ENGINE SERVICE MANUAL

DT 466 / DT 570 / HT 570 Service Manual - 2004 Emissions with EGR

Engine Family: DT 466
Engine Family: DT 570
Engine Family: HT 570

EGES-265-1, FORMERLY EGES-265-1

03/30/2004

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

Table of Contents

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Foreword

This publication provides general and specific service procedures and repair methods 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.

Departure from instructions in this publication or disregard of warnings and cautions can lead to injury or death, or both and damage to the engine or vehicle.

Read safety instructions below before doing service or test procedures in this publication for the engine or vehicle. See related engine manuals for more information.

Periodic revisions may be made to publications. When ordering publications, the latest revision will be supplied.

The following literature supporting International® Diesel Engines is available from:
International Truck and Engine Corporation
Moore Wallace North America
1750 Wallace Avenue
St. Charles, IL 60174
630-313-7507

Technical Service Literature

1171809R1	*DT 466, DT 570 and HT 570 Engine Operation and Maintenance Manual*
EGES-265	*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	DT 466, DT 570 and HT 570 Diagnostic Form (Pad of 50)

Service Diagnosis

Service diagnosis is a systematic procedure of investigation to be followed in order to locate and correct an engine problem. The engine is first considered as a complete unit in its specific application and then the problem is localized to components or systems; intake, exhaust, cooling, lubrication or injection. Testing procedures will then help analyze the source of the problem.

PREREQUISITES FOR EFFECTIVE DIAGNOSIS:

- Knowledge of the principles of operation for both the engine and application systems
- Knowledge to perform and understand all procedures in the diagnostic and service publications
- Availability of and the ability to use gauges and diagnostic test equipment
- Availability of the most current information for the engine application

Although the cause of an engine failure may be apparent, very often the real cause is not found until a repeat failure occurs. This can be prevented if specific diagnostic action is taken before, during and after engine disassembly and during engine assembly.

It is also very important that specific diagnostic tests follow engine assembly before and after the engine is placed back into service.

Identification of the symptoms which lead to engine failure is the result of proper service diagnosis. Effective service diagnosis requires use of the following references:

- Engine Service Manual
- Hard Start and No Start Diagnostics
- Performance Diagnostics
- Electronic Control Systems Diagnostics
- Service Bulletins

NOTE: Metric values precede English values for test procedures and reference.

Examples: 96 kPa (14 psi), 20°C (68°F)

Safety Information

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

SAFETY TERMINOLOGY

Three terms are used in this manual to stress your safety and safe operation of the engine: **Warning**, **Caution**, and **Note**.

Warning: This symbol is used to make you aware of an unsafe condition, hazard, or practice that can result in personal injury or death.

Caution: This symbol is used to alert you to a condition or practice that can cause damage to the engine or vehicle, or both.

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

SAFETY INSTRUCTIONS

Vehicle

- Make sure the vehicle is in neutral, the parking brake is set, and the wheels are blocked before doing any work or diagnostic procedures on the engine or vehicle.

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

Fire prevention

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

NOTE: Check 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

Batteries produce highly flammable gas during and after charging.

