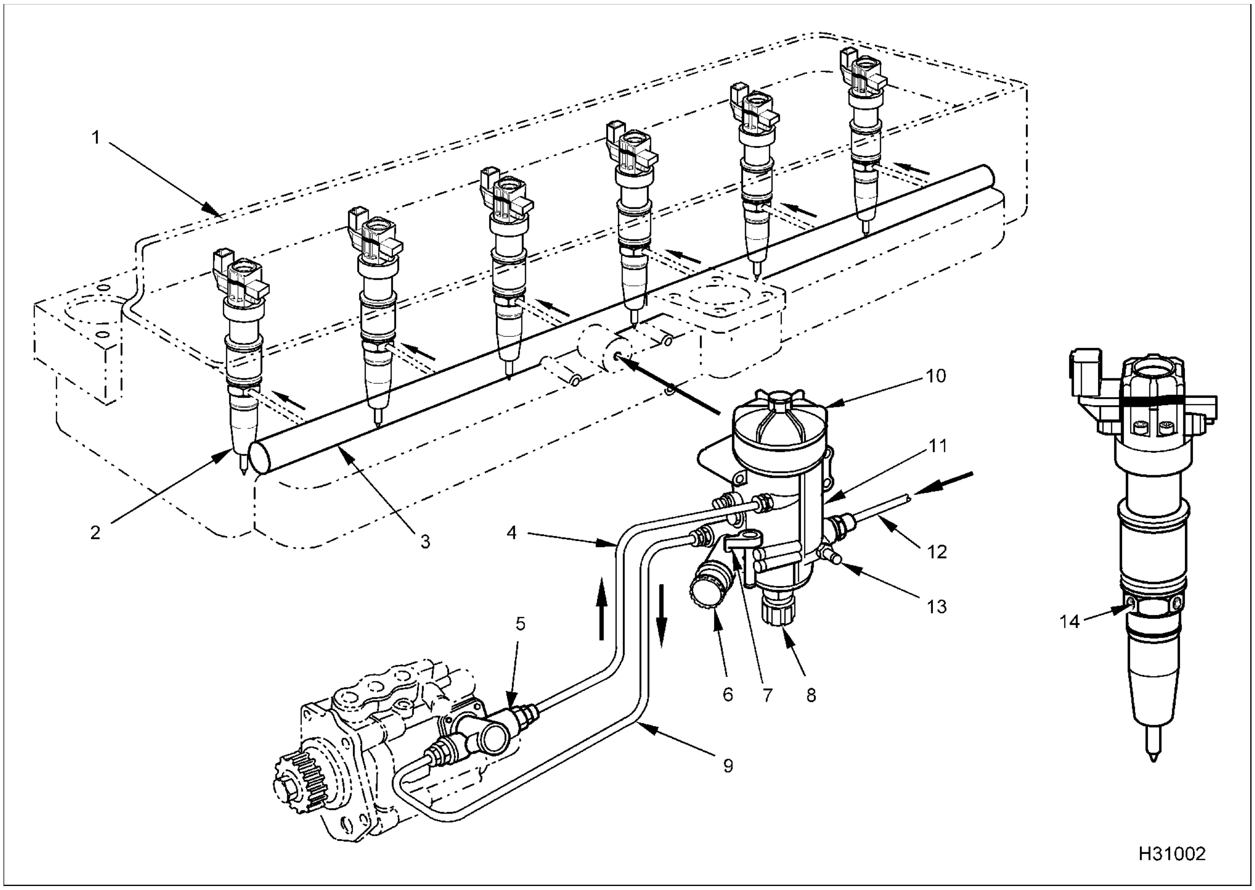


Figure 28 Fuel supply system

1. Cylinder head assembly
2. Fuel injector
3. Low-pressure fuel rail
4. Transfer pump outlet tube assembly
5. Transfer pump fuel supply pump
6. Primer pump assembly
7. Water drain valve
8. Drain valve (fuel)
9. Transfer pump inlet tube assembly
10. Fuel filter access cap
11. Fuel filter header assembly
12. Fuel line from tank
13. Test fitting
14. Fuel inlet (4)

Fuel Flow Schematic

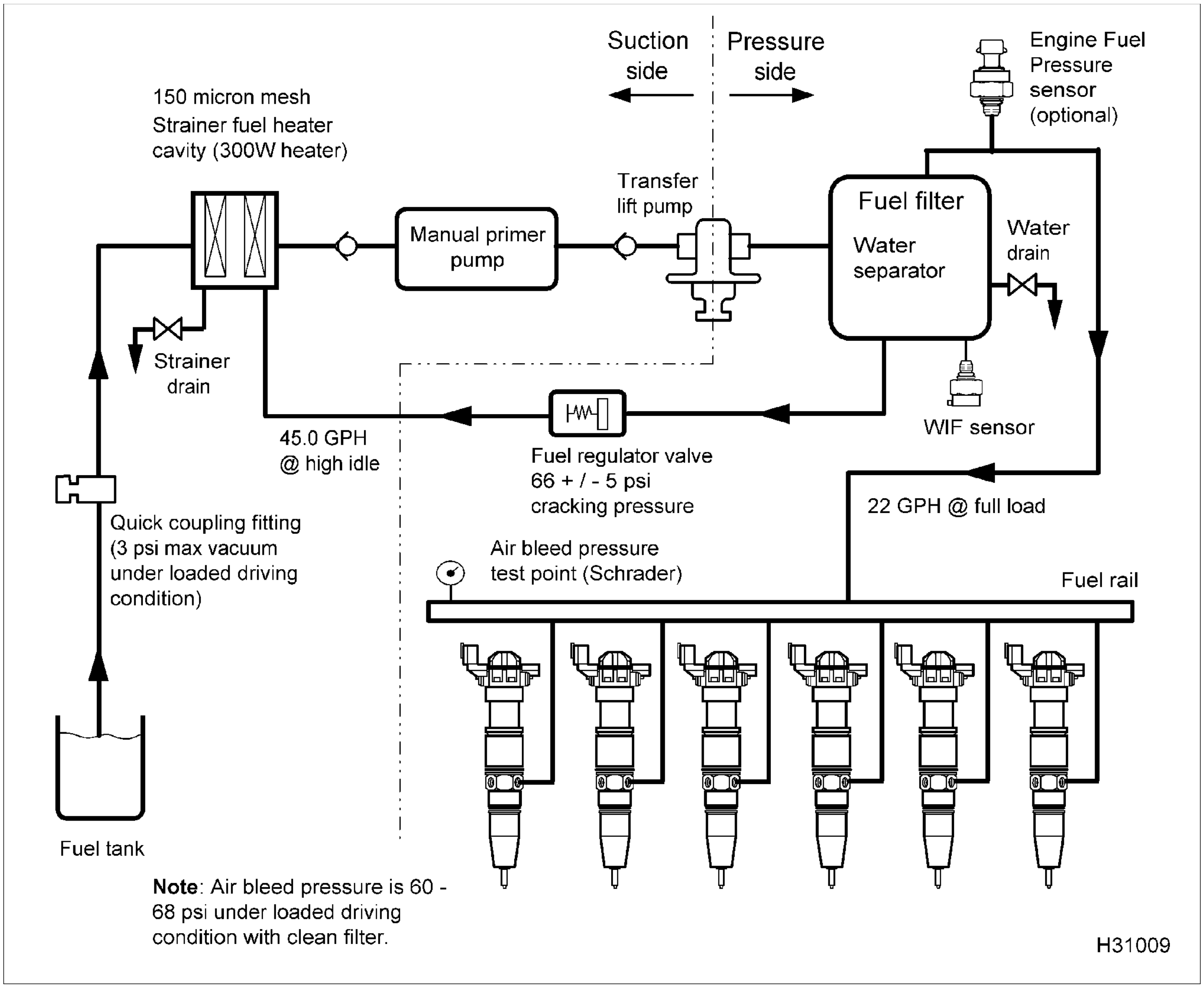


Figure 29 Fuel flow

The fuel filter housing includes the following components:

- 150 micron fuel strainer
- 300 W fuel heating element (optional)
- Primer pump assembly
- Fuel filtering element
- Water separator
- Water In Fuel (WIF) sensor
- Water drain valve
- Fuel pressure regulator
- Engine Fuel Pressure (EFP) sensor (optional)

Fuel Flow

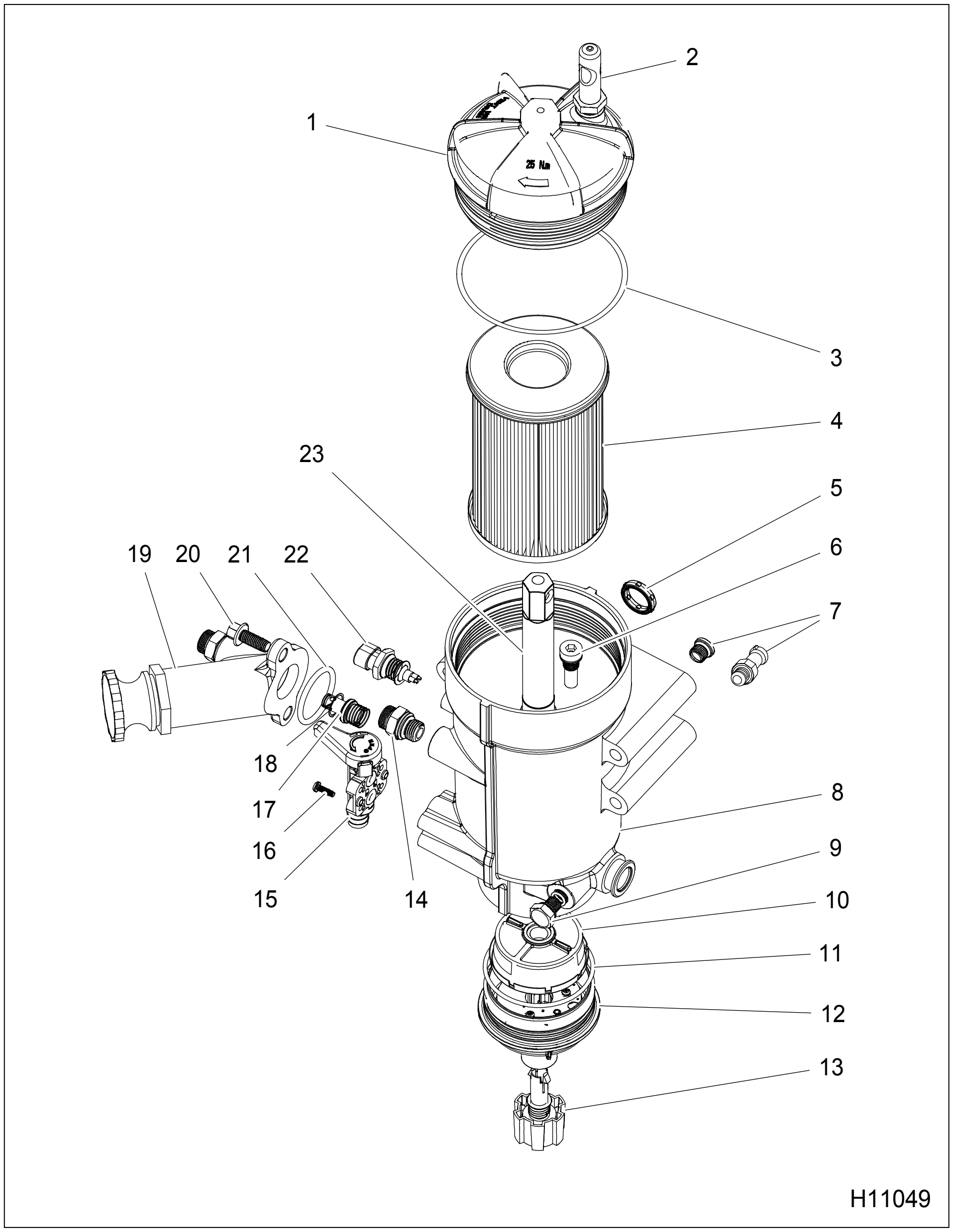


Figure 30 Fuel filter assembly

1. Housing cover assembly
2. M12 port fitting (factory fill)
3. O-ring seal
4. Fuel filter element
5. O-ring seal
6. Fuel pressure regulator assembly
7. Plug or EFP sensor (optional)
8. Fuel filter housing
9. Plug assembly, M10
10. Fuel strainer
11. Bowl O-ring seal
12. Fuel bowl (with heater option)
13. Drain valve
14. Fitting assembly, ⅜ tube
15. Water drain valve assembly
16. Self tapping screw (4)
17. Cartridge check valve
18. Retainer ring
19. Primer pump assembly
20. Bolt, M8 x 20 (2)
21. Primer pump seal
22. Water In Fuel (WIF) sensor
23. Stand pipe

NOTE: Early fuel filter assemblies may have item 2 in the location of item 9. Item 2 is used by the assembly plants as a fuel fill.

- If item 2 is installed on housing cover assembly, it can be used to measure unfiltered fuel pressure.
- If item 2 is installed in item 9 location, it can be used to measure fuel inlet restriction.

The low-pressure fuel supply pump draws fuel from the fuel tank through a 150 micron strainer in the fuel filter assembly.

An optional electric heating element in the fuel filter housing warms incoming fuel to prevent waxing.

If water is in the fuel, the filter element repels water molecules, water collects at the bottom of the element cavity in the fuel filter housing, and a Water In Fuel (WIF) sensor in the element cavity detects water in the fuel. When enough water accumulates in the element cavity, the WIF sensor signal changes to the Electronic Control Module (ECM). The ECM sends a message to illuminate the amber water and fuel lamp, alerting the operator. A fuel drain valve handle on the housing can be opened to drain contaminants (usually water) from the fuel filter housing. Another drain valve in the bottom of the housing drains strainer cavity.

A built-in fuel regulator valve, calibrated to open at about 414 - 482 kPa (60 - 70 psi), regulates and relieves excessive pressure. During idle and light engine loads, when injector demand is low, most of the fuel is recycled between the fuel filter housing and fuel pump. When engine demand increases, engine fuel consumption increases resulting in less fuel recycling. Under heavy loads fuel flows through the filter with little or no recycling.

Fuel is conditioned as it flows through a main filter and stand-pipe. The stand-pipe prevents fuel from draining from the fuel rail during servicing.

An optional Engine Fuel Pressure (EFP) sensor detects low pressure caused by high fuel filter restriction and sends a signal to the ECM. The ECM illuminates the amber FUEL FILTER lamp on the instrument panel.

Fuel flows from the fuel filter housing into the fuel rail, through the fuel rail into six separate passages, one for each injector.

When the fuel injectors are activated, fuel flows (from fuel rail) into four inlets in each injector.

Engine Lubrication System

Lubrication System Components and Oil Flow

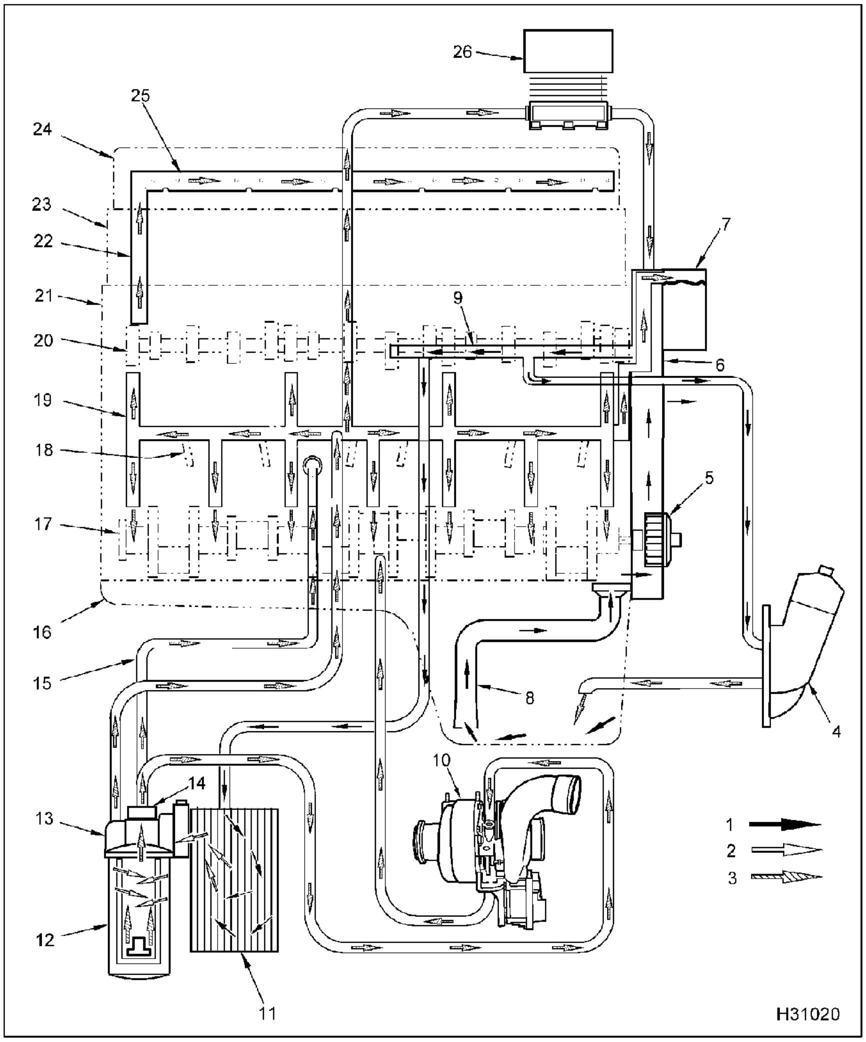


Figure 31 Lubrication system

1. Unfiltered oil
2. Cooled unfiltered oil
3. Filtered oil
4. Secondary filtration filter (optional)
5. Gerotor oil pump
6. Front cover
7. Reservoir for high-pressure oil pump
8. Pick-up tube
9. Unfiltered oil gallery
10. Variable Geometry Turbocharger (VGT)
11. Oil cooler
12. Oil filter
13. Oil cooler / filter header assembly
14. Oil pressure regulator relief valve
15. Regulator relief valve drain to crankcase
16. Oil pan assembly
17. Crankshaft
18. Piston cooling tube (6)
19. Main filtered oil gallery
20. Camshaft
21. Crankcase
22. Vertical gallery
23. Cylinder head
24. Valve cover
25. Rocker arm assembly
26. Air compressor (optional)

Oil Flow Diagram

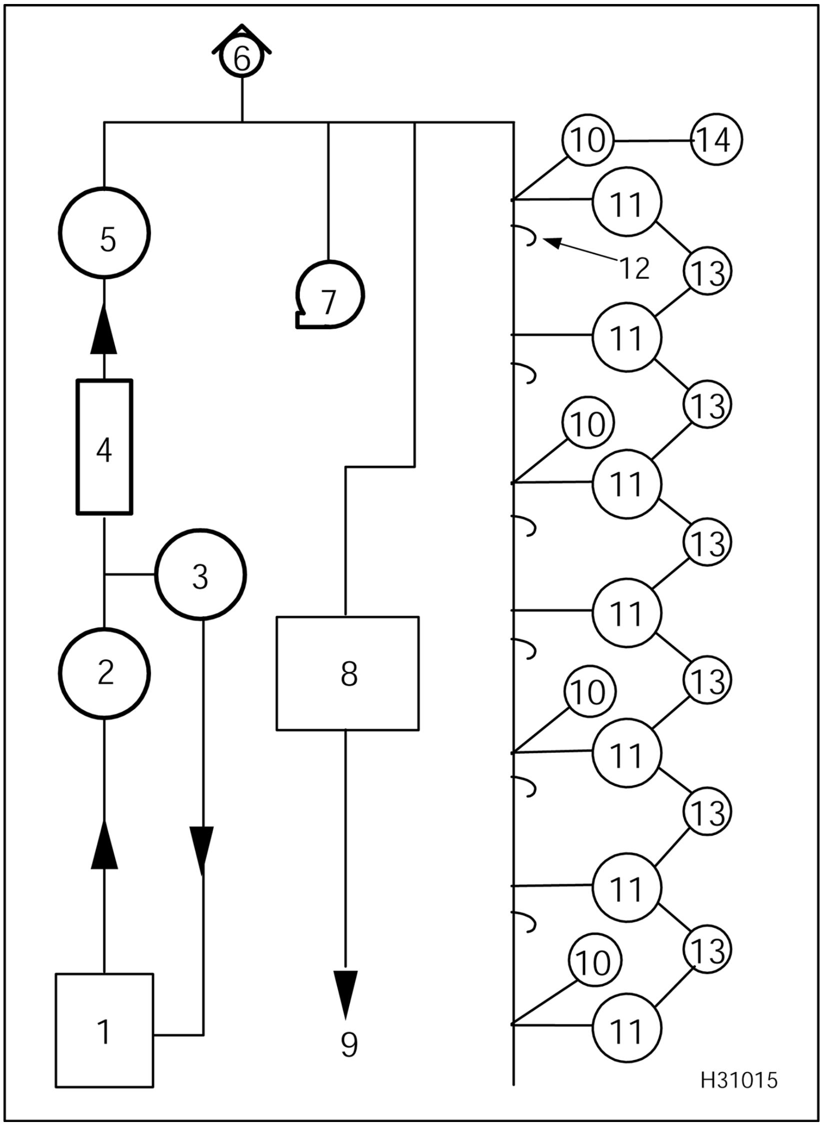


Figure 32 Lubrication system

1. Sump
2. Oil pump
3. Secondary filter
4. Oil cooler
5. Oil filter
6. Oil pressure regulator relief valve
7. Variable Geometry Turbocharger (VGT)
8. Oil reservoir for high-pressure pump
9. To high-pressure oil system
10. Cam bearing
11. Main bearings
12. Piston cooling tube (6)
13. Connecting rods
14. Rocker arm shaft

The gerotor oil pump, driven by the engine crankshaft, draws unfiltered oil from the oil pan through an oil pick-up tube into the inlet port of the front cover. Unfiltered oil (under pressure) flows through the outlet port in the front cover into the unfiltered oil gallery in the crankcase.

The unfiltered oil gallery has one exit port to the header of the oil cooler. The oil is then internally diverted to the oil cooler plate stack or by-passed into the oil cooler/filter module.

An oil temperature control valve, in the oil cooler/filter header, senses inlet oil temperature. During engine start-up, when the oil is cold, the oil temperature control valve allows unfiltered oil to bypass the oil cooler plate stack. When the unfiltered oil reaches engine operating temperature, the oil temperature control valve routes unfiltered oil to the oil cooler. Oil flows through both the oil cooler core and bypass gallery when the valve is partially open.

Unfiltered oil at full flow moves through plates in the oil cooler. Engine coolant flows through the plates to cool the surrounding oil.

The cooled, unfiltered oil leaving the oil cooler stack mixes with the uncooled, unfiltered oil (that bypassed the oil cooler). The oil mixture flows through the oil filter (from element outside to element inside). The oil filter bypass valve in the header ensures full flow of oil to the engine should the filter element become plugged. Oil bypass occurs within the module when differential filter pressure reaches 345 kPa (50 psi).

Cooled, filtered oil flows to and past the oil pressure regulator relief valve, in the oil cooler module. The oil pressure regulator valve maintains correct operating oil pressure.

The pressure regulator valve opens at 379 kPa (55 psi) and dumps excess oil into the crankcase. The filtered oil continues to the main oil gallery for distribution throughout the engine.

Connecting rod bearings are fed through drilled passages in the crankshaft from main journals to rod journals, that receive pressurized oil from the main bearings.

Camshaft journals are fed through passages drilled vertically in the main bearing webs. Pressurized oil from the main gallery, through piston cooling tubes, lubricates and cools the pistons.

Valve rocker arms are lubricated through an annulus on the outside of the rear camshaft bushing. The oil passes up and through the vertical gallery in the rear of the crankcase, through a passage in the cylinder head. Oil continues through rocker arm shaft pedestal and into the rocker arm shaft. Oil continues flowing through drillings in the rocker arm shaft to the rocker arms. The oil then drains to the oil pan sump through push rod holes.

Filtered oil from the main gallery flows up through a passage in the front of the crankcase and front cover into the oil reservoir for the high-pressure oil pump.

The turbocharger receives filtered oil through an external tube connected to the oil cooler header. Oil drains back to the oil pan sump through a tube connected to the crankcase.

The air compressor (if equipped) receives filtered oil from the main oil gallery through an external tube connected to the left side of the crankcase. Oil drains to the front cover and back to the oil pan.

The front gear train is splash lubricated with oil draining from the high-pressure reservoir and the air compressor (if equipped).

Cooling System

Cooling System Components and Coolant Flow

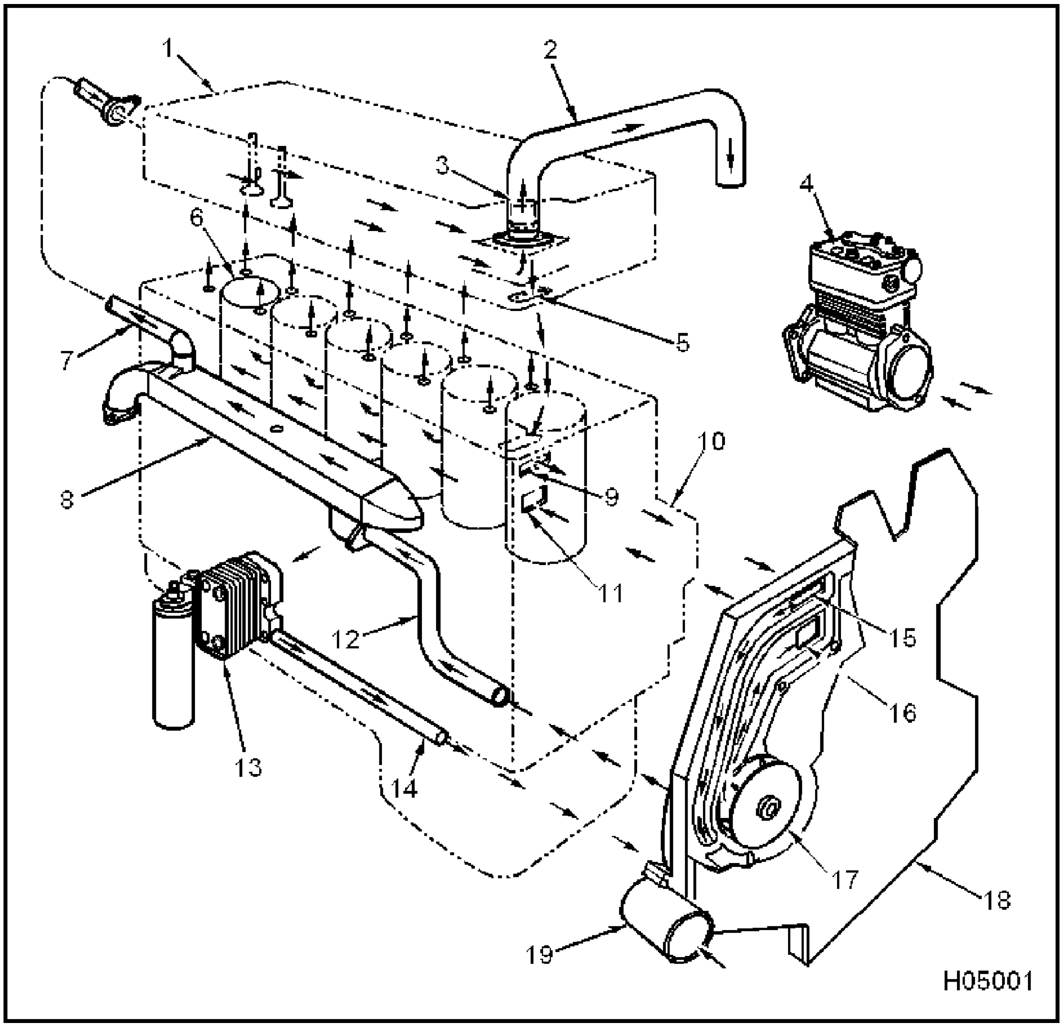


Figure 33 Engine cooling system

1. Cylinder head assembly
2. Water outlet tube assembly (thermostat outlet)
3. Thermostat assembly
4. Air compressor
5. Water return from cylinder head to crankcase
6. Cylinder sleeve
7. EGR cooler return tube assembly
8. EGR cooler assembly
9. Water outlet from crankcase to front cover
10. Crankcase
11. Water inlet to crankcase
12. EGR cooler supply tube
13. Oil module assembly
14. Oil cooler tube
15. Water inlet to front cover and water pump
16. Water supply from front cover to crankcase
17. Water pump impeller assembly
18. Front cover
19. Water inlet elbow

Cooling System Flow

The cooling system keeps the engine within a designated temperature range. The major components of the cooling system include the following:

- Radiator and fan combination (chassis components)
- Water pump assembly
- Thermostat assembly
- Oil system module assembly
- EGR cooler assembly

A belt-driven centrifugal water pump is set into the front cover. The front cover has three related passages. One passage channels coolant from the water pump to the crankcase, the second returns coolant to the water pump, and the third (a bypass) channels coolant back to the water pump when the thermostat is closed.

Incoming coolant flows from the bottom of the radiator through a water inlet elbow to the front cover and water pump. Coolant is pumped to the crankcase through a passage in the front cover and crankcase.

Water jackets in the crankcase direct coolant from front to rear, distributing coolant evenly to the lower sections of the cylinder sleeves. Coolant flow is directed tangent to each cylinder sleeve, causing a swirling motion up to the cylinder head. The swirling action improves heat absorption.

Coolant flows from the cylinder sleeve areas in three ways:

- Coolant flows into the oil system module assembly through the right side of the crankcase, passes through the oil system module, and returns through a tube to the front cover.
- Coolant is routed through hoses to and from the air compressor on the left side of the crankcase.
- Coolant exits the crankcase at the upper end of each cylinder sleeve bore and is distributed evenly through metering holes in the cylinder head gasket. Coolant then flows through the cylinder head (back to front) to the thermostat.

The EGR cooler receives coolant from the front cover. Coolant flows from the front of the cooler and exits the rear of the cooler into the rear of the cylinder head. A deaeration port is on top of the EGR cooler.

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 88 °C (190 °F) and is fully open at 96 °C (205 °F).

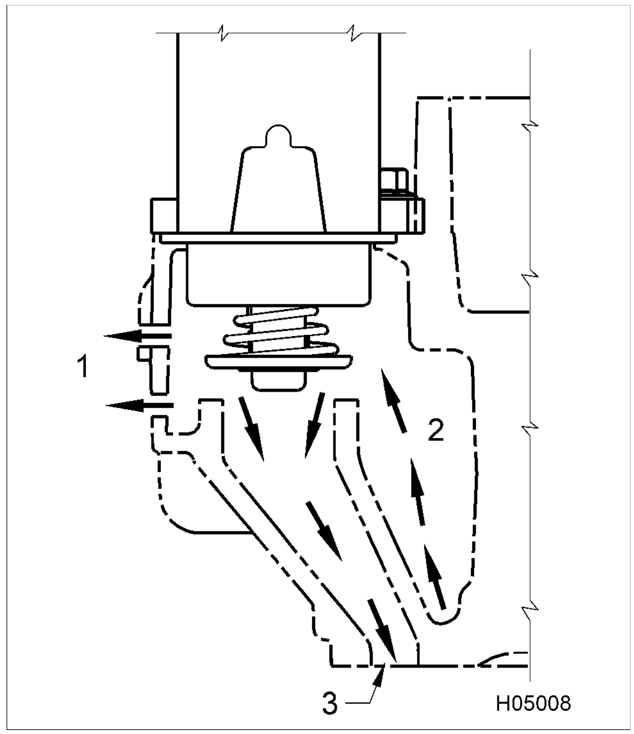


Figure 34 Thermostat closed

1. Coolant flow to heater port
2. Coolant in from engine
3. Bypass to water pump

When engine coolant is below the 88 °C (190 °F) the thermostat is closed, blocking flow to the radiator. Coolant is forced to flow through a bypass port back to the water pump.

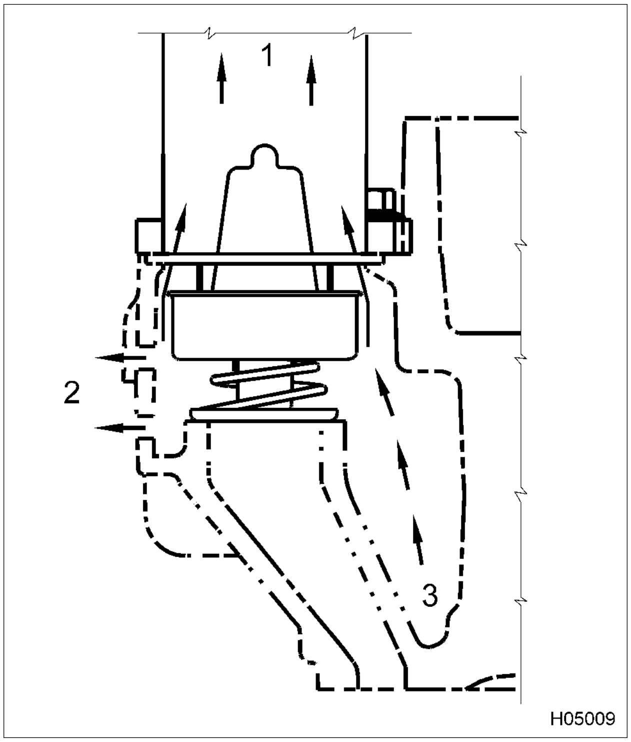


Figure 35 Thermostat open

1. Coolant out to radiator
2. Coolant flow to heater port
3. Coolant in from engine

When coolant temperature reaches the nominal opening temperature (88 °C [190 °F]) the thermostat opens allowing some coolant to flow to the radiator. When coolant temperature exceeds 96 °C (205 °F), the lower seat blocks the bypass port directing full coolant flow to the radiator.

Electronic Control System

Electronic Control System Components

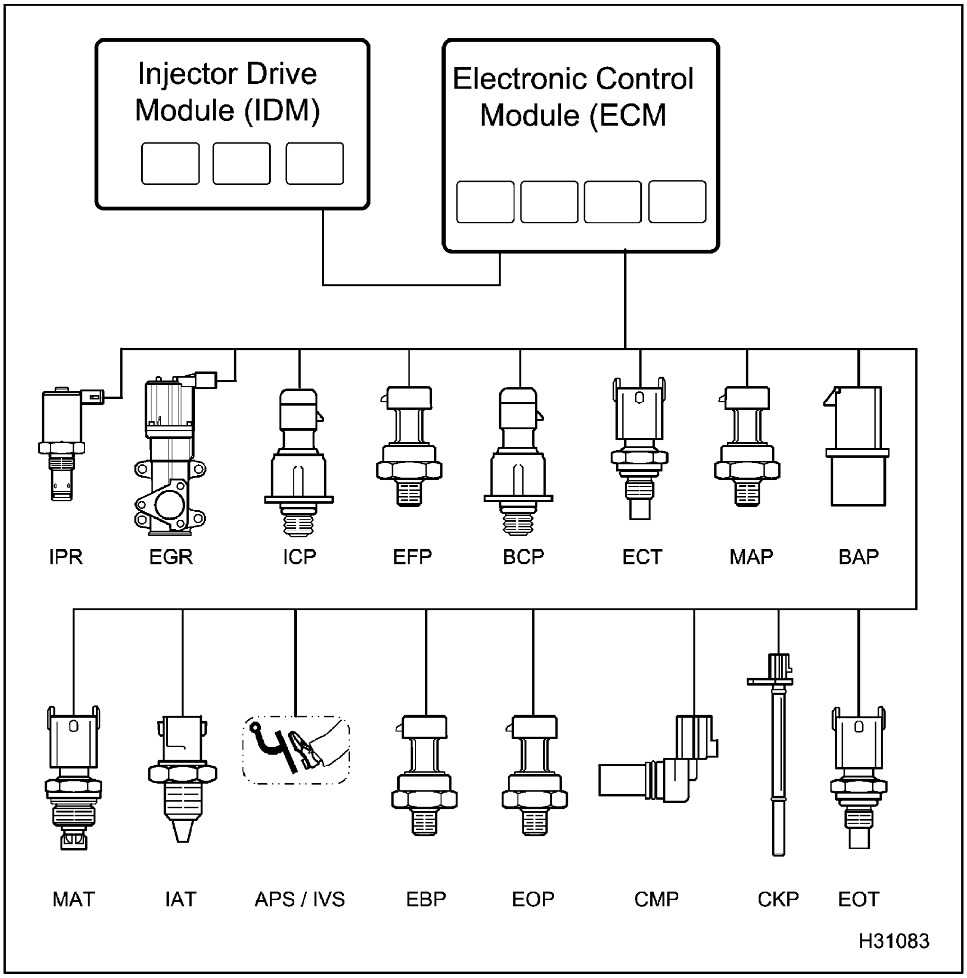


Figure 36 Electronic Control System

Operation and Function

The Electronic Control Module (ECM) monitors and controls engine performance to ensure maximum performance and adherence to emissions standards. The ECM has four primary functions:

1. Provides Reference Voltage (V_{REF})
2. Conditions input signals
3. Processes and stores control strategies
4. Controls actuators

1. Voltage reference(V_{REF})

The ECM supplies a 5 volt V_{REF} signal to input sensors in the electronic control system. By comparing the 5 volt V_{REF} signal sent to the sensors with their respective returned signals, the ECM determines pressures, positions, and other variables important to engine and vehicle functions.

The ECM supplies two independent circuits for V_{REF}:

- V_{REF} A supplies 5 volts to engine sensors
- V_{REF} B supplies 5 volts to vehicle sensors

2. Signal conditioner

The signal conditioner in the internal microprocessor converts analog signals to digital signals, squares up sine wave signals, or amplifies low intensity signals to a level that the ECM microprocessor can process.

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

Diagnostic Trouble Codes (DTCs) are generated by the microprocessor, if inputs or conditions do not comply with expected values.

Diagnostic strategies are also programmed into the ECM. Some strategies monitor inputs continuously and command the necessary outputs to achieve the correct performance of the engine.

Microprocessor Memory

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

ROM

ROM stores permanent information for calibration tables and operating strategies. Permanently stored information cannot be changed or lost by turning the ignition switch to 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

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

4. Actuator control

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

Actuators are controlled in three ways, determined by the kind of actuator.

- A duty cycle (percent time on/off)
- A controlled pulse-width
- Switched on or off

ECM Control of Engine Operation

The ECM controls engine operation with the following:

- Variable Geometry Turbocharger (VGT) control module
- EGR drive module and control valve
- Diamond Logic® engine brake (brake shut-off valve)
- IPR valve
- Inlet Air Heater (IAH) assembly

Variable Geometry Turbocharger (VGT) Control Module

The VGT control module controls vane position in the turbine housing. Vane position is controlled by a switching voltage source in the ECM. The ground circuit is supplied directly from the battery ground at all times.

The actuator control is set by a pulse-width modulated signal in response to engine speed, desired fuel quantity, boost or exhaust back pressure and altitude.

Exhaust Gas Recirculation (EGR) Control Valve

The EGR valve controls the flow of exhaust gases into the inlet and EGR mixer duct.

The EGR drive module controls the EGR actuator.

The EGR drive module receives the desired EGR actuator position from the ECM across the CAN 2 datalink to activate the valve for exhaust gas recirculation. The EGR drive module provides feedback to the ECM on the valve position.

The EGR drive module constantly monitors the EGR actuator. When an EGR control error is detected, the EGR drive module sends a message to the ECM and a DTC is set.

Brake Shut-off Valve

The brake shut-off valve controls pressure in the oil gallery of the high-pressure oil rail. When the engine brake is activated, the ECM provides power to activate the brake shut-off valve to allow oil from the injector oil gallery to flow to the brake oil gallery. High oil pressure activates the brake actuator pistons to open the exhaust valves.

Injection Pressure Regulator (IPR)

The IPR valve controls pressure in the Injection Control Pressure (ICP) system. The IPR valve is a variable position valve controlled by the ECM. This regulated pressure actuates the fuel injectors. The valve position is controlled by switching the ground circuit in the ECM. The voltage source is supplied by the ignition switch.

Inlet Air Heater (IAH)

The IAH system warms the incoming air supply prior to cranking to aid cold engine starting and reduce white smoke during warm-up.

The ECM is programmed to energize the IAH elements through the IAH relays while monitoring certain programmed conditions for engine coolant temperature, engine oil temperature, and atmospheric pressure.

Injection Drive Module (IDM)

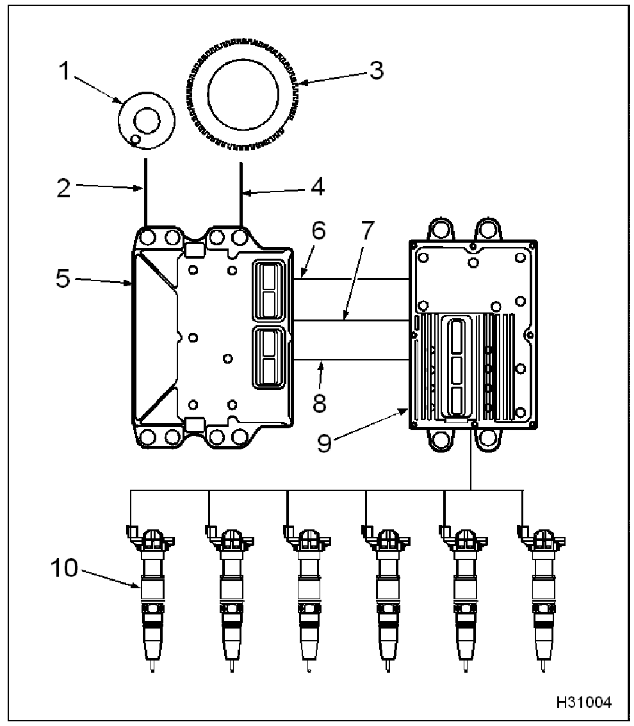


Figure 37 Injection Drive Module (IDM)

1. Camshaft with peg
2. Camshaft Position (CMP) signal
3. Crankshaft position sensor timing disk
4. Crankshaft Position (CKP) signal
5. Electronic Control Module (ECM)
6. Camshaft Position Output (CMPO) signal
7. Crankshaft Position Output (CKPO) signal
8. Controller Area Network (CAN 2) communication
9. Injection Drive Module (IDM)
10. Fuel injectors

The IDM has three functions:

- Electronic distributor for injectors
- Power source for injectors
- IDM and injector diagnostics

Electronic Distributor for Injectors

The IDM distributes current to the injectors. The IDM controls fueling to the engine by sending high voltage pulses to the OPEN and CLOSE coils of the injector. The IDM uses information from the ECM to determine the timing and quantity of fuel for each injector.

The ECM uses CMP and CKP input signals to calculate engine speed and position. The ECM conditions both input signals and supplies the IDM with CMP and CKP output signals. The IDM uses CMP and CKP output signals to determine the correct sequence for injector firing.

The ECM sends information (fuel volume, EOT, and ICP) through the CAN 2 datalink to the IDM; the IDM uses this information to calculate the injection cycle.

Injector Power Source

The IDM creates a constant 48 volt (DC) supply to all injectors by making and breaking a 12 volt source across a coil in the IDM. The 48 volts created by the collapsed field is stored in capacitors until used by the injectors.

The IDM controls when the injector is turned on and how long the injector is active. The IDM first energizes the OPEN coil, then the CLOSE coil. The low side driver supplies a return circuit to the IDM for each injector coil (open and close). The high side driver controls the power supply to the injector. During each injection event, the low and high side drivers are switched on and off for each coil.

IDM and Injector Diagnostics

The IDM determines if an injector is drawing enough current. The IDM sends a fault to the ECM, indicating potential problems in the wiring harness or injector, and the ECM will set a DTC. The IDM also does self-diagnostic checks and sets a DTC to indicate failure of the IDM.

On demand tests can be done using the Electronic Service Tool (EST). The EST sends a request to the ECM and the ECM sends a request to the IDM to do a test. Some tests generate a DTC when a problem exists. Other tests require the technician to evaluate parameters, if a problem exists.