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

Compressed air

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

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

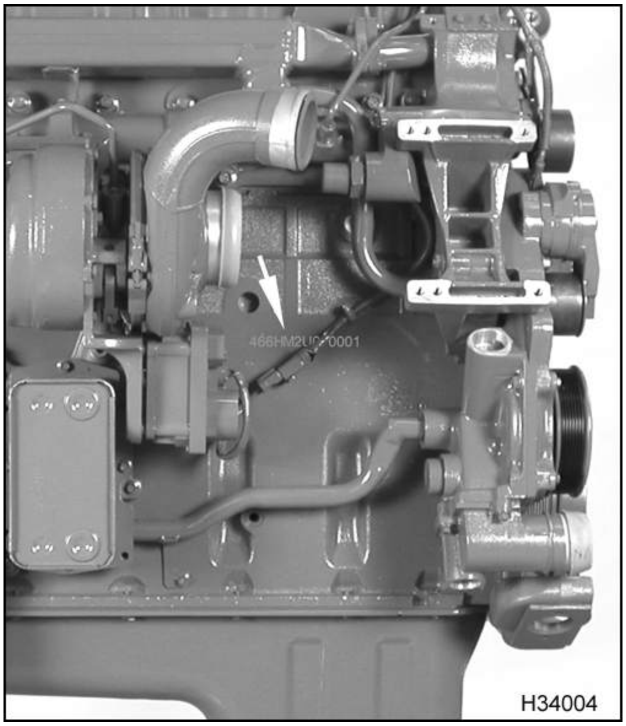

Figure 1 Engine serial number

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
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.

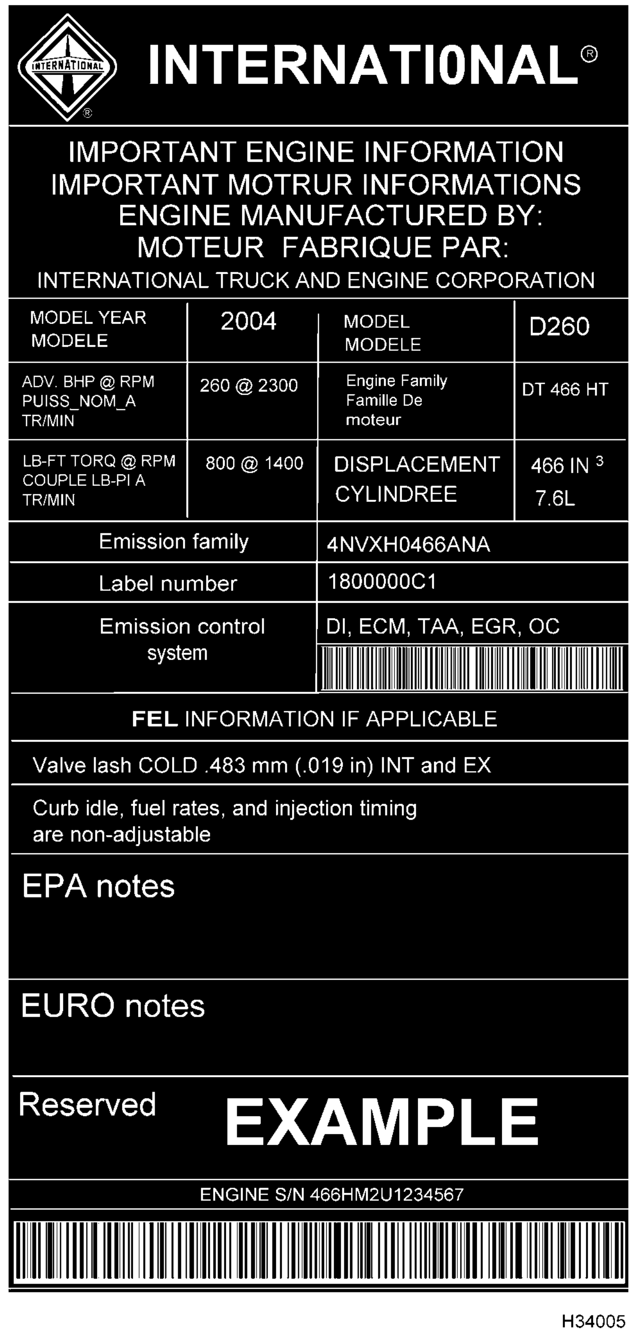

Figure 2 Engine emission label (Example)

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

Table 1 International® DT 466 and DT 570 Features and Specifications

Engine	4 stroke, in-line 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	146 mm (5.75 in)
Compression ratio	
DT 466	16.5 : 1
DT 570	17.5 : 1
Aspiration	VGT turbocharged and Charge Air Cooled (CAC)
Rated power @ rpm	
DT 466*	210 bhp @ 2600 rpm
DT 570**	285 bhp @ 2200 rpm
Peak torque @ rpm	
DT 466*	520 lbf•ft @ 1400 rpm
DT 570**	800 lbf•ft @ 1200 rpm
Engine rotation (facing flywheel)	Counterclockwise
Combustion system	International® common rail high-pressure injection
Total engine weight (dry without accessories)	
DT 466	671 kg (1,480 lbs)
DT 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

* Base rating shown. See Appendix A in the *Engine Diagnostics Manual*.