Engine and Vehicle Sensors

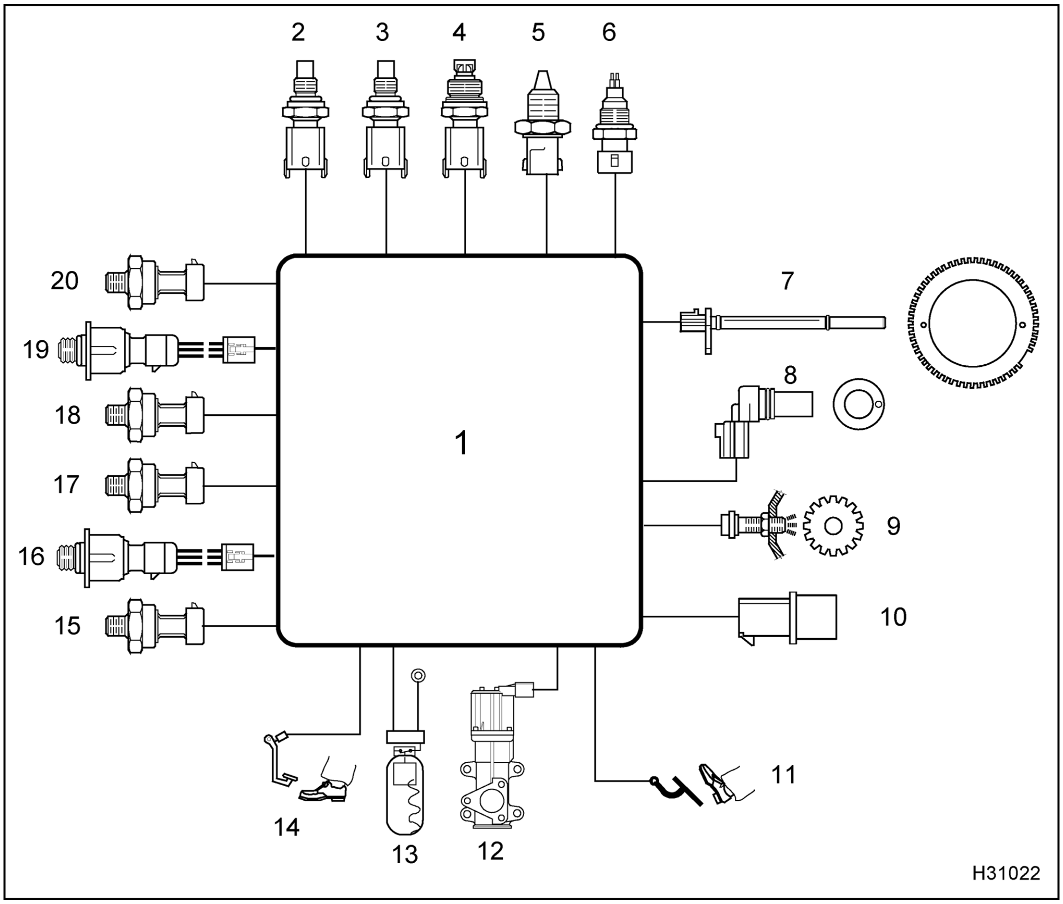


Figure 38 Engine and vehicle sensors

1. Electronic Control Module (ECM)
2. Engine Oil Temperature (EOT)
3. Engine Coolant Temperature (ECT)
4. Manifold Air Temperature (MAT)
5. Intake Air Temperature (IAT)
6. Water In Fuel (WIF)
7. Crankshaft Position (CKP)
8. Camshaft Position (CMP)
9. Vehicle Speed Sensor (VSS)
10. Barometric Absolute Pressure (BAP)
11. Accelerator Position Sensor (APS)
12. Exhaust Gas Recirculation valve Position (EGRP)
13. Engine Coolant Level (ECL)
14. Driveline Disengagement Switch (DDS)
15. Manifold Absolute Pressure (MAP)
16. Brake Control Pressure (BCP)
17. Engine Oil Pressure (EOP)
18. Engine Fuel Pressure (EFP)
19. Injection Control Pressure (ICP)
20. Exhaust Back Pressure (EBP)

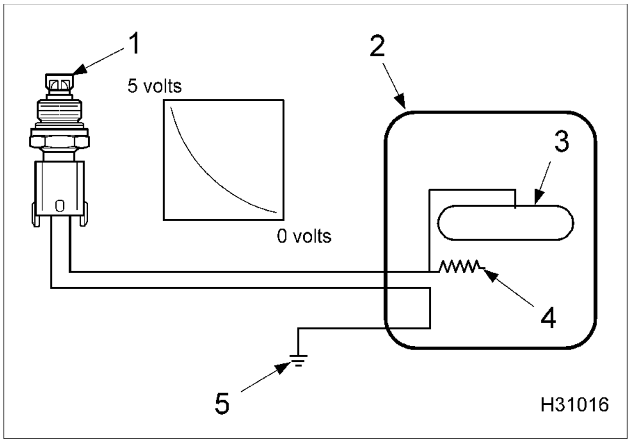


Figure 39 Thermistor

1. Temperature sensor
2. Electronic Control Module (ECM)
3. Microprocessor
4. Voltage reference (V_{REF})
5. Ground

Thermistors

- ECT
- EOT
- IAT
- MAT

A thermistor sensor changes its 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. A thermistor sensor has two electrical connectors, signal return and ground. The output of a thermistor sensor is a nonlinear analog signal.

Engine Coolant Temperature (ECT)

The ECM monitors the ECT signal and uses this information for the instrument panel temperature gauge, coolant compensation, Engine Warning Protection System (EWPS), and inlet air heater operation. The ECT is a backup, if the EOT is out-of-range. The ECT sensor is installed in the water supply housing (Freon® compressor bracket), right of the flat idler pulley assembly.

Engine Oil Temperature (EOT)

The ECM monitors the EOT signal to control fuel quantity and timing when operating the engine. The EOT signal allows the ECM and IDM to compensate for differences in oil viscosity for temperature changes. This ensures that power and torque are available for all operating conditions. The EOT sensor is installed in the rear of the front cover, left of the high-pressure oil pump assembly.

Intake Air Temperature (IAT)

The ECM monitors the IAT signal to control timing and fuel rate during cold starts. The IAT sensor is chassis mounted on the air filter housing.

Manifold Air Temperature (MAT)

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

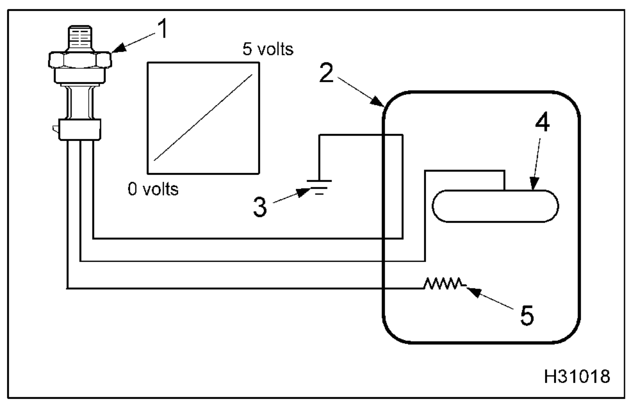


Figure 40 Variable capacitance sensor

1. Pressure sensor
2. Electronic Control Module (ECM)
3. Ground
4. Microprocessor
5. Voltage reference (V_{REF})

Variable Capacitance Sensors

- BAP
- MAP
- EBP

- EFP
- EOP

Variable capacitance sensors measure pressure. The pressure measured is applied to a ceramic material. The pressure forces the ceramic material closer to a thin metal disk. This action changes the capacitance of the sensor.

The sensor is connected to the ECM by three wires:

- V_{REF}
- Signal return
- Signal ground

The sensor receives the V_{REF} 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.

Barometric Absolute Pressure (BAP)

The ECM monitors the BAP signal to determine altitude, adjust timing, fuel quantity, and inlet air heater operation. The BAP sensor is located in the cab.

Manifold Absolute Pressure (MAP)

The ECM monitors the MAP signal to determine intake manifold pressure (boost). This information is used to control fuel rate and injection timing. The MAP sensor is installed left of the MAT sensor in the intake manifold.

Engine Oil Pressure (EOP)

The ECM monitors the EOP signal, and uses this information for the instrument panel pressure gauge and EWPS. The EOP sensor is installed in the left side of the crankcase below and left of the fuel filter housing.

Exhaust Back Pressure (EBP)

The EBP sensor measures exhaust back pressure so that the ECM can control the VGT and EGR systems. The sensor provides feedback to the ECM for closed loop control of the Variable Geometry Turbocharger (VGT). The EBP sensor is installed in a bracket mounted on the water supply housing (Freon® compressor bracket).

Engine Fuel Pressure (EFP)

The ECM uses the EFP sensor signal to monitor engine fuel pressure and give an indication when the fuel filter needs to be changed. The EFP sensor is installed in the rear of the fuel filter assembly (crankcase side).

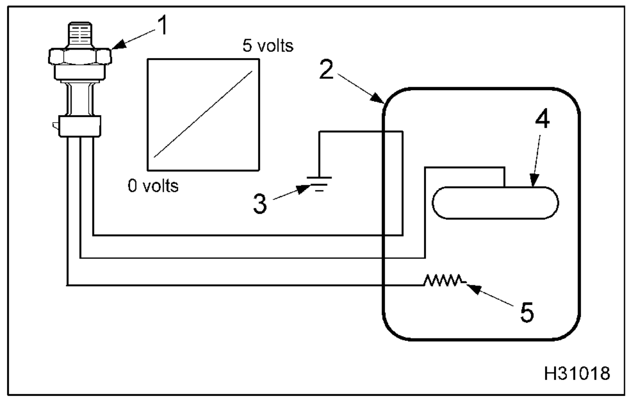


Figure 41 Micro Strain Gauge sensor

1. Pressure sensor
2. Electronic Control Module (ECM)
3. Ground
4. Microprocessor
5. Voltage reference (V_{REF})

Micro Strain Gauge (MSG) Sensors

- BCP
- ICP

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

The sensor is connected to the ECM by three wires:

- V_{REF}
- Signal return
- Signal ground

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

Brake Control Pressure (BCP)

The ECM monitors the BCP signal to determine the oil pressure in the brake gallery of the high-pressure oil rail. The BCP sensor is under the valve cover, forward of the No. 2 fuel injector in the high-pressure oil rail.

Injection Control Pressure (ICP)

The ECM monitors the ICP signal to determine the injection control pressure for engine operation. The ICP signal is used to control the IPR valve. The ICP sensor provides feedback to the ECM for Closed Loop ICP control. The ICP sensor is under the valve cover, forward of the No. 6 fuel injector in the high-pressure oil rail.

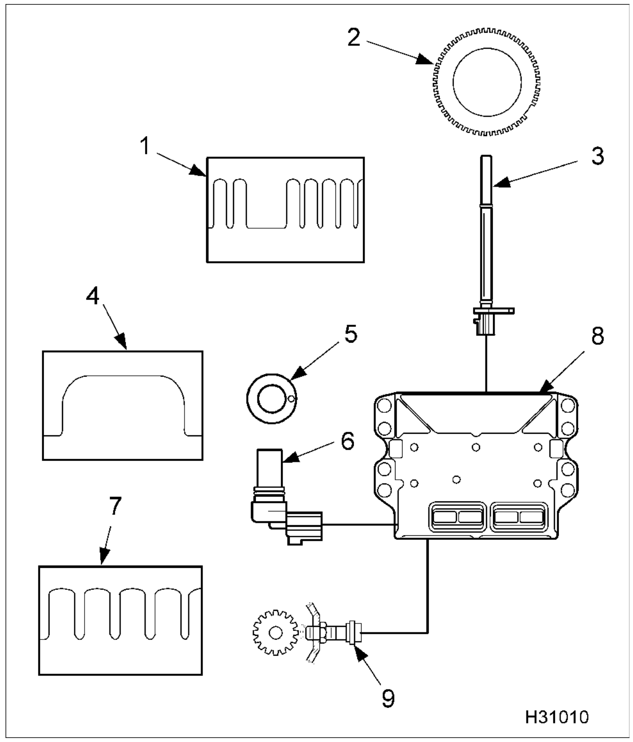


Figure 42 Magnetic pickups

1. Crankshaft Position (CKP) signal
2. Crankshaft position sensor timing disk
3. Crankshaft Position (CKP) sensor
4. Camshaft position (CMP) signal
5. Camshaft with peg
6. Camshaft position (CMP) sensor
7. Vehicle speed signal
8. Electronic Control Module (ECM)
9. Vehicle Speed Sensor (VSS)

Magnetic Pickup Sensors

- CKP
- CMP
- VSS

A magnetic pickup sensor generates an alternating frequency that indicates speed. Magnetic pickups have a two wire connection for signal and ground. This sensor has a permanent magnetic core surrounded by a wire coil. The signal frequency is generated by the rotation of gear teeth that disturb the magnetic field.

Crankshaft Position (CKP)

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 top left side of the flywheel housing.

NOTE: This long CKP sensor, used with International® DT 466, DT 570, and HT 570 diesel engines, is the Camshaft Position (CMP) sensor used with other International® diesel engines.

Camshaft Position (CMP)

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 cover, above and to the right of the water pump pulley.

NOTE: This short CMP sensor, used with International® DT 466, DT 570, and HT 570 diesel engines, is the Crankshaft Position (CKP) sensor used with other International® diesel engines.

Vehicle Speed Sensor (VSS)

The VSS provides the ECM with transmission tail shaft speed by sensing the rotation of a 16 tooth gear on the rear of the transmission. The detected sine wave signal (AC), received by the ECM, is used with tire size and axle ratio to calculate vehicle speed. The VSS is on left side of the transmission.

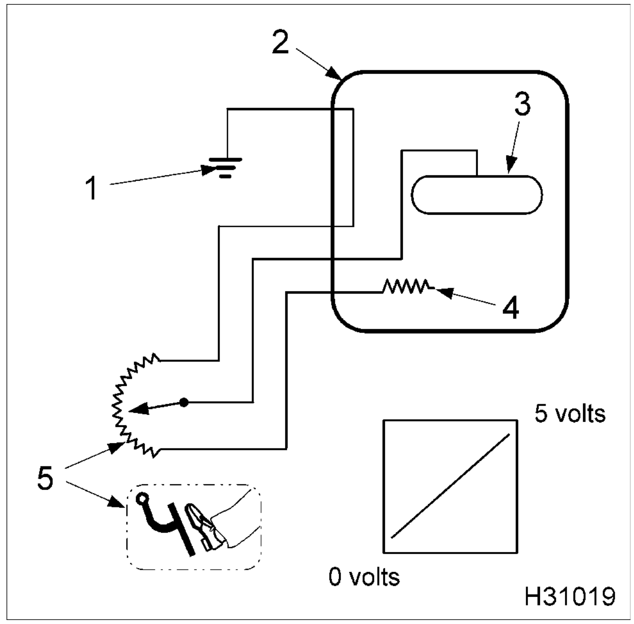


Figure 43 Potentiometer

1. Ground
2. Electronic Control Module (ECM)
3. Microprocessor
4. Voltage reference (V_{REF})
5. Accelerator Position Sensor (APS)

Potentiometers

- 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 mounted in the accelerator pedal.

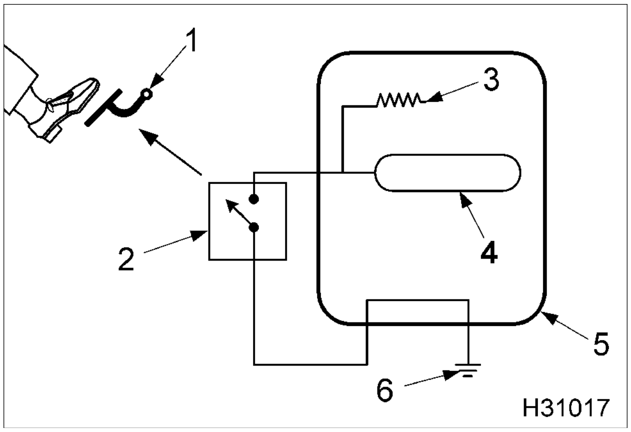


Figure 44 Switch

1. Accelerator pedal
2. Idle Validation Switch (IVS)
3. Voltage source with current limiting resistor
4. Microprocessor
5. ECM
6. Ground

Switches

- DDS
- ECL
- IVS
- WIF

Switch sensors indicate position, level, or status. They operate open or closed, allowing or preventing the flow of current. A switch sensor 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 DDS determines if a vehicle is in gear. For manual transmissions, the clutch switch serves as the DDS. For automatic transmissions, the neutral indicator switch or datalink communication functions as the DDS.

Engine Coolant Level (ECL)

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 ENGINE lamp on the instrument panel is illuminated.

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)

A Water In Fuel (WIF) sensor in the element cavity of the fuel filter housing detects water. When enough water accumulates in the element cavity, the WIF sensor signal changes to the Electronic Control Module (ECM). The ECM sends a message to illuminate the amber water and fuel lamp, alerting the operator. The WIF is installed in the base of the fuel filter housing.

Diamond Logic® Engine Brake

Engine Brake Components

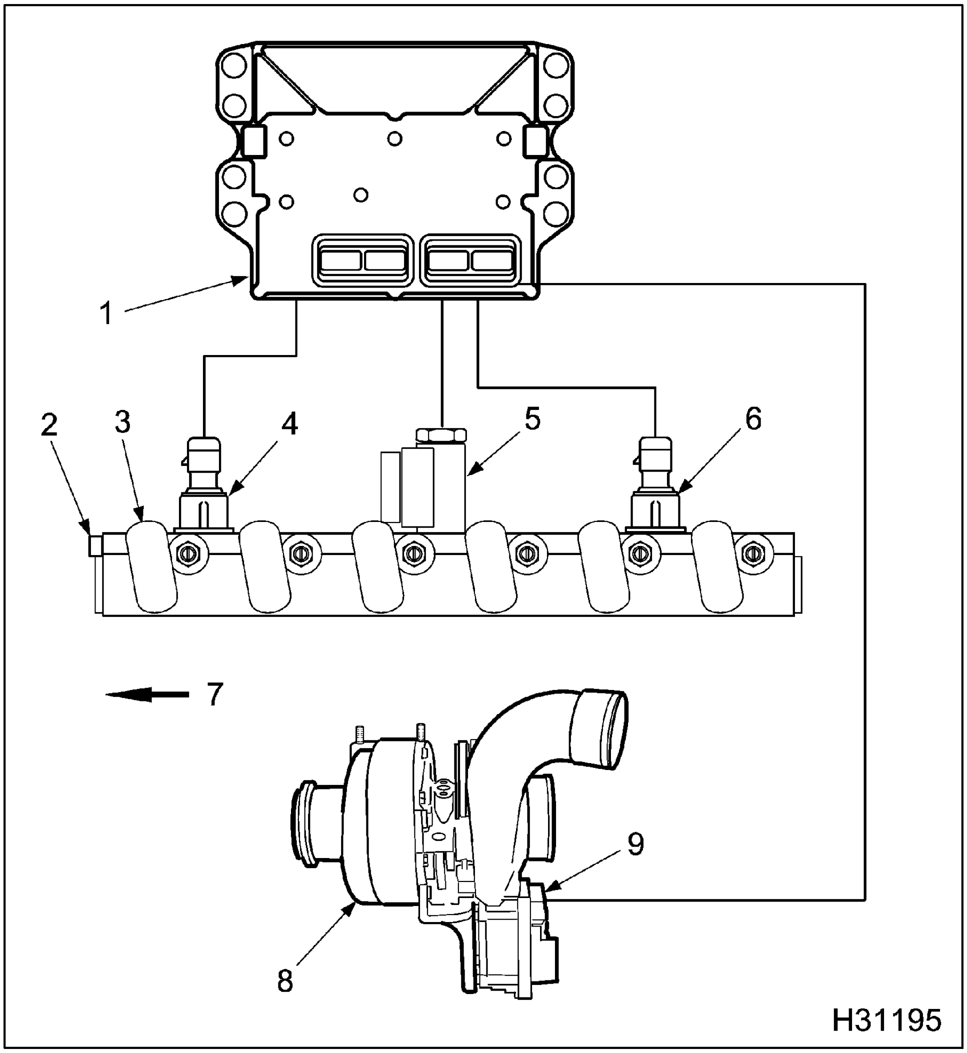


Figure 45 Diamond Logic® engine brake – system

1. ECM
2. Brake pressure relief valve
3. High-pressure oil rail
4. Brake Control Pressure (BCP) sensor
5. Brake shut-off valve assembly
6. Injection Control Pressure (ICP) sensor
7. Front of engine
8. Variable Geometry Turbocharger (VGT)
9. VGT control module

The Diamond Logic® engine brake, a compression release brake system, provides the following:

- Significant noise reduction
- Improved engine braking
- High durability
- Compatibility with cruise control system
- Lower operating cost and longer service life for brake shoes

The Diamond Logic® engine brake is available for all engine displacements. The operator can select one of three brake settings, depending on terrain and driving conditions. See vehicle *Operator's Manual* for complete operating instructions.

Engine Brake Concept

The engine brake system retards vehicle speed during deceleration or braking. During deceleration and braking, the vehicle wheels drive the engine; the engine acts as an energy absorber.

Engine Brake Operation

To absorb energy, the Diamond Logic® engine brake combines bleeding off compressed intake air, VGT controlling exhaust back pressure, and vehicle driven piston movement.

- Energy is absorbed during the compression stroke, when intake air is compressed and forced through a slightly open exhaust valve, providing compressed air flow to the VGT.
- VGT turbine vanes create the desired energy absorbing, back pressure and intake boost.
- At the top of the compression stroke energy dissipates, pressure to force the piston down is eliminated, and energy is absorbed by the vehicle drive pulling the piston down.