**Base rating shown. See Appendix B in the *Engine Diagnostics Manual*.

Engine Features

Table 2

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® common rail high-pressure injection system	Diamond Logic™ engine brake
Variable Geometry Turbocharger (VGT)	Diamond Logic™ exhaust brake
Exhaust Gas Recirculation (EGR)	Intake air heater
Water supply housing (Freon® compressor bracket)	Oil pan heater
Alternator bracket	Coolant heater assembly
Control modules	Fuel heater
Water In Fuel (WIF) separation	
Water In Fuel (WIF) sensor	

Standard Features

DT 466, DT 570, and HT 570 are in-line 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 for each engine. 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 kinds of pistons are used in the in-line 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® common rail high-pressure injection system includes a cast iron oil manifold, fuel injectors, and a high-pressure oil pump.

The key feature of the VGT is 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.

A water supply housing (Freon® compressor bracket) is a coolant supply housing includes an auxiliary water connection.

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 sends a signal to the Electronic Control Module (ECM). 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™ 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 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.

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

- **Intake air heater**

  The air intake heater warms intake air entering the cylinder head.

- **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

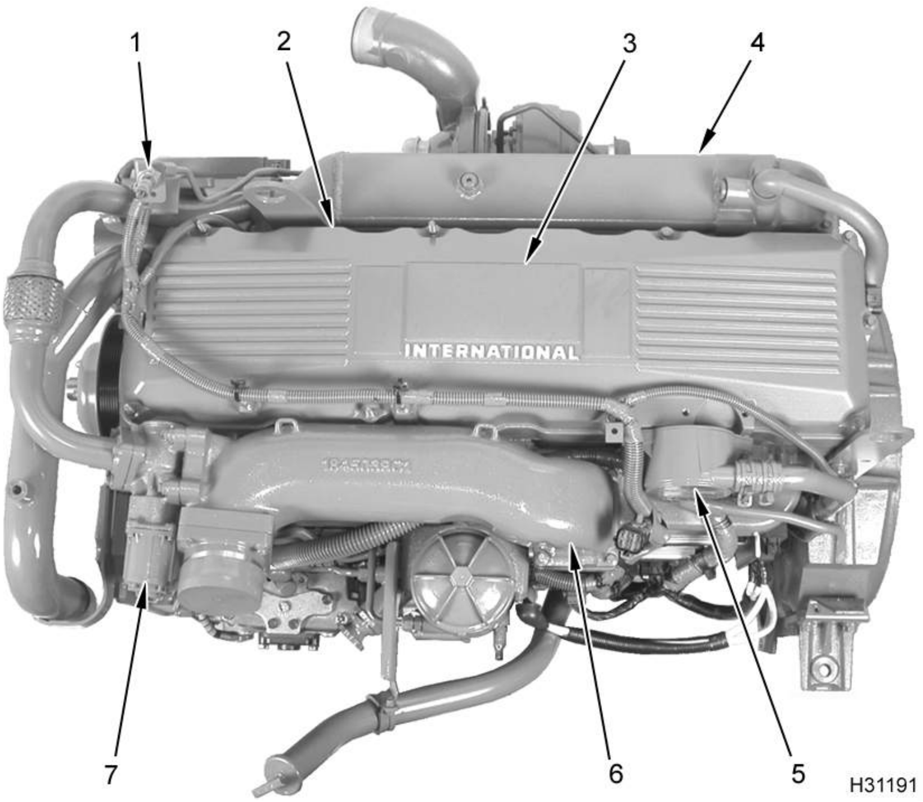

Figure 3 Component location – top

1. Exhaust Back Pressure (EBP) sensor
2. Valve cover
3. Exhaust emission label (location)
4. EGR cooler assembly
5. Breather assembly
6. Inlet and EGR mixer duct
7. EGR control valve

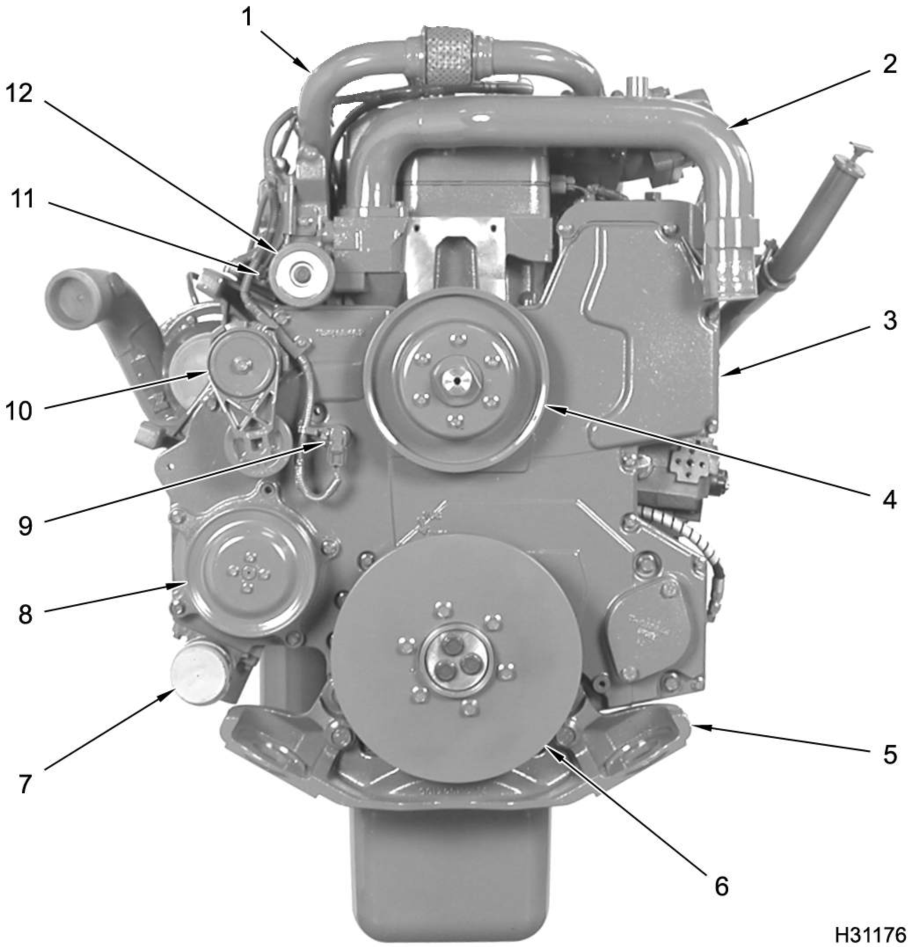

Figure 4 Component location – front

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

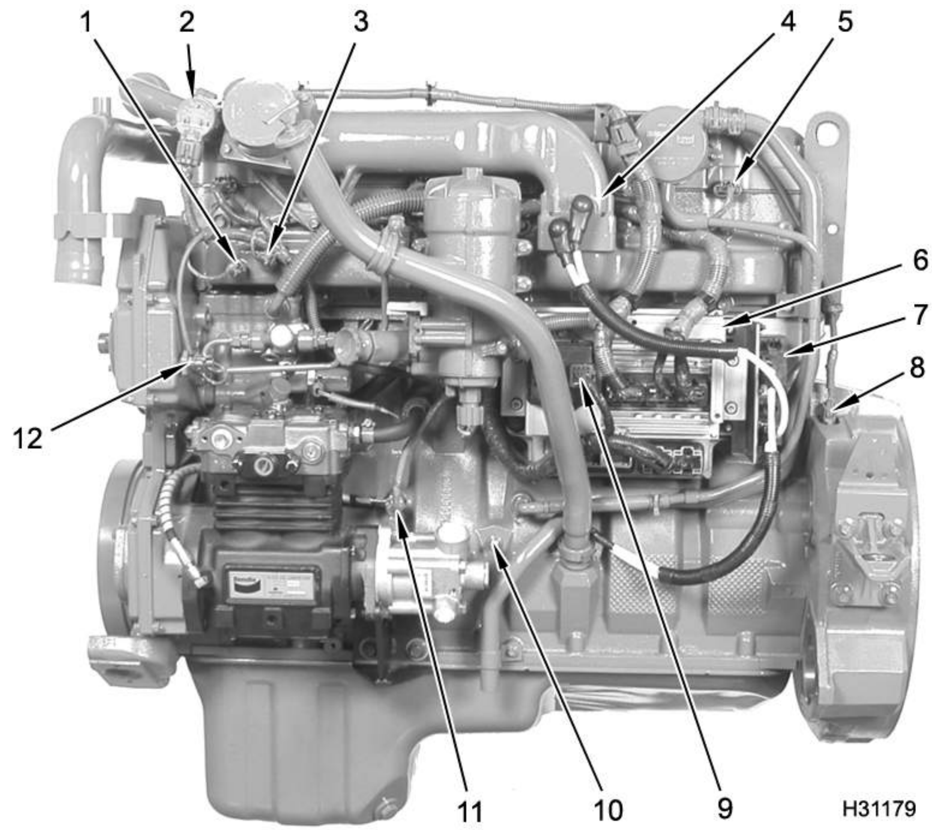

Figure 5 Component location, electrical– left

1. Manifold Absolute Pressure (MAP) sensor
2. EGR control valve
3. Manifold Air Temperature (MAT) sensor
4. Air intake heater assembly (optional)
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 valve.
6. ECM and IDM module assembly
7. Air heater relay (optional)
8. Crankshaft Position (CKP) sensor
9. EGR drive module
10. Ground stud
11. Engine Oil Pressure (EOP) sensor
12. Engine Oil Temperature (EOT) sensor