Engine Brake Control

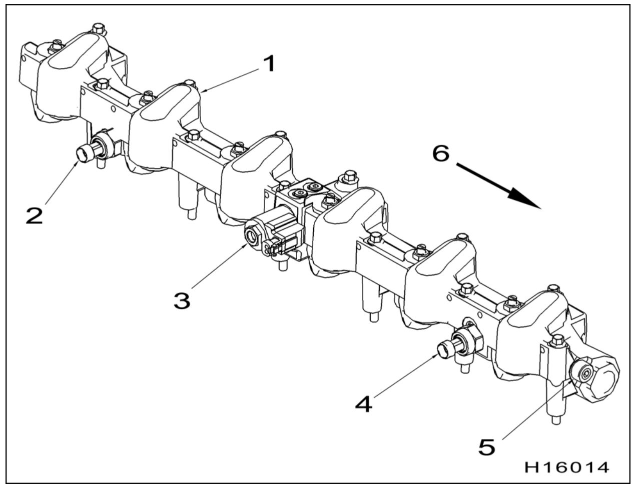


Figure 46 High-pressure oil rail

1. High-pressure oil rail
2. ICP sensor
3. Brake shut-off valve assembly
4. BCP sensor
5. Brake pressure relief valve
6. Front of engine

The high-pressure oil rail uses high-pressure oil from the injection control pressure system to open exhaust valves.

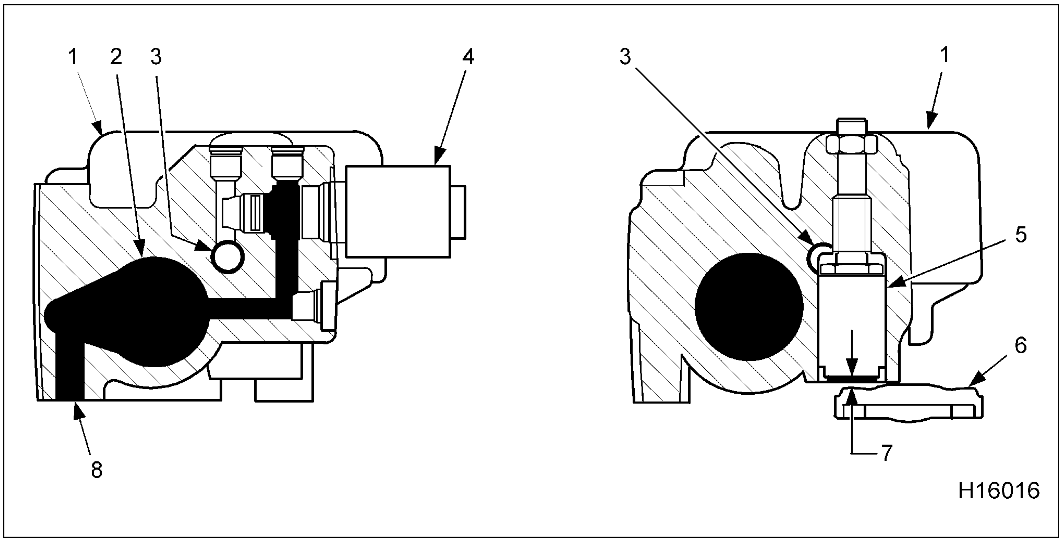


Figure 47 Brake shut-off valve and brake actuator– OFF

1. High-pressure oil rail
2. Injector oil gallery
3. Brake oil gallery
4. Brake shut-off valve assembly
5. Brake actuator piston assembly
6. Exhaust valve bridge
7. Valve lash (actuator retracted)
8. Oil inlet

During normal engine operation, oil in the high-pressure rail goes to the fuel injectors only. A brake shut-off valve, mounted in the high-pressure oil rail, is closed to prevent oil from entering the brake gallery.

Operation of Diamond Logic® Engine Brake in Braking Mode

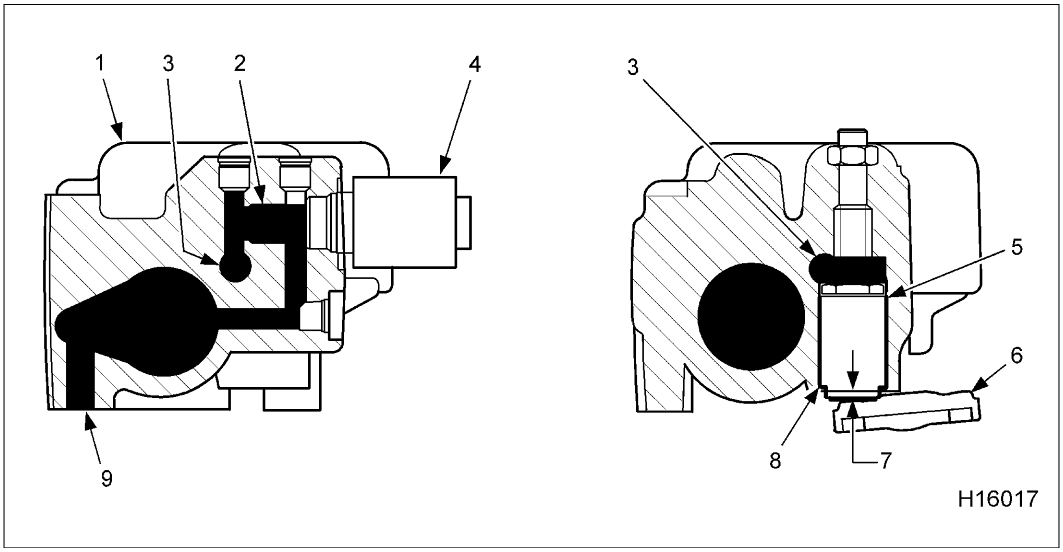


Figure 48 Brake shut-off valve and brake actuator– ON

1. High-pressure oil rail
2. High-pressure oil flow to brake oil gallery
3. Brake oil gallery
4. Brake shut-off valve assembly
5. Brake actuator piston assembly
6. Exhaust valve bridge
7. Valve lash (actuator deployed)
8. Normal oil seepage
9. Oil inlet

The ECM monitors the following criteria to make sure certain conditions are met.

- ABS (inactive)
- RPM (greater than 1200)
- APS (less than 5%)
- Idle validation
- EOT (greater than or equal to 60 °C [140 °C])
- Operator input switches (On/Off) (power selection – Low, Med, High)

If On is selected, and the preceding criteria is met, the engine brake will activate.

When the engine brake is activated, the ECM provides the power to activate the brake shut-off valve to allow oil from the injector oil gallery to flow to the brake oil gallery. High oil pressure activates the brake actuator pistons to open the exhaust valves.

During an ABS event, the engine brake is deactivated. The engine brake is activated once the ABS event is over.

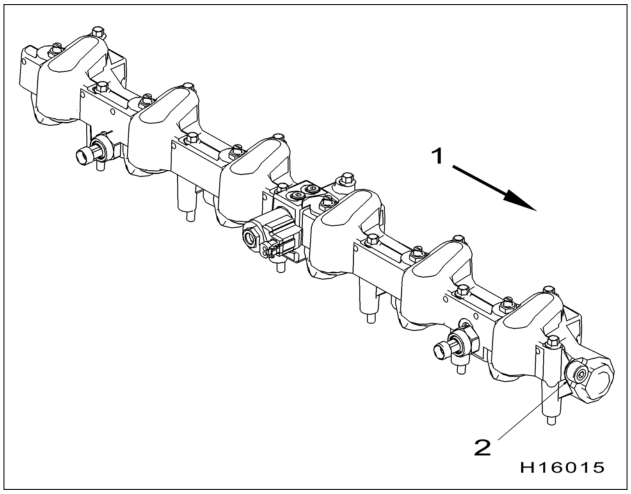


Figure 49 Brake pressure relief valve in high-pressure oil rail

1. Front of engine
2. Brake pressure relief valve

The ECM removes the power source from the brake shut-off valve to deactivate the engine brake. Residual brake gallery pressure initially bleeds from the actuator bore. When brake gallery pressure bleeds down to 6895 kPa (1000 psi), the brake pressure relief valve opens, and oil drains back to sump.

Table of Contents

Standard Features

Electronic Governor Control

International® engines are electronically controlled for all operating ranges.

American Trucking Association (ATA) Datalink

Vehicles are equipped with the ATA datalink connector for communication between the Electronic Control Module (ECM) and the Electronic Service Tool (EST).

The ATA datalink supports:

- Transmission of engine parameter data.
- Transmission and clearing of Diagnostic Trouble Codes (DTCs).
- Diagnostics and troubleshooting.
- Programming performance parameter values.
- Programming engine and vehicle features.
- Programming calibrations and strategies in the ECM and Injector Drive Module (IDM).

For additional information, see “ATA Datalink” in Section 7 (page 309).

Service Diagnostics

The EST provides diagnostic information using the ATA datalink. The recommended EST is the EZ-Tech® with MasterDiagnostics® software provided by International®.

Faults from sensors, actuators, electronic components, and engine systems are detected by the ECM and sent to the EST as DTCs. Effective engine diagnostics require and rely on DTCs.

Event Logging System

The event logging system records engine operation above maximum rpm (overspeed), high coolant temperature, low coolant level, 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.

Electronic Speedometer and Tachometer

The engine control system calibrates vehicle speed up to 157,157 pulses per mile. The new speed calibration information must be programmed with an EST.

The tachometer signal is generated by the ECM by computing signals for the Camshaft Position (CMP) sensor and Crankshaft Position (CKP) sensor. Calculations for each sensor are sent to the instrument panel through the Drivetrain Datalink (CAN 1) and to the EST through the ATA datalink.

Inlet Air Heater

The inlet air heater feature improves engine start-up in cold weather. The ECM controls the intake air heater and monitors the engine temperature. When the engine is ready for cranking, the ECM sends a message to shut off the WAIT TO START lamp.

For additional information, see “IAH System” in Section 7 (page 444).

Fast Idle Advance

Fast idle advance increases engine idle speed up to 750 rpm for faster warm-up to operating temperature. This occurs by the ECM monitoring the EOT sensor input and adjusting the fuel injector operation accordingly.

Low idle speed is increased proportionally when the engine oil temperature is between 15 °C (59 °F) at 700 rpm to below -10 °C (14 °F) at 750 rpm.

Cold Ambient Protection (CAP)

CAP protects the engine from damage caused by prolonged idle at no load during cold weather. CAP also improves cab warm-up.

CAP maintains engine coolant temperature by increasing the engine rpm to a programmed value when the ambient air temperature is at or below 0 °C (32 °F) and the engine coolant temperature is below 65 °C (149 °F) while the engine has been idling with no load for more than 5 minutes.

CAP is standard on trucks without an Idle Shutdown Timer (IST).

Coolant Temperature Compensation (Engine Over Temperature Protection System)

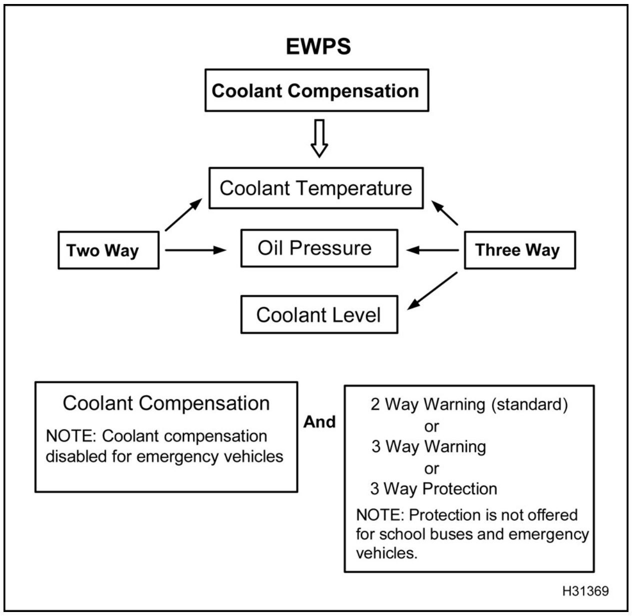


Figure 50 Coolant Temperature Compensation

Coolant temperature compensation reduces fuel delivery if the engine coolant temperature is above the cooling system specifications.

Before standard engine warning or optional warning/protection systems engage, the reduction in fuel delivery begins when the engine coolant temperature reaches approximately 107 °C (225 °F). A rapid reduction of 15 percent is achieved when engine coolant temperature reaches approximately 110 °C (230 °F).

NOTE: Coolant temperature compensation is disabled in emergency vehicles that require 100 percent power on demand.

Engine Crank Inhibit (ECI)

ECI will not allow the starting motor to crank when the engine is running or the automatic transmission is in gear. ECI is an optional system for vehicles with manual transmissions.

For additional information, see “ECI System” in Section 7 (page 366).

Change Engine Oil Interval Message

The change engine oil interval message can be programmed with the EST for mileage, hours, or amount of fuel used. The change oil message timer can be reset using the CRUISE ON and RESUME/ACCEL switches or EST.

Optional Features

Road Speed Limiting

Road speed limiting limits the speed to the maximum vehicle speed programmed by the customer.

Cruise Control

The ECM controls the cruise control feature. The cruise control system functions similarly for all electronic engines. Maximum and minimum allowable cruise control speeds will vary based on model. To operate cruise control, see appropriate truck model Operator’s Manual.

Engine Fuel Pressure (EFP) Monitor

The EFP monitors fuel pressure and indicates when the fuel filter needs to be serviced. For additional information, see “EFP Sensor” in Section 7 (page 406).

Traction Control

Traction control is a system that identifies when a wheel is going faster than the other wheels during acceleration.

When a traction control condition occurs, a datalink message is sent to the ECM to limit fuel for the purpose of reducing engine torque.

Vehicles must have a transmission and an Antilock Braking System (ABS) that supports traction control.

Diamond Logic® Engine Brake

International® now offers an optional engine brake. See “Diamond Logic® Engine Brake” in Section 1 (page 53) for feature description.

Diamond Logic® Exhaust Brake

International® now offers an optional integrated exhaust brake. This feature uses VGT to assist in braking.

Engine Warning Protection System (EWPS)

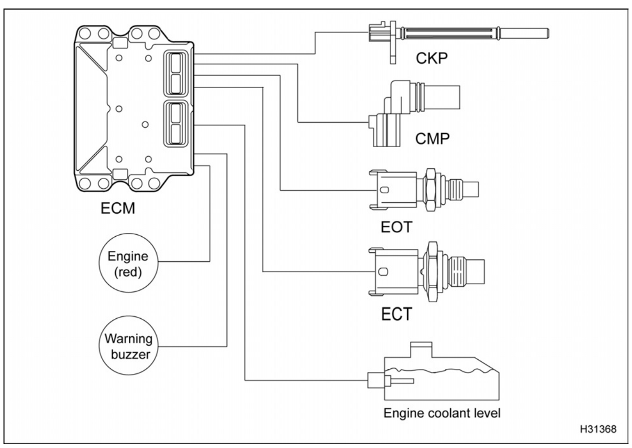


Figure 51 Engine Warning Protection System (EWPS)

The EWPS safeguards the engine from undesirable operating conditions to prevent engine damage and to prolong engine life. The ECM will illuminate the red ENGINE lamp and sound the warning buzzer when the ECM detects:

- High coolant temperature.
- Low oil pressure.
- Low coolant level (3–way system only).

When the protection feature is enabled and a critical engine condition occurs, the on-board electronics will shut the engine down. An event logging feature will record the event in engine hours and odometer readings. After the engine has shutdown, and the critical condition remains, the engine can be started for a 30 second run time.

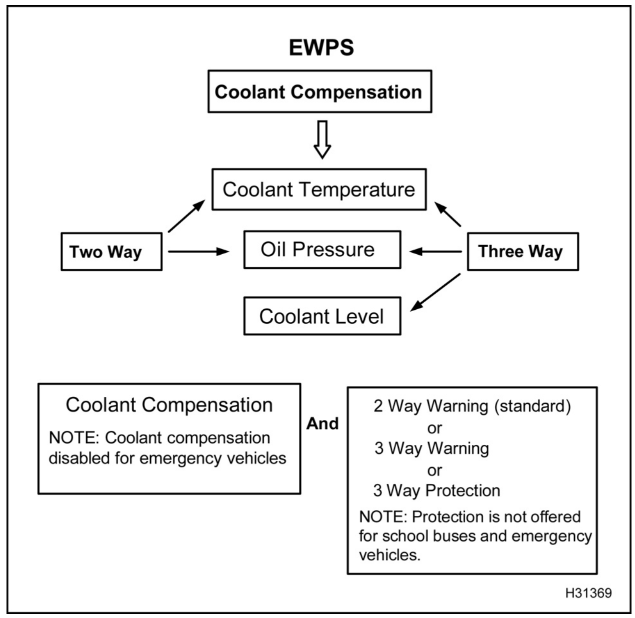


Figure 52 EWPS flowchart

Coolant Temperature Compensation and EWPS

Coolant temperature compensation reduces fuel delivery when the engine coolant temperature is above cooling system specifications.

The reduction in fuel delivery begins when engine coolant temperature reaches approximately 107 °C (225 °F). A reduction of 15% will be achieved as the temperature reaches approximately 110 °C (230 °F).

When the engine coolant temperature is *above* 110 °C (230 °F), the red ENGINE lamp is illuminated and an audible alarm sounds. After the alarm sounds, the engine will shutdown.

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

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

Fuel reduction is calibrated to a maximum of 30% before standard engine warning or optional EWPS is engaged. A DTC is stored in the ECM memory when a warning or shutdown occurs.

NOTE: Coolant temperature compensation is disabled in emergency vehicles that require 100% power on demand.

Idle Shutdown Timer (IST)

The IST feature allows the ECM to shutdown the engine when an extended idle condition occurs. The IST can be programmed for the customer to automatically shut the engine down for idle times that range from 2 to 120 minutes.

The red ENGINE lamp will illuminate before engine shutdown. The lamp will flash for 30 seconds to warn the operator engine shutdown is approaching. Idle time is measured from the last clutch or brake pedal transition. The engine must be out of gear for the IST to work.

For additional information and resets for engine shutdown timer, see “IST System” in Section 7 (page 497).

Electronic Fan (EFAN)

Engine electronics allow for the operation of an electronic fan or an air fan solenoid. For additional information, see “EFAN Control” in Section 7 (page 398).

Radiator Shutter Enable (RSE)

The RSE keeps the engine warm during cold weather operation. The RSE enables faster warm-up of the cab and faster windshield defrosting. For additional information, see “RSE” in Section 7 (page 514).

Table of Contents

Diagnostic Trouble Code Detection

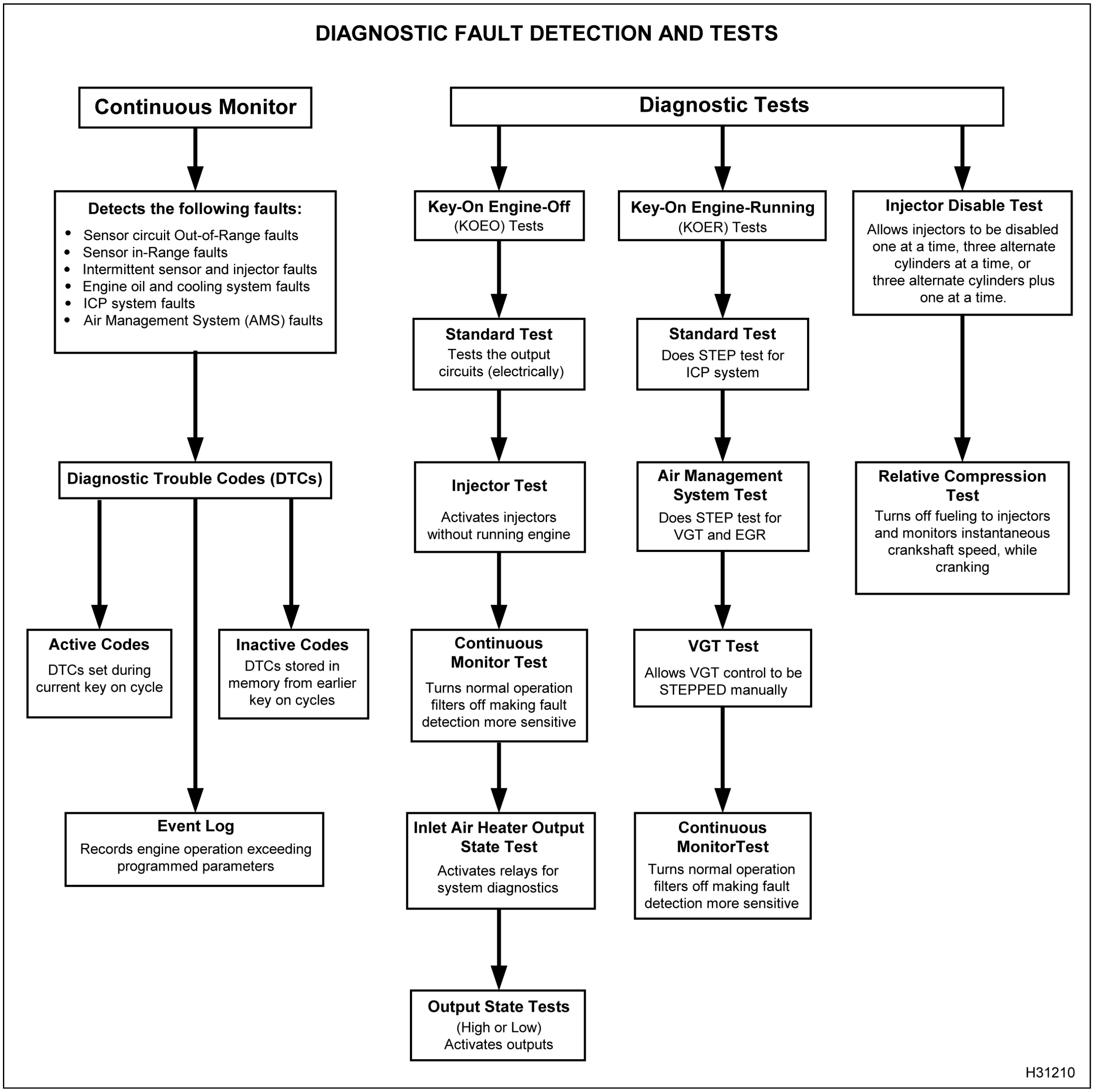


Figure 53

Continuous Monitor

Continuous Monitor is a series of continuous diagnostic tests done by the Electronic Control Module (ECM) to detect failure modes (Out of Range, In Range, and System Faults). During Continuous Monitor the ignition switch is on.