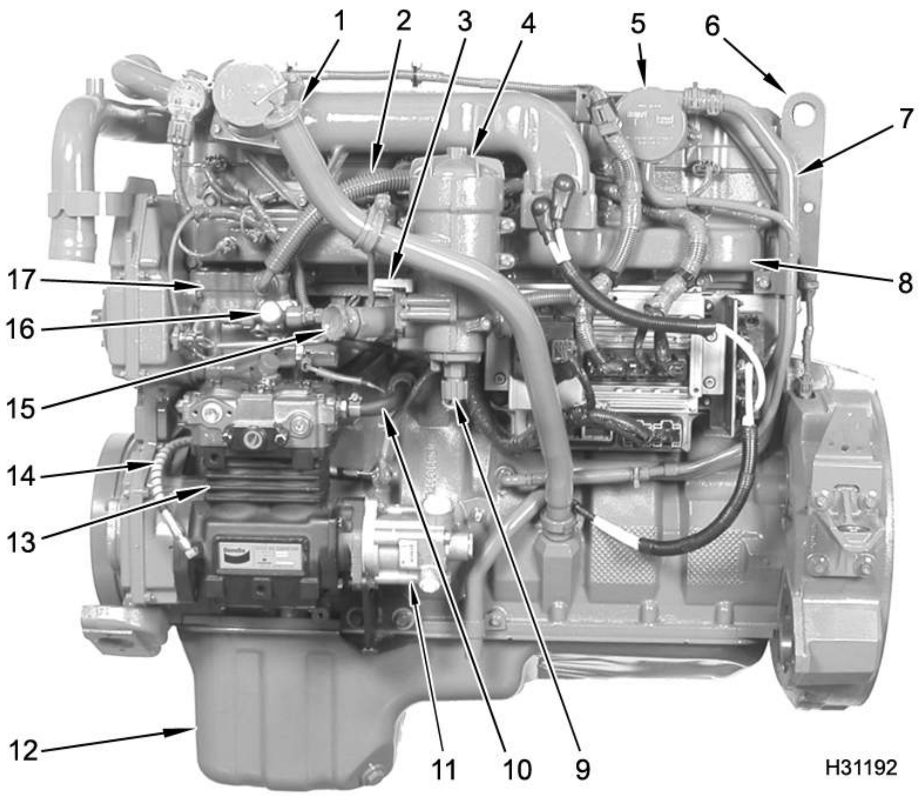

Figure 6 Component location, mechanical – left

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 line
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

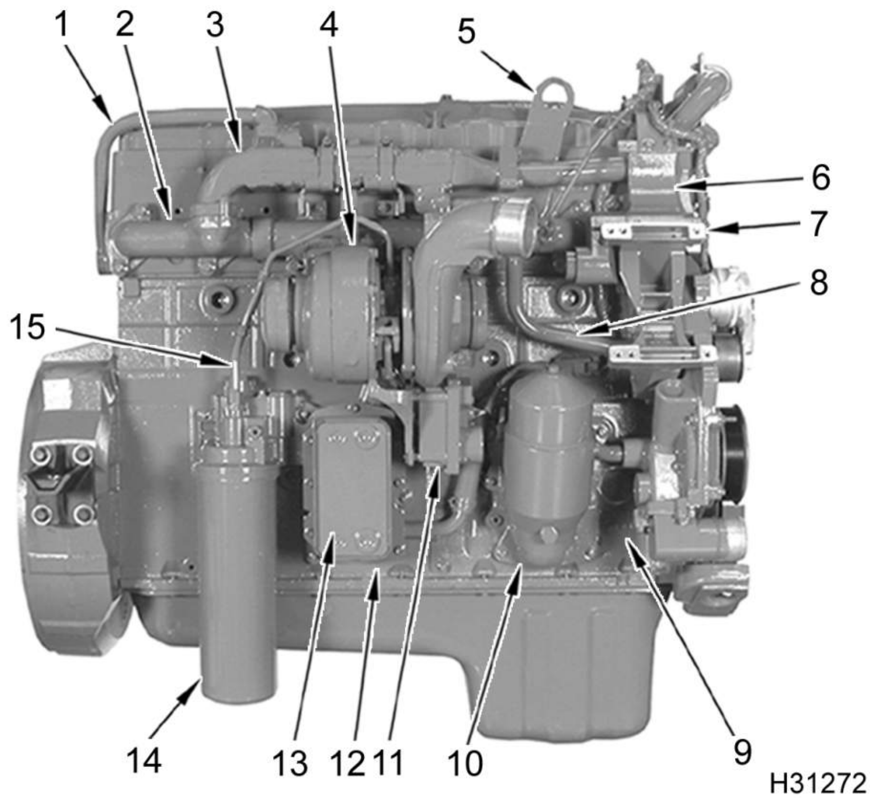

Figure 7 Component location – right

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

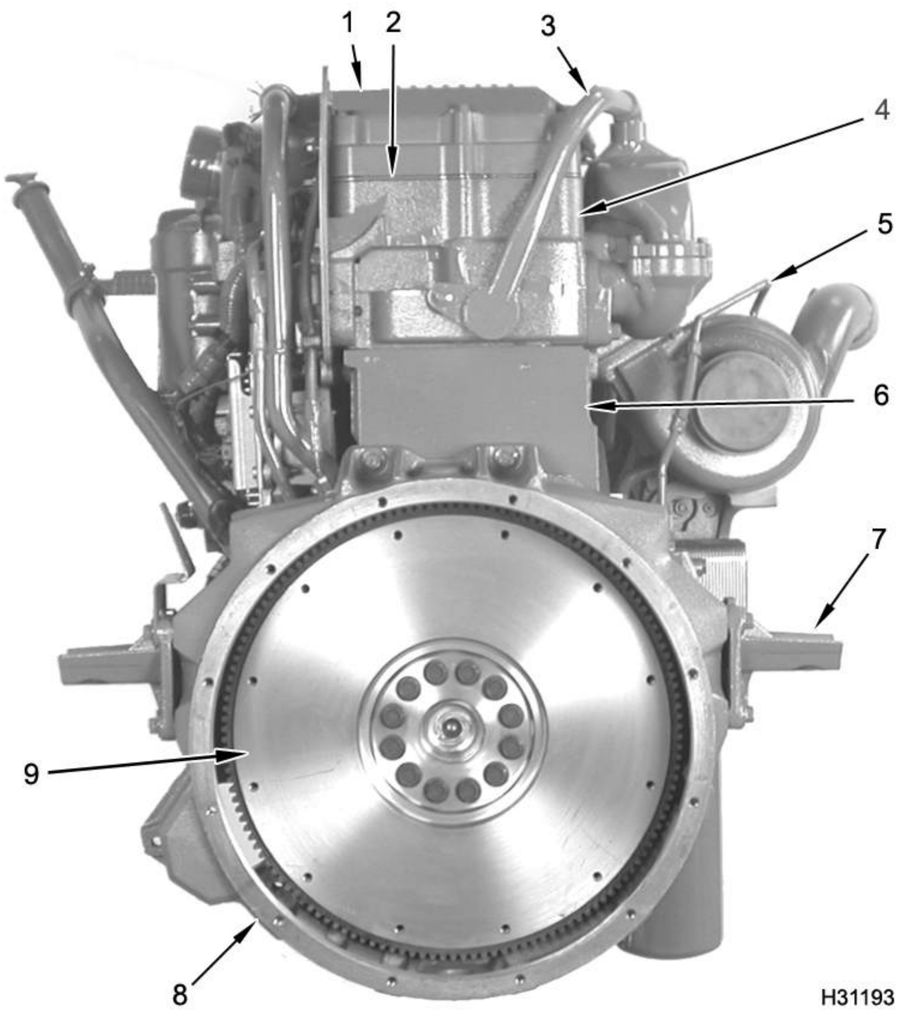

Figure 8 Component location – rear

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 brackets (2)