- **Out of Range High** (Voltage over normal operating range)
- **Out of Range Low** (Voltage under normal operating range)
- **In Range** (In normal operating range but not correct for conditions)
- **System Malfunction** (System is not operating according to conditions)

If an input signal is out of range (over or under normal operating range), the ECM logs a fault and sets a Diagnostic Trouble Code (DTC). The ECM monitors the operation of systems for in range conditions to determine if systems are working in a normal operational range; If the ECM detects that a system falls outside a predetermined range, it will log a fault and set a DTC.

Each DTC has a three digit number to identify the source of a malfunction measured or monitored electronically. A fault is a malfunction measured or monitored electronically.

The ECM continuously monitors the Injection Control Pressure (ICP) system and the Air Management System (AMS). If the ECM detects that a system falls outside a predetermined range, the ECM logs a fault and sets a DTC.

During normal engine operation, the ECM automatically performs several tests to detect faults. When a fault is detected, the ECM often runs a fault management strategy to allow continued, though sometimes degraded, vehicle operation.

With the engine running, engine events are permanently recorded in the ECM; engine events can be retrieved with the Electronic Service Tool (EST).

Engine Events

Standard Engine Events

Standard engine events include excessive coolant temperature and engine rpm (over-speed).

Optional Engine Events

Optional engine events are monitored and recorded, if the engine is equipped with the optional Engine Warning Protection System (EWPS). Optional engine events recorded by the ECM include low coolant level and low oil pressure.

Engine Event Hours/Odometer

The ECM records engine events in two ways, hours and odometer readings.

Examples

- Overheat Hour 1
- Overheat Hour 2
- Overheat Odometer 1
- Overheat Odometer 2

The ECM stores the two most recent events. Two events could happen in the same hour, and two events could happen in the same mile.

Diagnostic Trouble Codes

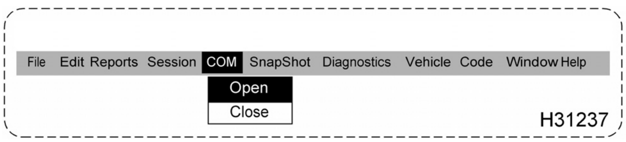
WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, make sure the transmission is in park or neutral, parking brake is set, and wheels are blocked before doing service bay diagnostics on engine or vehicle.

Using EST

Accessing Diagnostic Trouble Codes (DTCs)

NOTE: When opening VIN+ session to fill out form heading, the DTC window automatically appears.

1. Turn the ignition switch to ON.



2. Select Com from the menu bar in the main window, then select Open.

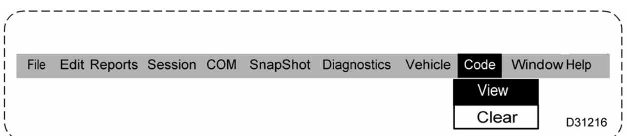


Figure 55 Menu bar Code/View

3. Select Code from the menu bar, then View for the Diagnostic Trouble Code window.

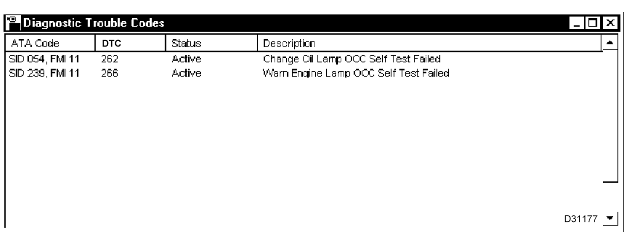


Figure 56 Diagnostic Trouble Code window

Reading DTCs

ATA code: Codes associated with a Subsystem Identifier (SID), Parameter Identifier (PID), and Failure Mode Indicator (FMI)

DTC: Diagnostic Trouble Code

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 ignition switch cycle. When the ignition switch is turned to OFF, inactive DTCs from previous ignition switch on cycles 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 a previous ignition switch cycle, if the code was not cleared.

Description: Defines each DTC

Clearing DTCs

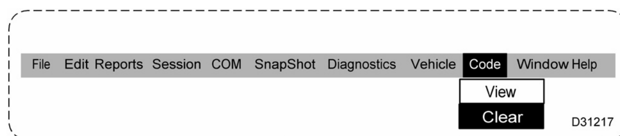


Figure 57 Menu bar Code/Clear

1. Select Code from the menu bar, then select Clear.

   NOTE: If unable to clear inactive DTCs, be sure Diagnostic Trouble Code window is active by clicking in the window area.

Using Cruise Switches

Accessing DTCs

NOTE: Read and be familiar with all steps and time limits in this procedure before starting.

1. Set parking brake for the correct signal from the Electronic System Controller (ESC).
2. Turn the ignition switch to ON. (Do not crank the engine.)

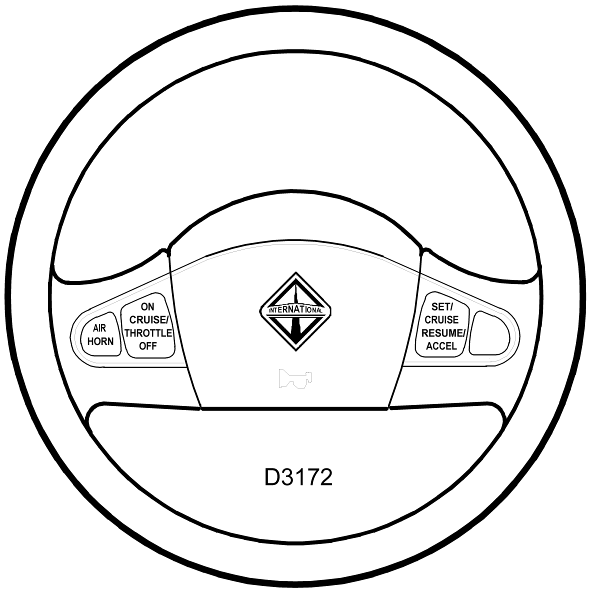


Figure 58 Cruise Switches

3. Press and release the CRUISE ON and RESUME/ACCEL switches at the same time within 3 seconds of the ignition switch on.

   NOTE: There could be as much as a 10 second delay from the time switches are pressed to the time DTCs are flashed.

Reading DTCs

1. The red ENGINE lamp will flash once to indicate the beginning of active DTCs.
2. The amber ENGINE lamp will flash repeatedly, signaling active DTCs.

   NOTE: All DTCs are three digits. For DTCs, see Appendix C in this manual or form CGE310-1. Code 111 indicates that no faults were detected.

3. Count the flashes of the amber ENGINE lamp in sequence. After each digit of the code a short pause will occur.
   - Two amber flashes, a pause; three amber flashes, a pause; and two amber flashes and a pause indicate code 232.
4. For more than one DTC, the red ENGINE lamp will flash once indicating the beginning of another active DTC.
5. After all active DTCs have flashed, the red ENGINE lamp will flash twice to indicate the start of inactive DTCs. Count the flashes from the amber ENGINE lamp. If there is more than one inactive code, the red ENGINE lamp will flash once between each DTC.
6. After all DTCs have been sent, the red ENGINE lamp will flash three times indicating end of DTC transmission.
7. To repeat DTC transmission, cycle the ignition switch and press and release the CRUISE ON and RESUME/ACCEL switches, at the same time, within 3 seconds of ignition switch on. The ECM will re-send stored DTCs.

Clearing DTCs

NOTE: Read and be familiar with all steps and time limits in this procedure before starting.

1. Set parking brake for the correct signal from the Electronic System Controller (ESC).
2. Turn the ignition switch to ON. (Do not crank the engine.)
3. Press and hold the CRUISE ON and RESUME/ACCEL switches at the same time.
4. Press and release the accelerator pedal three times within 6 seconds of the ignition switch on.
5. Release the cruise control switches to clear the inactive DTCs.

NOTE: Completing this procedure within 3 seconds of the ignition switch on, without turning the ignition switch off, will restart DTC transmission to the instrument panel.

Diagnostic Tests

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

Key-On Engine-Off Tests

Standard Test

The KOEO Standard test is done by the ECM. The technician runs this test, using the EST or the CRUISE ON and RESUME/ACCEL switches.

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, the Standard test detects shorts or opens in the harnesses, actuators, and ECM. If a circuit fails the test, a fault is logged and a DTC is set.

The ECM checks the following circuits:

- Injection Pressure Regulator (IPR)
- Brake shutoff valve (optional)
- Engine Fan (EFAN) (optional)
- Radiator Shutter Enable (RSE) (optional)

When the OCC is done, the DTC window will display DTCs, if there are problems.

Standard Test Using EST

1. Set parking brake to ensure the correct signal from the Electronic System Controller (ESC).
2. Turn the ignition switch to ON. (Do not crank the engine.)

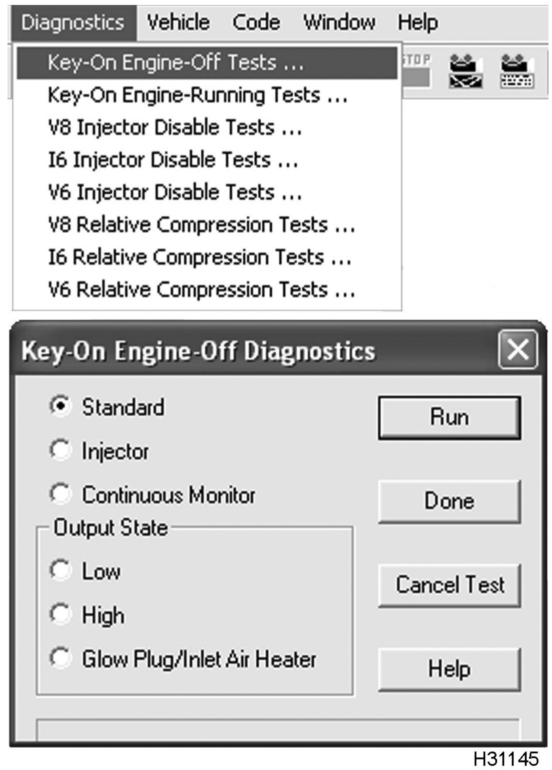


Figure 59 Standard test

3. Select Diagnostics from the menu bar.
4. Select Key-On Engine-Off tests from the drop down menu.
5. From the KOEO Diagnostics menu, select Standard and Run to start the 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.

Standard Test Using Cruise Switches

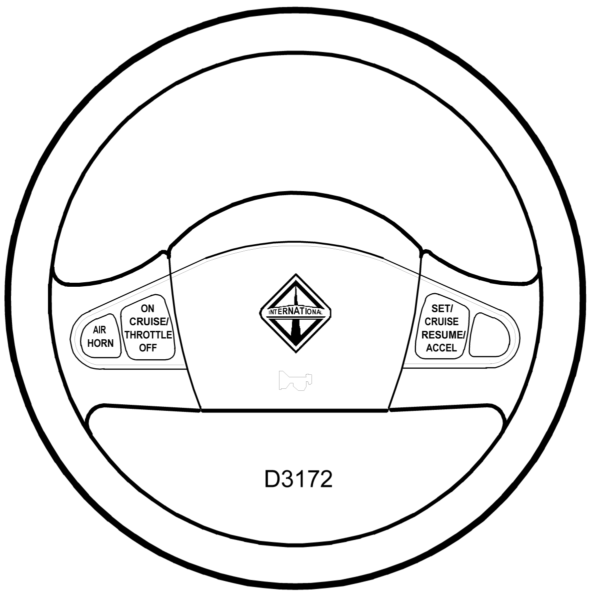


Figure 60 Cruise Switches

NOTE: Read and be familiar with all steps and time limits in this procedure before starting.

1. Set parking brake to ensure the correct signal from the Electronic System Controller (ESC).
2. Turn the ignition switch to ON. (Do not crank the engine.)
3. Press and release the CRUISE ON and RESUME/ACCEL switches at the same time, twice within 3 seconds of the ignition switch on.
   - The ECM will begin the Output Circuit Check (OCC).

     When the OCC is done, the ECM will flash the red ENGINE and amber ENGINE lamps to signal the DTCs.

NOTE: There could be as much as a 10 second delay from the time switches are pressed to the time DTCs are flashed.

Injector Test

NOTE: The Injector test can only be done with the EST; MasterDiagnostics® software is required. The Standard test must be done before doing the Injector test.

The Injector test diagnoses electrical problems in IDM wiring or injectors.

NOTE: Before doing the Injector test, DTCs should be accessed, noted, and cleared. This allows DTCs found to be displayed as Active DTCs.

During the Injector test, the ECM requests the IDM actuate the injectors in numerical order (1 through 6), not in firing order. The IDM 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 IDM sends a fault to the ECM. The ECM logs the fault, a DTC is 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 IDM. 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, if there are problems.

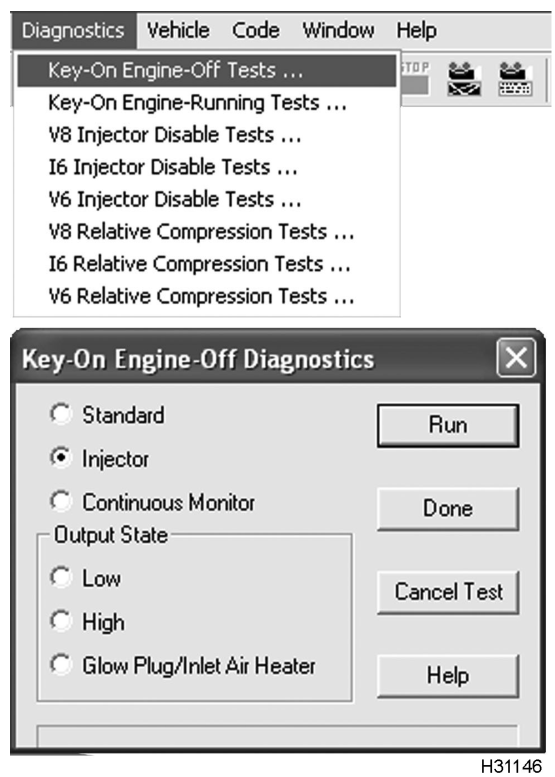


Figure 61 Injector test

1. Select Diagnostics from the menu bar.
2. Select Key-On Engine-Off Tests from the drop down menu.

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.

3. From the KOEO Diagnostics menu, select Injector and Run to start the test.

NOTE: During the Injector test, injector solenoids should click when actuated. If a series of clicks are not heard for each injector, one or more injectors are not activating.

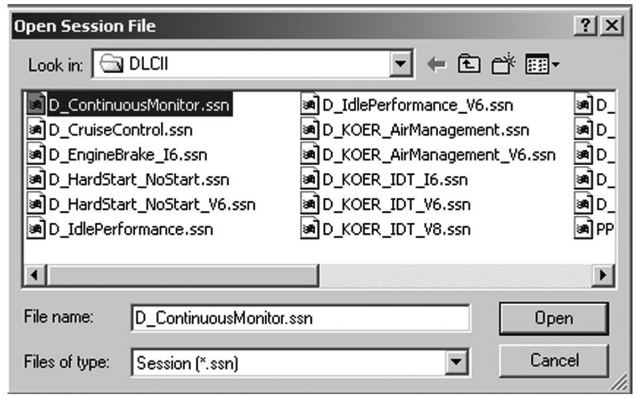
Continuous Monitor Test

NOTE: This test can only be done with the EST; MasterDiagnostics® software is required.

The Continuous Monitor test troubleshoots intermittent connections between the ECM and sensors. The engine can be off or running.

The EST monitors the following circuits:

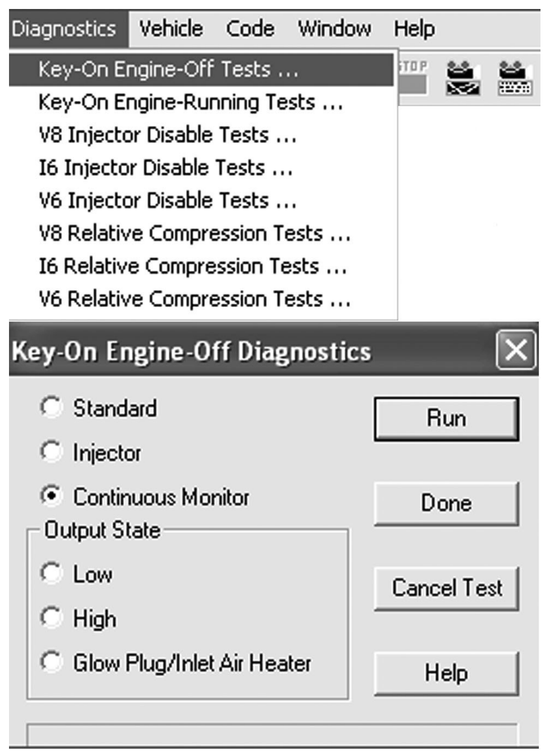
- Accelerator Position Sensor (APS)
- Barometric Absolute Pressure (BAP)
- Battery Voltage (V_{Batt})
- Brake Control Pressure (BCP) (optional)
- EGR Valve Position (EGRP)
- Exhaust Back Pressure (EBP)
- Engine Coolant Level (ECL)
- Engine Fuel Pressure (EFP) (optional)
- Engine Oil Pressure (EOP)
- Engine Oil Temperature (EOT)
- Intake Air Temperature (IAT)
- Injection Control Pressure (ICP)
- Manifold Air Temperature (MAT)
- Manifold Absolute Pressure (MAP)



J31240

Figure 62 Continuous Monitor session

1. Select D_ContinuousMonitor.ssn from the open session file window and select OPEN to open the session.



H31229

Figure 63 Continuous Monitor test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Off Tests from the drop down menu.

4. From the KOEO Diagnostics menu, select Continuous Monitor and select Run to start the test.

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, be careful to avoid rotating parts (belts and fan) and hot engine surfaces.

5. Wiggle connectors and wires at all suspected problem locations. If circuit continuity is interrupted, the EST will display DTCs related to the condition.
6. Correct problem causing active DTCs.
7. Clear DTCs.

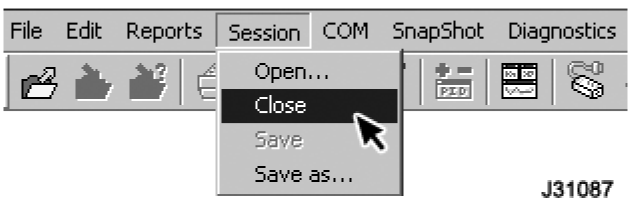


Figure 64 Close session

8. When finished with this test, select Session from menu bar, then Close.

Output State Low Test

NOTE: This test can only be done with the EST; MasterDiagnostics® software is required.

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.

The following actuators are activated when toggled low during the test:

- Injection Pressure Regulator (IPR) (electrical circuit only)
- Engine Fan (EFAN) relay (optional) (electrical circuit and inspect if clutch is engaged)
- Radiator Shutter Enable (RSE) (optional) (electrical circuit, audible, and visual inspection of shutter position)
- EGR (audible and visual inspection only) continuous monitoring by EGR drive module
- VGT vanes full open (electrical circuit, audible, and visual inspection of actuator arm)

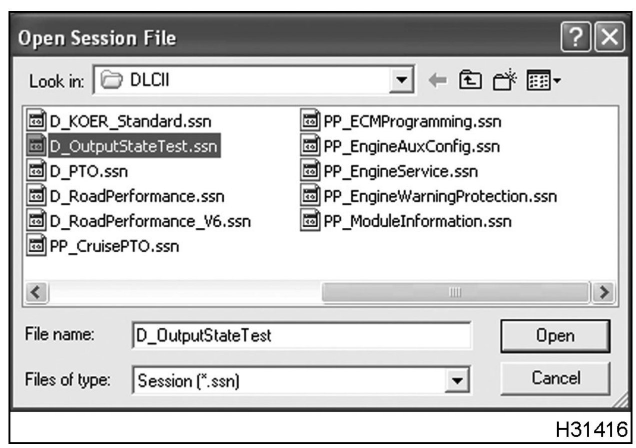
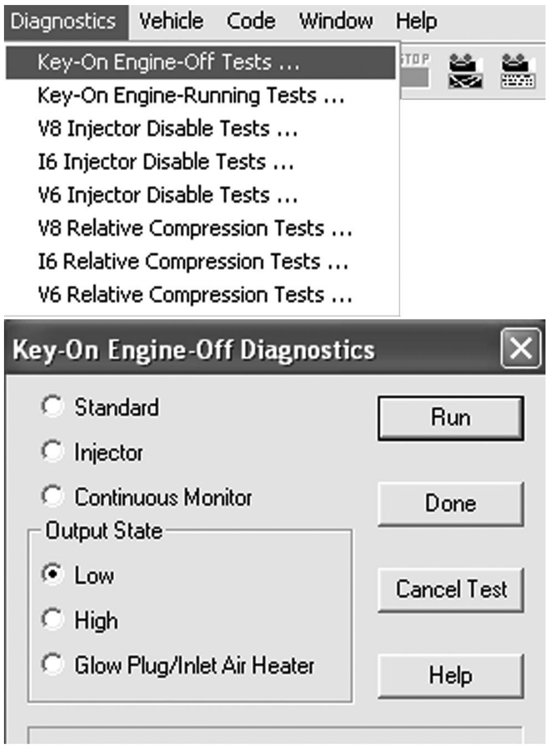


Figure 65 Output State Test Session

1. Select D_OutputStateTest.ssn from the open session file window.



H31231

Figure 66 Output State Low test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Off Tests from the drop down menu.

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.

4. From the KOEO Diagnostics menu, select Output State Low and Run to start the test.
5. Toggle between the Low and High tests in the Output State Test. Listen and observe actuator control or circuit operation.

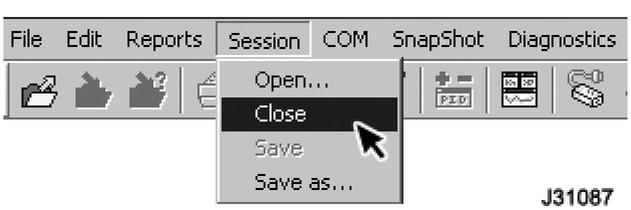


Figure 67 Close session

6. When finished with this test, select Session from menu bar, then Close.

Output State High Test

NOTE: This test can only be done with the EST; MasterDiagnostics® software is required.

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.

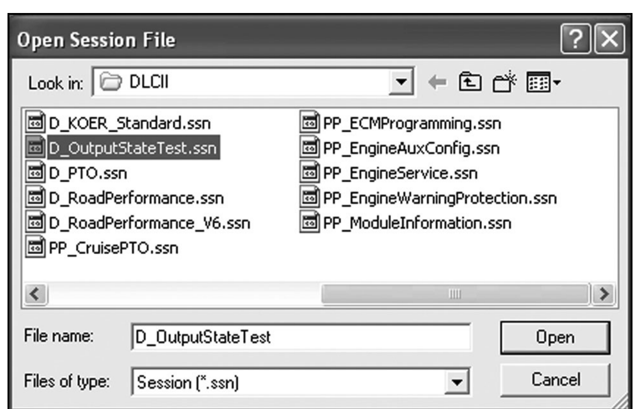
During this test, the output of the circuit in question is monitored with a DMM. The DMM measures a high voltage state, as the outputs are toggled. The actual voltage will vary with the circuit tested.

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.

The following actuators are activated when toggled high during the test:

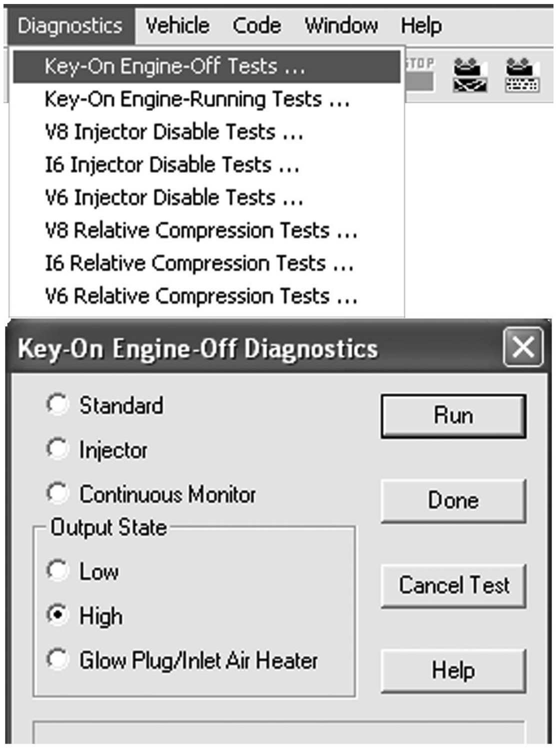
- VGT vanes full closed (electrical circuit, audible, and visual inspection of actuator arm)
- Brake Shutoff valve (optional) (electrical circuit only)



H31416

Figure 68 Output State Test Session

1. Select D_OutputStateTest.ssn from the open session file window.



H31230

Figure 69 Output State High test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Off Tests from the drop down menu.

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.

4. From the KOEO Diagnostics menu, select Output State Test High and Run to start the test.
5. Toggle between the Output State Test Low and the Output State Test High. Listen and observe actuator control or circuit operation.

Figure 70 Close session

6. When finished with this test, select Session from menu bar, then Close.

Glow Plug/Inlet Air Heater Output State Test

NOTE: This test can only be done with the EST; MasterDiagnostics® software is required.

The Glow Plug/Inlet Air Heater Output State test allows the technician to determine if the Inlet Air Heater System is 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.

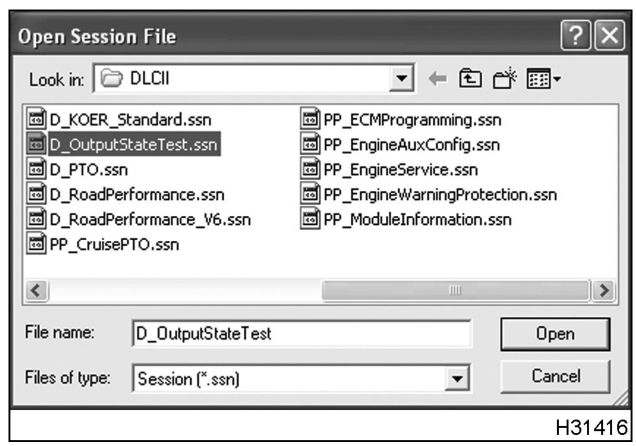
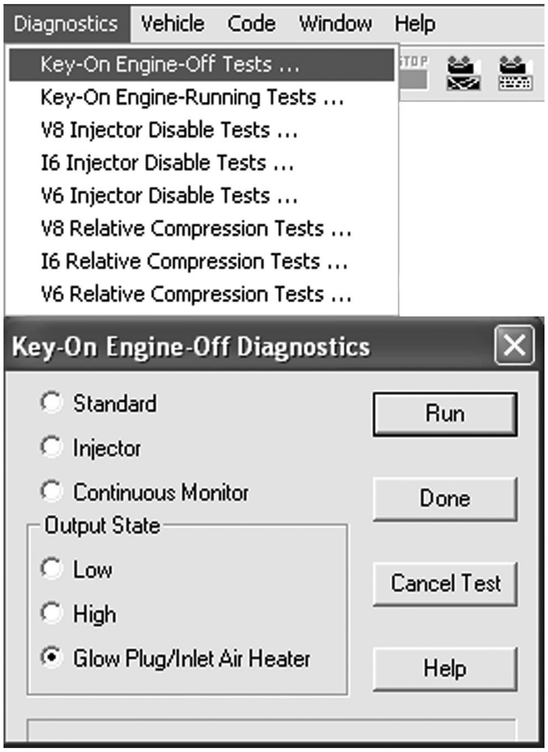


Figure 71 Output State Test Session

1. Select D_OutputStateTest.ssn from the open session file window.



J31139

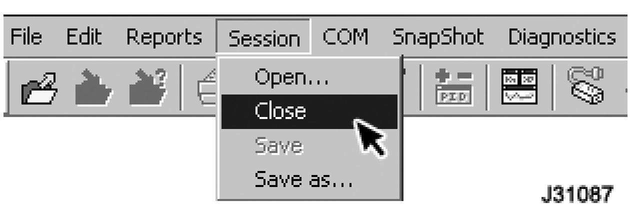
Figure 72 Glow Plug/Inlet Air Heater Output State test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Off Tests from the drop down menu.

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.

4. From the KOEO Diagnostics menu, select Glow Plug/Inlet Air Heater and Run to start the test.

NOTE: This test can only be run twice for each ignition switch cycle. Earlier calibration may not allow the test to be run, contact International® Technical Services.



J31087

Figure 73 Close session

5. When finished with this test, select Session from menu bar, then Close.

Key-On Engine-Running Tests

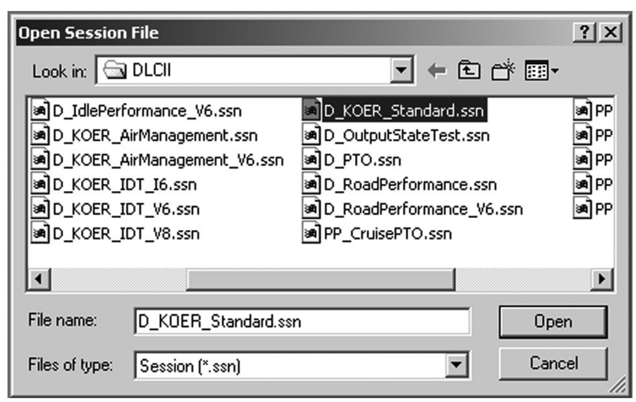
Standard Test

NOTE: The KOER Standard test can only be done with the EST; MasterDiagnostics® software is required.

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: Before doing this test, confirm the following conditions:

- Problems causing active DTCs were corrected, and active DTCs were cleared.
- Engine coolant temperature must be at least 70 °C (158 °F).
- Battery voltage must be higher than 10.5 volts.
- No signal from Vehicle Speed Sensor (VSS)
- Transmission in park or neutral



J31180

Figure 74 KOER Standard session

1. With the engine running, select D_KOER_Standard.ssn from the open session file window.

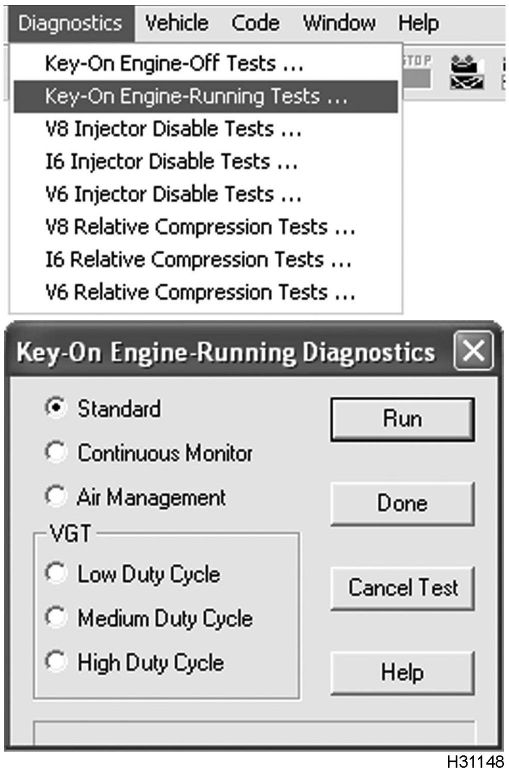


Figure 75 Standard test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Running Tests from the drop down menu.
4. From the KOER Diagnostics menu, select Standard and select Run to start the test.

The ECM increases engine idle to a predetermined value and commands the IPR valve to set ICP to rated speed pressure. If the performance of the ICP system is acceptable, the ECM will control the IPR valve and reduce the pressure in steps, while continuing to monitor the ICP system.

When the test is done, the ECM restores normal engine operation, and the Diagnostic Trouble Code window will display DTCs, if there are problems.

5. Correct problem causing active DTCs.
6. Clear DTCs.

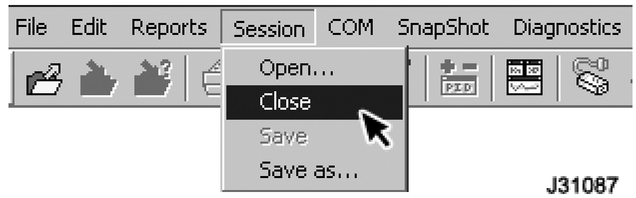


Figure 76 Close session

7. When finished with this test, select Session from menu bar, then Close.

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.

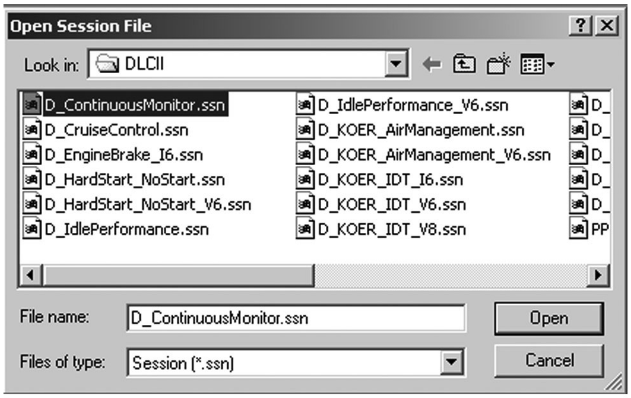
Continuous Monitor Test

NOTE: This test can only be done with the EST; MasterDiagnostics® software is required.

The Continuous Monitor test troubleshoots intermittent connections at sensors and actuators. The engine can be off or running.

The EST monitors the following circuits:

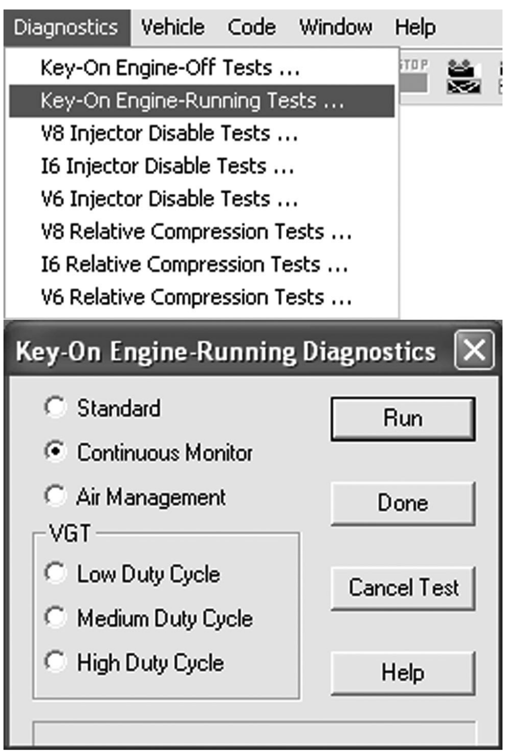
- Accelerator Position Sensor (APS)
- Barometric Absolute Pressure (BAP)
- Battery Voltage (V_{Batt})
- Brake Control Pressure (BCP) (optional)
- EGR Valve Position (EGRP)
- Exhaust Back Pressure (EBP)
- Engine Coolant Level (ECL)
- Engine Fuel Pressure (EFP) (optional)
- Engine Oil Pressure (EOP)
- Engine Oil Temperature (EOT)
- Intake Air Temperature (IAT)
- Injection Control Pressure (ICP)
- Manifold Air Temperature (MAT)
- Manifold Absolute Pressure (MAP)



J31240

Figure 77 Continuous Monitor session

1. With the engine running, select D_ContinuousMonitor.ssn from the open session file window.



H31233

Figure 78 Continuous Monitor test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Running Tests from the drop down menu.
4. From the KOER Diagnostics menu, select Continuous Monitor and select Run to start the test.

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, be careful to avoid rotating parts (belts and fan) and hot engine surfaces.

5. Wiggle connectors and wires at all suspected problem locations. If circuit continuity is interrupted, the EST will display DTCs related to the condition.
6. Correct problem causing active DTCs.
7. Clear DTCs.

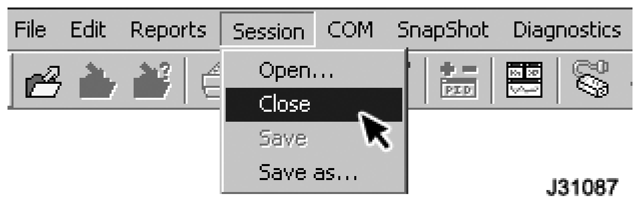


Figure 79 Close session

8. When finished with this test, select Session from menu bar, then Close.

Air Management Test

NOTE: Before doing this test, Performance Diagnostics tests 1 through 12 should be completed. Problems with other systems (injectors, fuel supply, etc.) can affect Air Management test results.

NOTE: The Air Management test can only be done with the EST; MasterDiagnostics® software is required. The Standard test must be done before doing the Air Management test.

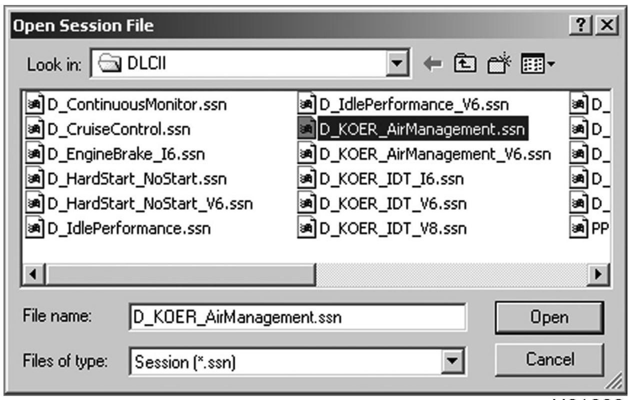
The Air Management test checks the operation of the Air Management System and the following:

- EVRT® electronically controlled turbocharger - International's version of a Variable Geometry Turbocharger (VGT)
- Exhaust Gas Recirculation (EGR) valve

During the Air Management test, the ECM commands the VGT control actuator and EGR actuator through a step test sequence to determine if actuators and the Air Management System are performing as expected. The ECM monitors the feedback signal values from the Exhaust Back Pressure (EBP) sensor and compares those values to the expected values.

If a fault is detected the test will end, engine operation will return to normal, and a DTC will be set.

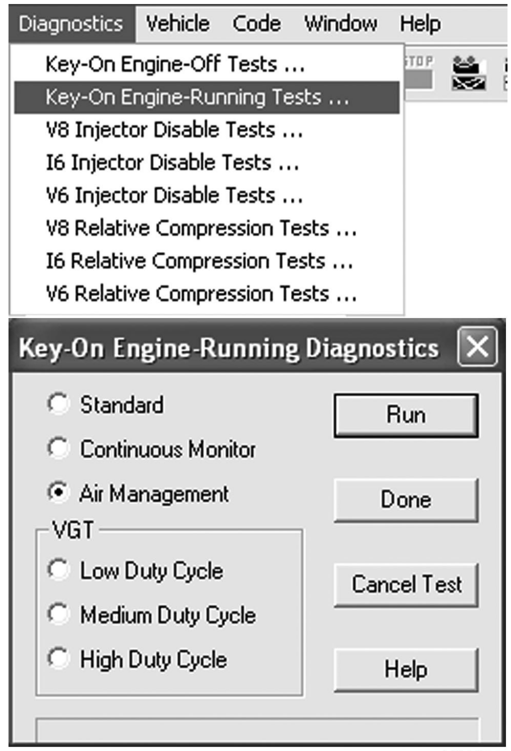
If there are no faults, the test will be completed and engine operation will return to normal.



H31238

Figure 80 Air Management session

1. With the engine running, select D_KOER_AirManagement.ssn from the open session file window and select OPEN to open the session.



H31234

Figure 81 Air Management test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Running Tests from the drop down menu.

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.

4. From KOER Diagnostics menu, select Air Management and Run to start the test.
5. Correct problem causing active DTCs.
6. Clear DTCs.

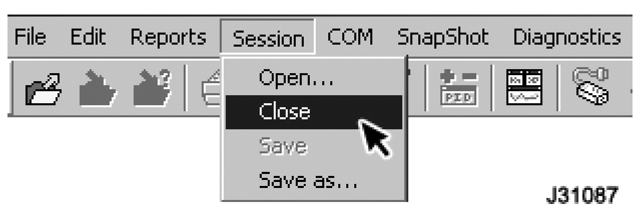


Figure 82 Close session

7. When finished with this test, select Session from menu bar, then Close.

Air Management Test

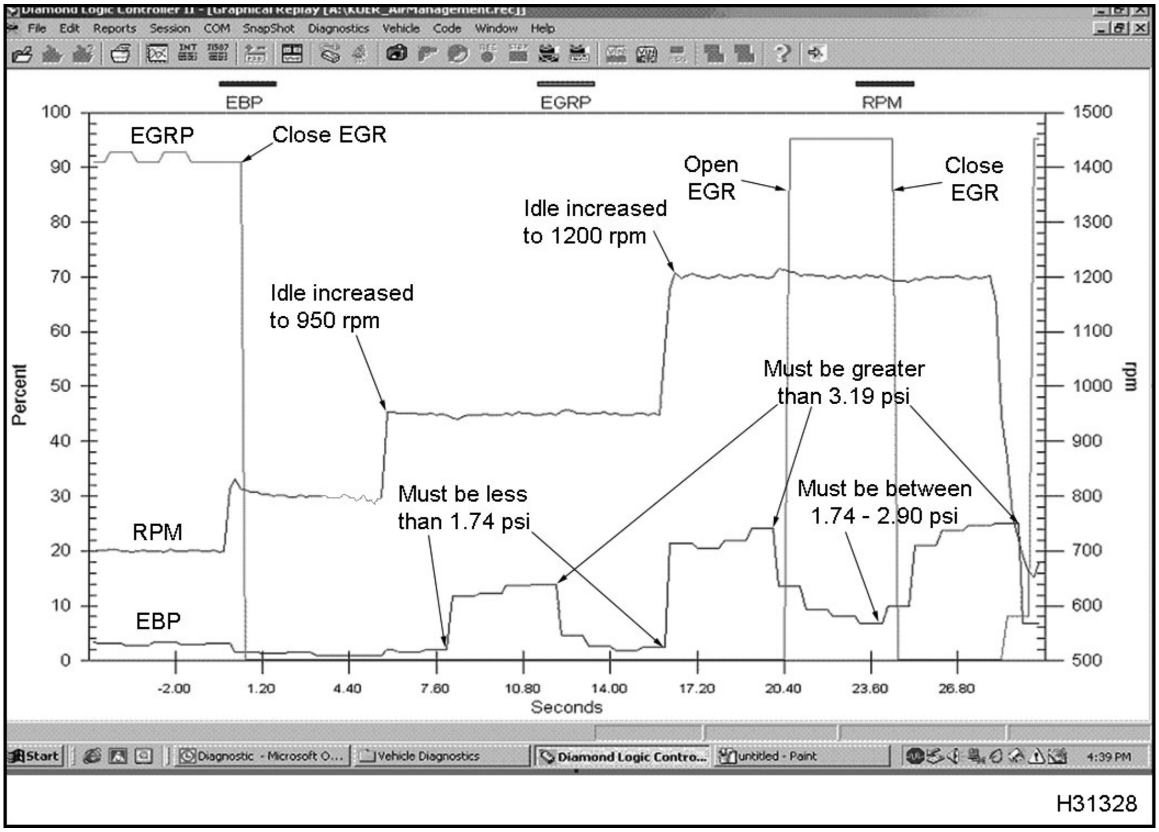


Figure 83 Air Management diagnostic readout

The ECM commands the EGR valve to close. The ECM then increases engine idle speed to 950 RPM and commands the VGT vanes to fully open. The ECM allows EBP to stabilize. The ECM monitors the EBP pressure and compares this pressure to the expected pressure; pressure is expected to drop. If EBP pressure does not match expected pressure, DTC 345 is set and the test is cancelled.

NOTE: Although commanding the EGR to close, it may be stuck partially open, which would cause EBP values to be lower than expected causing the test to fail during the VGT portion of this test. If this is suspected, the operation of the EGR valve should be visually inspected using the Output State tests.

With the EGR still closed, the ECM commands the VGT vanes to fully close. The ECM allows EBP to stabilize. The ECM monitors the EBP pressure and compares this pressure to the expected pressure; pressure is expected to increase. If EBP pressure does not match expected pressure, DTC 345 is set and the test is cancelled.

With the EGR still closed, the ECM commands the VGT vanes to fully open. The ECM allows EBP to stabilize. The ECM monitors EBP pressure and compares this pressure to the expected pressure; pressure is expected to drop. If EBP pressure does not match expected pressure, DTC 345 is set and the test is cancelled.

If all pressures matched the expected pressures, no DTC is set and the test will continue for EGR.

With the EGR still closed, the ECM increases engine RPM to 1200 rpm and commands the VGT vanes to fully close. The ECM allows EBP to stabilize. The ECM monitors the EBP pressure and compares this pressure to the expected pressure; pressure is expected to increase. If EBP pressure does not match expected pressure, DTC 346 is set and the test is cancelled.

With the VGT vanes still closed, the ECM commands the EGR to open, and allows EBP to stabilize. The ECM monitors the EBP pressure and compares this pressure to the expected values; pressure is expected to drop. If EBP pressure does not match expected pressure, DTC 346 is set and the test is cancelled.

With the VGT still closed, the ECM then commands the EGR to close, and allows EBP to stabilize. The ECM monitors the EBP pressure and compares this pressure to the expected pressure; pressure is expected to increase. If EBP pressure does not match expected pressure, DTC 346 is set and the engine will return to normal operation.

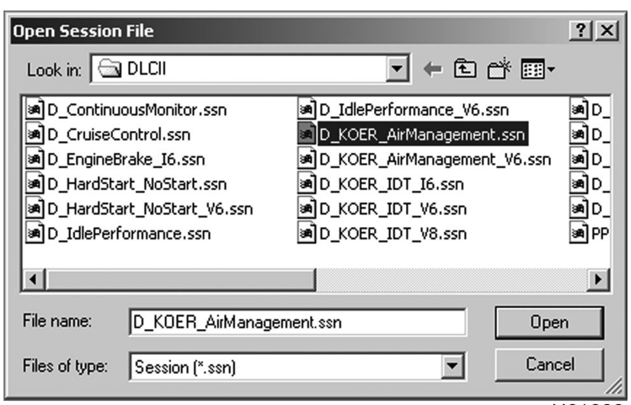
If all pressures matched the expected pressures, no DTC is set and the engine is returned to normal operation.

VGT Test

NOTE: The VGT test can only be done with the EST; MasterDiagnostics® software is required. The Standard test must be done before doing the VGT test.

The VGT test is a manual test that allows the technician to set the VGT duty to low, medium, or high and inspect the exhaust system for leaks.

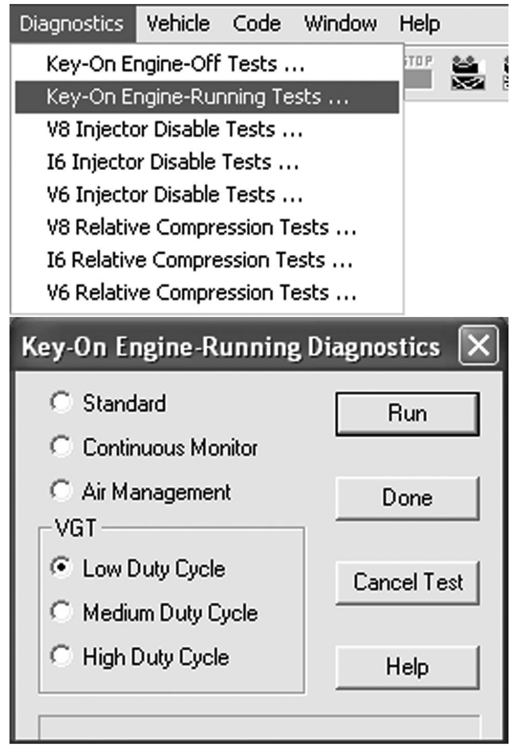
NOTE: Monitor EBP and MAP as VGT duty cycles are changed.



H31238

Figure 84 VGT session

1. With the engine running, select D_KOER_AirManagement.ssn from the open session file window and select OPEN to open the session.



H31232

Figure 85 VGT Low Duty cycle test

2. Select Diagnostics from the menu bar.
3. Select Key-On Engine-Running Tests from the drop down menu.

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.

4. From the KOER Diagnostics menu, select Low Duty Cycle from VGT, and select Run to start test:

   Use the suggested toggle sequence below, to check turbocharger operation from one duty cycle to the other.

   - Low to medium
   - Medium to high
   - High to low
   - Low to high

If the ECM does not receive a request from the EST, after about 40 seconds, the test will automatically end and the engine will return to normal operation.

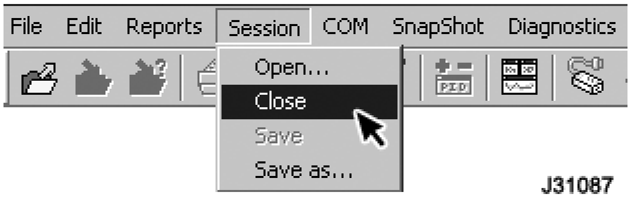


Figure 86 Close session

5. When finished with this test, select Session from menu bar, then Close.

Injector Disable Tests

NOTE: The Injector Disable tests can only be done with the EST; MasterDiagnostics® software is required.

The Injector Disable tests allows the technician to shut off injectors to determine if a specific cylinder is contributing to engine performance. Injectors can be shut off one at a time, alternative cylinders at a time or alternative cylinders plus one.

Alternate cylinders are every other cylinder in firing order.

Firing order: 1-5-3-6-2-4

When all cylinders are active, the contribution of each cylinder is 17% of its overall effect to maintain governed speed. When three cylinders are shut off, contribution of each remaining cylinder is 33% of its overall effect to maintain governed speed. The technician should monitor fuel rate and engine load.

NOTE: The Relative Compression test should be done after doing the Injector Disable test to distinguish between an injector or mechanical problem.

NOTE: Before doing the Auto test or Manual test for injector disable, make sure Performance Diagnostics tests 1 through 10 were completed and the following conditions are maintained:

- Make sure accessories are turned off (for example: engine fan and air conditioning). Items cycled during this test could corrupt the test results.
- Maintain engine idle.
- Keep EOT within a 2 °C (5 °F) range from the beginning to the end of the test. EOT affects injection timing; too much of a change in EOT temperature could corrupt the test results.

NOTE: If any injectors are removed and reinstalled or replaced, test drive vehicle for 20 miles before checking for misfire or rough idle.

Automatic Test

The Automatic test is best used when comparing cylinder to cylinder test data.

NOTE: If MasterDiagnostics® software does not have the Automatic test (auto run feature), see "Injector Disable - Manual test - Engine Hot" later in this section for procedure to compare cylinder to cylinder.

NOTE: Do KOER Standard test before doing this test.

WARNING: To avoid serious personal injury, possible death or damage to the engine or vehicle - comply with the following: When running the engine in the service bay, make sure the parking brake is set, the transmission is in neutral or park, and the wheels are blocked.

NOTE: If any injectors are removed and reinstalled or replaced, test drive vehicle for 20 miles before checking for misfire or rough idle.

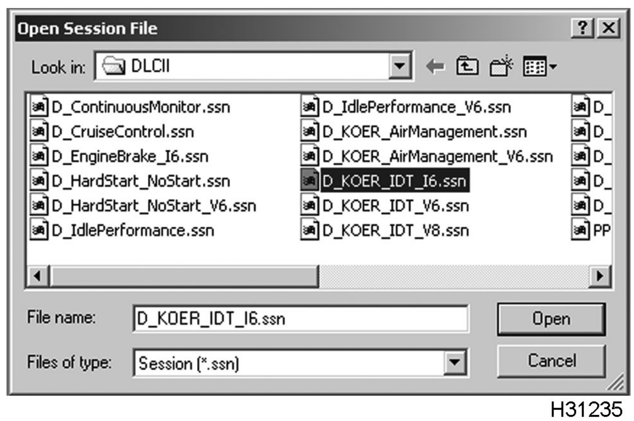


Figure 87 KOER IDT I6 session

1. While engine is running, select D_KOER_IDT_I6.ssn from the open session file window and select OPEN to open the session.

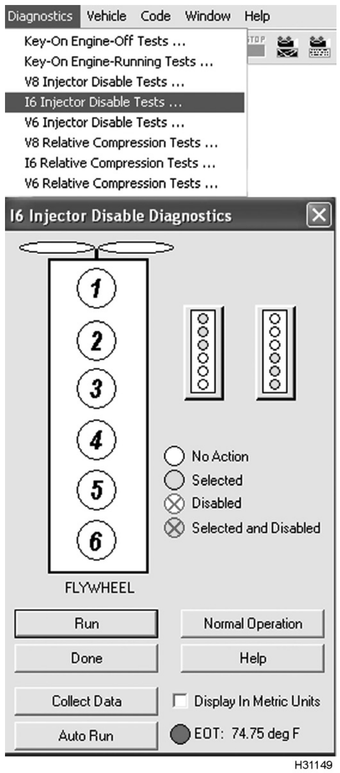


Figure 88 Injector Disable Tests

2. Select Diagnostics from menu bar.
3. Select I6 Injector Disable Tests from drop down menu.

   NOTE: The EOT indicator will change from red to green when engine temperature reaches 70 °C (158 °F) or higher.

   - If the EOT indicator is red, erroneous comparisons are likely from cylinder to cylinder.

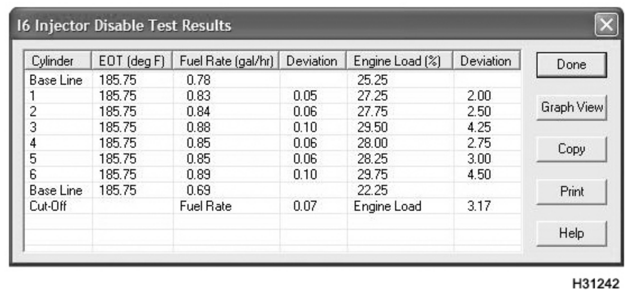
     However, when diagnosing a cold misfire, a technician can listen to tone changes from cylinder-to-cylinder.

   - When the EOT indicator is green and the engine is at 70 °C (158 °F) or higher, fuel rate and timing are more stable, making comparisons from cylinder to cylinder more accurate. Overall engine operation is more stable.

4. Select Auto Run.

NOTE: While running the engine listen for tone changes from cylinder-to-cylinder.

NOTE: If any injectors are removed and reinstalled or replaced, test drive vehicle for 20 miles before checking for misfire or rough idle.


I6 Injector Disable Test Results

Cylinder	EOT (deg F)	Fuel Rate (gal/hr)	Deviation	Engine Load (%)	Deviation
Base Line	185.75	0.78		25.25	
1	185.75	0.83	0.05	27.25	2.00
2	185.75	0.84	0.06	27.75	2.50
3	185.75	0.88	0.10	29.50	4.25
4	185.75	0.85	0.06	28.00	2.75
5	185.75	0.85	0.06	28.25	3.00
6	185.75	0.89	0.10	29.75	4.50
Base Line	185.75	0.69		22.25	
Cut-Off		Fuel Rate	0.07	Engine Load	3.17

Done
Graph View
Copy
Print
Help
H31242

Figure 89 I6 Injector Disable test results (Auto Run - Text View)

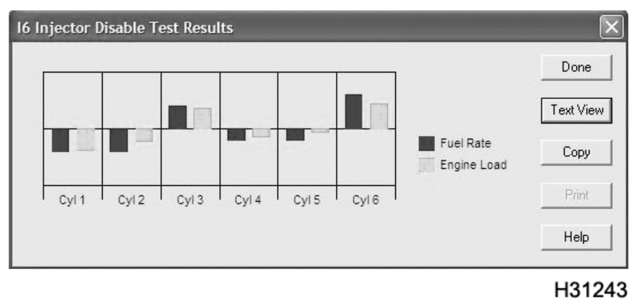


Figure 90 I6 Injector Disable test results (Auto Run - Graph View)

During Auto Run, injectors are shutoff one at a time (1 through 6 numerical sequence). Base line data and results for each cylinder is displayed in the window (Text View) for I6 Injector Disable test results. Test data for each cylinder can also be viewed by selecting the (Graph View). When finished the engine will return to normal operation.

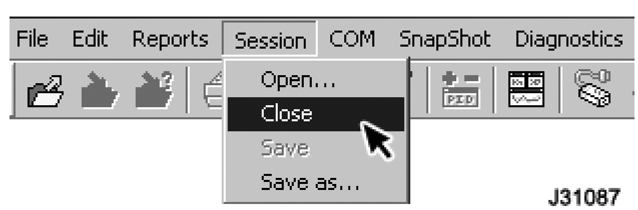


Figure 91 Close session

5. When finished with this test, select Session from menu bar, then Close.

Manual Test - Engine Cold

The Manual test is best used when diagnosing each cylinder for cold misfire, considering EOT changes.

The EOT indicator will change from red to green when engine temperature reaches 70 °C (158 °F) or higher.

- If the EOT indicator is red, erroneous comparisons are likely from cylinder to cylinder.

  However, when diagnosing a cold misfire, a technician can listen to tone changes from cylinder-to-cylinder.

- When the EOT indicator is green and the engine temperature is 70 °C (158 °F) or higher, fuel rate and timing are more stable, making comparisons from cylinder to cylinder more accurate. Overall engine operation is more stable.

Shut off one injector at a time and listen for changes in exhaust tone.

NOTE: If any injectors are removed and reinstalled or replaced, test drive vehicle for 20 miles before checking for misfire or rough idle.

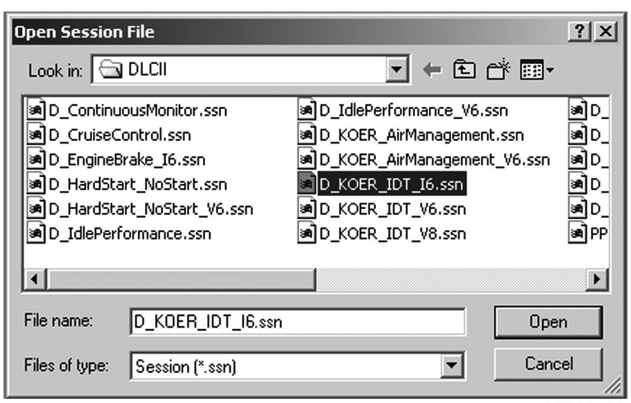


Figure 92 KOER IDT I6 session

1. While engine is running, select D_KOER_IDT_I6.ssn from the open session file window and select OPEN to open the session.

WARNING: To avoid serious personal injury, possible death or damage to the engine or vehicle - comply with the following: When running the engine in the service bay, make sure the parking brake is set, the transmission is in neutral or park, and the wheels are blocked.

2. Select Diagnostics from menu bar.

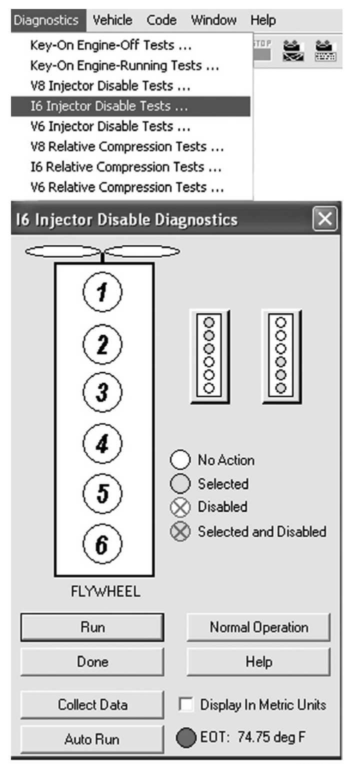


Figure 93 Injector Disable tests

3. Select I6 Injector Disable Tests from drop down menu.

NOTE: The EOT indicator will change from red to green when engine temperature reaches 70 °C (158 °F) or higher.

- If the EOT indicator is red, erroneous comparisons are likely from cylinder to cylinder.

  However, when diagnosing a cold misfire, a technician can listen to tone changes from cylinder-to-cylinder.
- When the EOT indicator is green and the engine temperature is 70 °C (158 °F) or higher, fuel rate and timing are more stable, making comparisons from cylinder to cylinder more accurate. Overall engine operation is more stable.

4. Select cylinder number and select Run. (Injector selected will be disabled and engine noise should change.)
5. Select Normal Operation. Injector will be enabled and engine noise should return to previous state of operation.
6. Repeat steps 4 and 5 for the remaining cylinders.

NOTE: Listen for tone changes from cylinder-to-cylinder.

NOTE: If any injectors are removed and reinstalled or replaced, test drive vehicle for 20 miles before checking for misfire or rough idle.

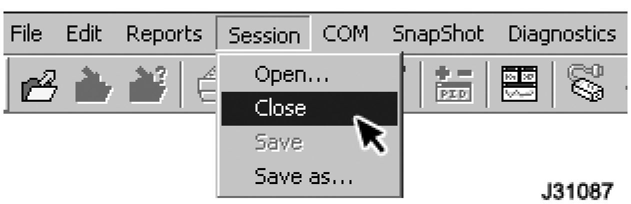


Figure 94 Close session

7. When finished with this test, select Session from menu bar, then Close.

Manual Test - Engine Hot

NOTE: This is an alternate method only. This Manual test should only be used when MasterDiagnostics® software does not have the Automatic test (auto run feature) and the engine is hot.

The EOT indicator will change from red to green when engine temperature reaches 70 °C (158 °F) or higher.

- If the EOT indicator is red, erroneous comparisons are likely from cylinder to cylinder.
- When the EOT indicator is green and the engine temperature is 70 °C (158 °F) or higher, fuel rate and timing are more stable, making comparisons from cylinder to cylinder more accurate. Overall engine operation is more stable.

Shut off one injector at a time and listen for changes in exhaust tone.

NOTE: Do KOER Standard test before doing the I6 Injector Disable test - Run.

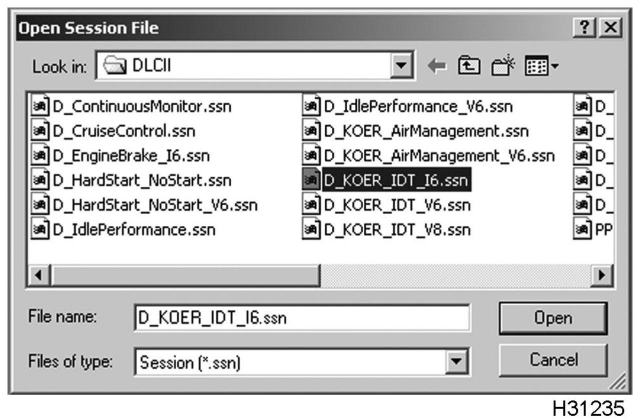


Figure 95 KOER IDT I6 session

1. While engine is running, select D_KOER_IDT_I6.ssn from the open session file window and select OPEN to open the session.

WARNING: To avoid serious personal injury, possible death or damage to the engine or vehicle, when running the engine in the service bay, make sure the parking brake is set, the transmission is in neutral, and the wheels are blocked.

2. Select Diagnostics from menu bar.

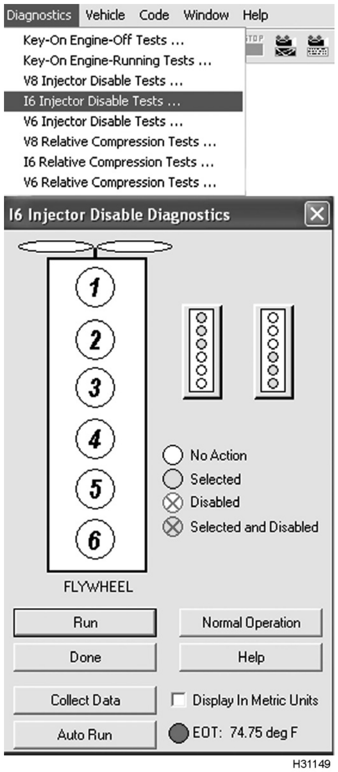


Figure 96 Injector Disable tests

3. Select I6 Injector Disable Tests from drop down menu.

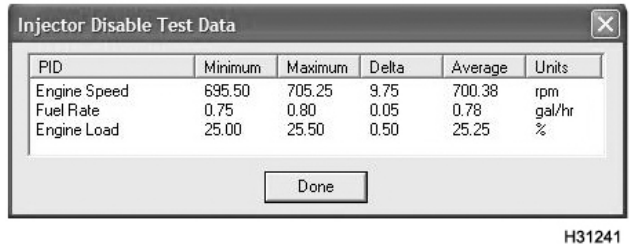
NOTE: The EOT indicator will change from red to green when engine temperature reaches 70 °C (158 °F) or higher.

- If the EOT indicator is red, erroneous comparisons are likely from cylinder to cylinder.

  However, when diagnosing a cold misfire, a technician can listen to tone changes from cylinder-to-cylinder.

- When the EOT indicator is green and the engine temperature is 70 °C (158 °F) or higher, fuel rate and timing are more stable, making comparisons from cylinder to cylinder more accurate. Overall engine operation is more stable.

4. Select Collect Data from I6 Injector Disable Diagnostics window. (Baseline values will be shown.)



Injector Disable Test Data

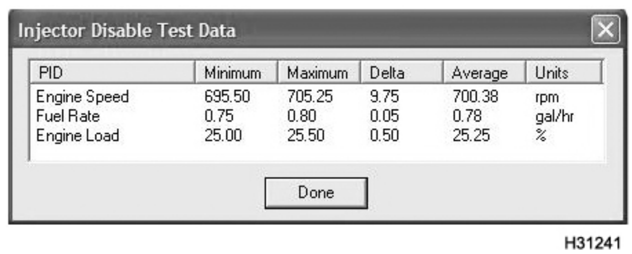
PID	Minimum	Maximum	Delta	Average	Units
Engine Speed	695.50	705.25	9.75	700.38	rpm
Fuel Rate	0.75	0.80	0.05	0.78	gal/hr
Engine Load	25.00	25.50	0.50	25.25	%

Figure 97 Injector Disable test data

5. Record baseline values for EOT, average fuel rate, and average engine load on Diagnostic Form.

NOTE: Listen for tone changes from cylinder-to-cylinder.

6. Select cylinder number and select Run. (Injector selected will be disabled and engine tone should change.)



Injector Disable Test Data

PID	Minimum	Maximum	Delta	Average	Units
Engine Speed	695.50	705.25	9.75	700.38	rpm
Fuel Rate	0.75	0.80	0.05	0.78	gal/hr
Engine Load	25.00	25.50	0.50	25.25	%

Figure 98 Injector Disable test data

7. Select Collect Data.
8. Record values for EOT, average fuel rate, and average engine load on Diagnostic Form.
9. Select Done to close Collect Data window.
10. Repeat steps 6 through 9 for the remaining cylinders.
11. Select Normal Operation
12. Subtract the baseline for (average fuel rate) from the (average fuel rate) for each injector and record the difference (deviation) on Diagnostic Form.
13. Add deviations for (average fuel rate) for all injectors and divide by 6. (Round to the nearest tenth - this is the cut off value for fuel rate.)
14. Record cut off value on Diagnostic Form.

15. Subtract the baseline for (average engine load) from the (average engine load) for each injector and record the difference (deviation) on Diagnostic Form.
16. Add deviations for (average engine load) for all injectors and divide by 6. (Round to the nearest tenth - this is the cut off value for engine load.)
17. Record cut off value on Diagnostic Form.
    - If deviation values for average fuel rate and average engine load are less than the cut off values for fuel rate and engine load, the injector is suspect for weak cylinder contribution (fuel rate and engine load).
    - If only one deviation value is less than a cut off value, do not suspect that cylinder.
    - If a suspect cylinder(s) is identified, do Relative Compression test to distinguish between an injector or mechanical problems.
    - If the Relative Compression test shows that cylinders are mechanically sound but the Injector Disable test shows that one or more cylinders are bad, replace suspected injector.

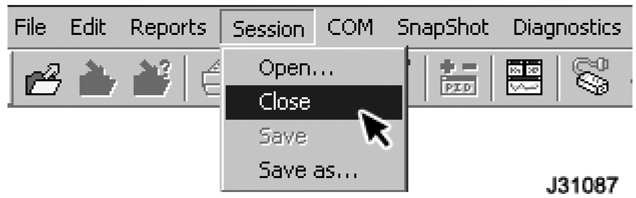


Figure 99 Close session

18. When finished with this test, select Session from menu bar, then Close.

Relative Compression

NOTE: During this test the IDM shuts off the injectors so no fueling occurs.

NOTE: The Relative Compression test can only be done with the EST; MasterDiagnostics® software is required.

NOTE: This test is used in conjunction with the Injector Disable test to distinguish between an injector problem or a mechanical problem.

The Relative Compression test provides the difference between the fastest and slowest crankshaft speed during the power stroke of each cylinder.

As the engine is cranked, the IDM uses the CMP and CKP sensor signals to measure crankshaft speed, as piston reaches two points: Top Dead Center (TDC) compression and about 30 degrees after TDC compression.

When the piston approaches TDC, crankshaft speed should be slower because of compression resistance. As the piston passes TDC, compression resistance dissipates and crankshaft speed increases.

At TDC compression, the cylinder reaches its highest compression and resistance to crankshaft rotation - Crankshaft speed is the slowest. A cylinder with low compression will have less resistance to crankshaft rotation. Crankshaft speed will be faster than normal.

About 30 degrees after TDC, crankshaft speed should be fastest because compression has dissipated. On a cylinder that has low compression, crankshaft speed will be close to, or less than crankshaft speed at TDC.

At TDC of each power cylinder, and about 30 degrees past TDC, the IDM collects data for crankshaft speed.

NOTE: If not cranked long enough to collect data, the EST will display 255. 255 represents an erroneous rpm value

The TDC value is subtracted from the value about 30 degrees after TDC and is recorded for each cylinder.

Example

200 rpm (30 degrees after TDC) - 180 rpm (TDC) = 20 rpm

The EZ-Tech® will display a value on the screen for each cylinder.

Example

Relative Compression Test	Value
Cylinder 1 Relative Compression	18
Cylinder 2 Relative Compression	22
Cylinder 3 Relative Compression	24
Cylinder 4 Relative Compression	20
Cylinder 5 Relative Compression	21
Cylinder 6 Relative Compression	22

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Compare the compression values of each cylinder with the other cylinder values. A cylinder with compression lower than the other cylinders indicates a suspect cylinder. Test value of 18 for cylinder one indicates a suspect cylinder.

If a cylinder value is zero or a much lower than other cylinders and this cylinder is a non-contributor (identified in the Injector Disable Test), check for a mechanical problem.

Example

Relative Compression Test	Value
Cylinder 1 Relative Compression	5
Cylinder 2 Relative Compression	22
Cylinder 3 Relative Compression	24
Cylinder 4 Relative Compression	20
Cylinder 5 Relative Compression	21
Cylinder 6 Relative Compression	0

H31311

If TDC rpm is greater than rpm 30 degrees after TDC, the EST will display 0.

If the test value for a power cylinder is 0, the cylinder is suspect.

If the test value for a power cylinder is significantly below 15 rpm, the cylinder is suspect.

Test value 5 for cylinder 1 indicates a suspect cylinder. Test value 0 for cylinder 6 indicates a suspect cylinder.

When the Relative Compression test is done, the EST indicates, stop cranking the engine, and will display test values.

Test data displayed in this test should be compared with data collected from the Injector Disable test.

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

NOTE: Batteries must be fully charged before doing this test. Use battery charger during this test, if multiple tests are needed; battery drain can be extensive.

NOTE: Read and be familiar with all steps and time limits in this procedure before starting.

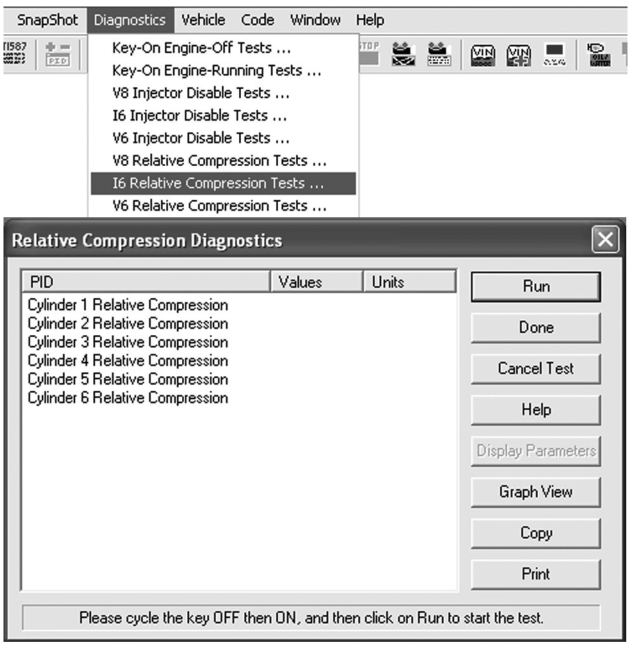


Figure 102 Relative Compression test

1. Select Diagnostics from the menu bar.
2. Select Relative Compression Tests from the drop down menu.
3. Follow the messages at the bottom of the window.
   - Turn the ignition switch to ON.
   - Select Run.

   WARNING: To avoid serious injury, possible death, or damage to the engine or vehicle, after clicking Run, turn the ignition switch, within 5 seconds, to crank the engine; if not done in 5 seconds, the IDM will cancel the test and the engine will start.

   - Within 5 seconds of selecting run, crank engine for 15 seconds. Another message will read Stop Cranking within 5 seconds. **Do not turn the ignition switch to OFF**. **If the ignition switch is turned to OFF, test results will be lost**.

   NOTE: If test results are identical to previous test results, the current test failed and the previous results were displayed.
4. Interpret results.
   - If a Relative Compression test and Injector Disable test identify a suspect cylinder, check for a mechanical problem.
   - If a Relative Compression test does not identify a suspect cylinder, but the Injector Disable test does, replace suspect injector(s).

Reset Change Engine Oil Interval Message

Using EST

1. Turn the ignition switch to ON.

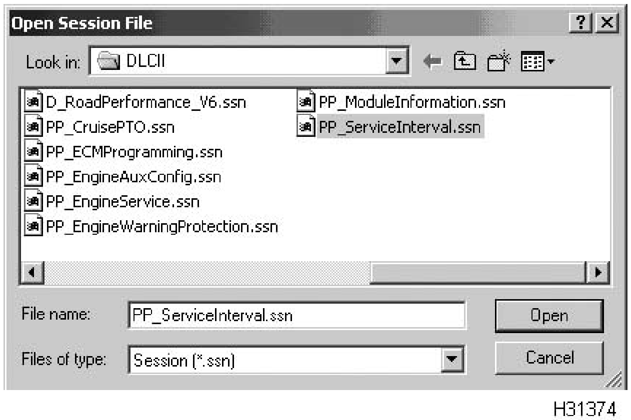
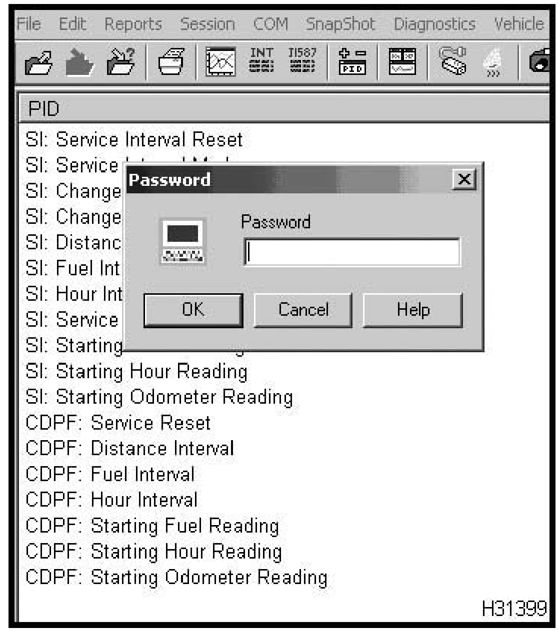


Figure 103 Select Service Interval session

2. Select PP_ServiceInterval.ssn from the Open Session File window, and select OPEN to open Vehicle Programming.



3. Click the right mouse button and select Enter Password.
4. Enter password in the dialog box, select OK.

   NOTE: If the password is not entered or is not entered correctly, you will get an error message indicating the password does not match, and the service interval will not reset.

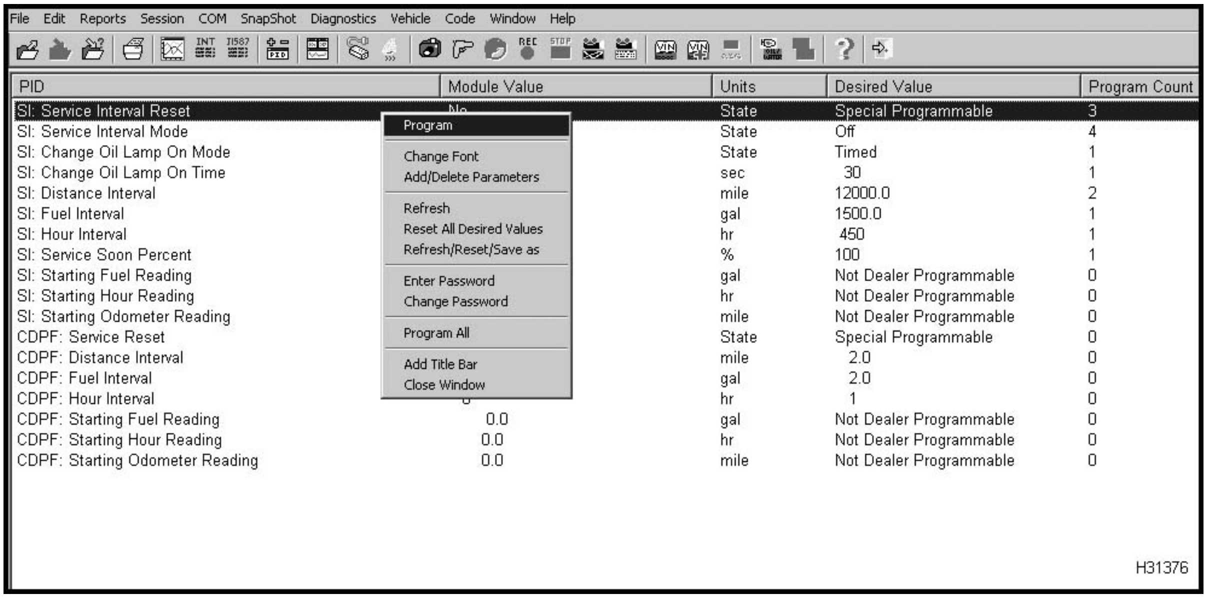


Figure 105 Select Parameter and Select Program

5. Select SI: Service Interval Reset, click the right mouse button and select Program.

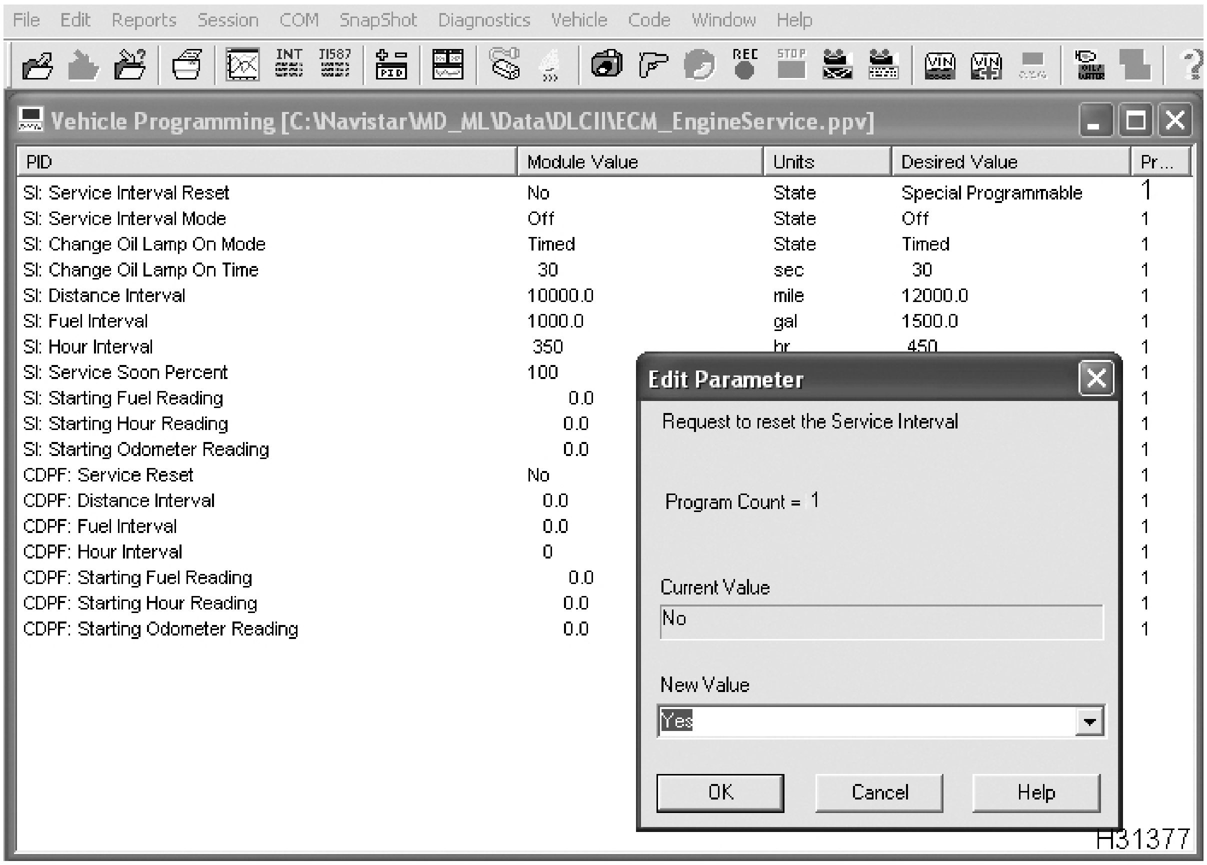


Figure 106 Change Edit Parameter to New

6. In the New Value box in the Edit Parameter dialog box click on the pull down arrow to select Yes, and select OK.

NOTE: If the password has not been entered or has not been entered correctly, an error message will indicate the password does not match, and the service interval will not reset.

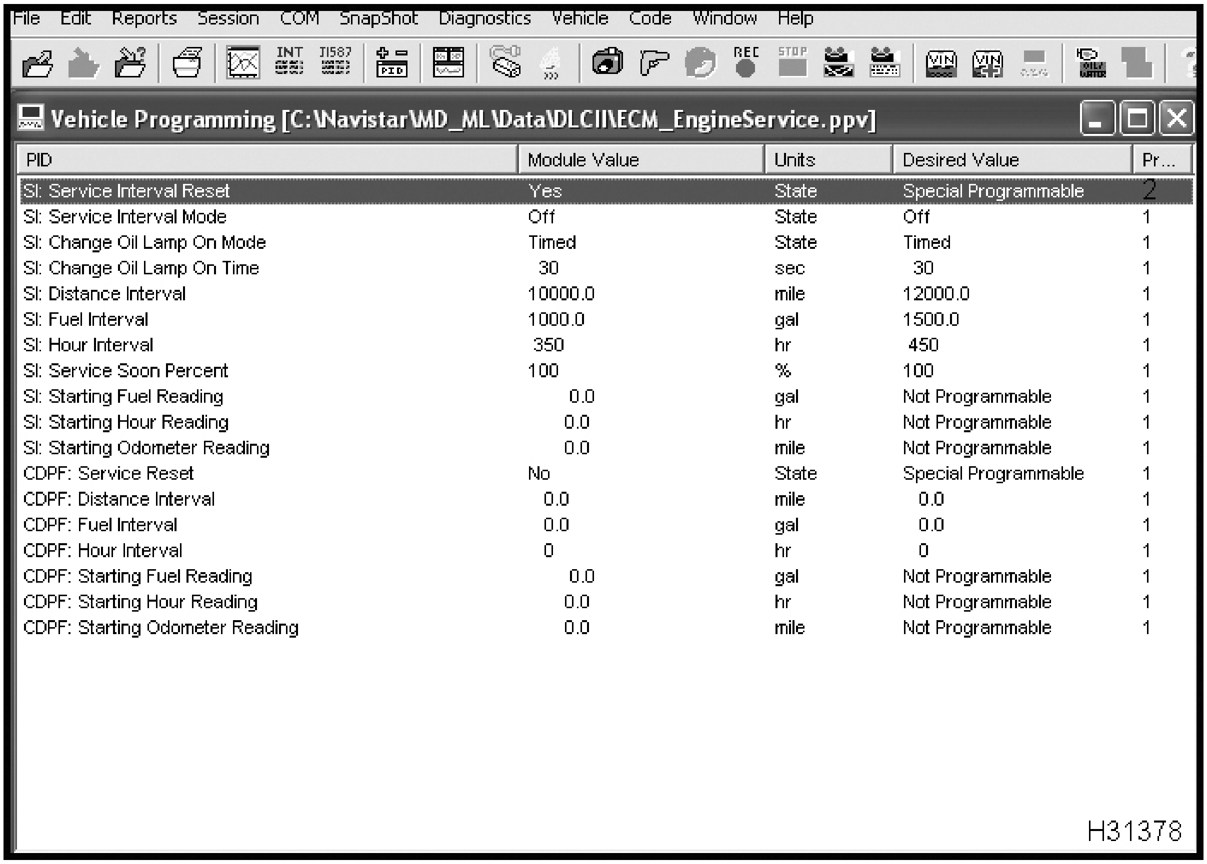


Figure 107 Module Value changed

7. Note that the Module Value has changed to Yes and Program Count number has increased.

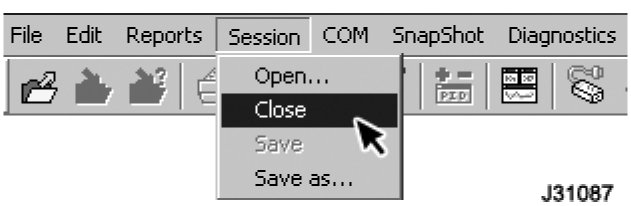


Figure 108 Close session

8. When finished, select Session from menu bar, then Close.

Using Cruise Switches

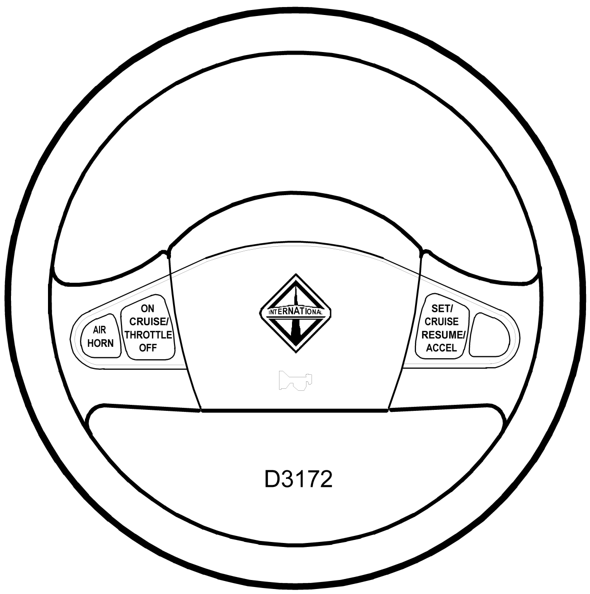


Figure 109 Switches for CRUISE ON and RESUME/ACCEL

Reset the change engine oil message feature as follows:

1. Set the parking brake (required for correct ESC signal).
2. Turn ignition switch to ON.

NOTE: The entire sequence must be completed within twelve seconds. The change engine oil message will now turn off and will activate when the next oil change is due.

3. Press and release both the CRUISE ON and RESUME/ACCEL switches four times within 6 seconds.
4. Press and hold both the CRUISE ON and RESUME/ACCEL switches for 3 seconds.
5. Release both Cruise buttons.