8. Flywheel housing
9. Flywheel or flexplate assembly

Engine Systems

Engine System Diagram

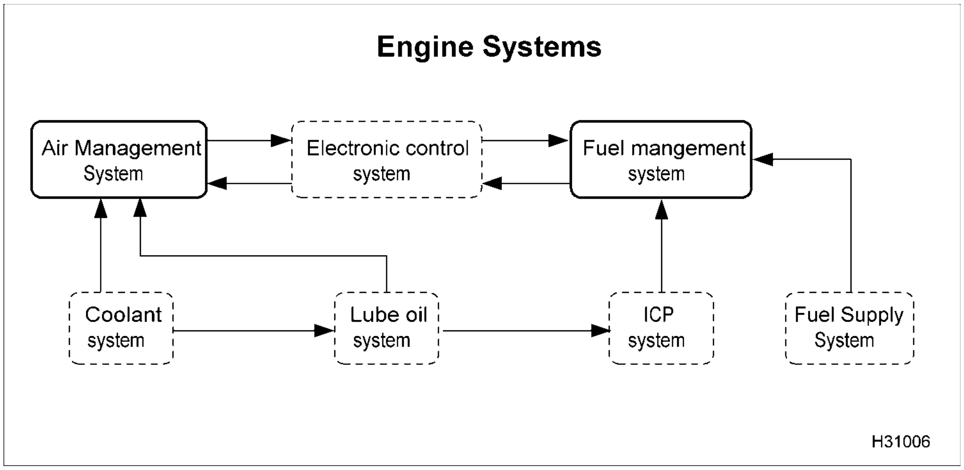

Figure 9 Engine systems

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

Air Management System

Air Management Components and Air Flow

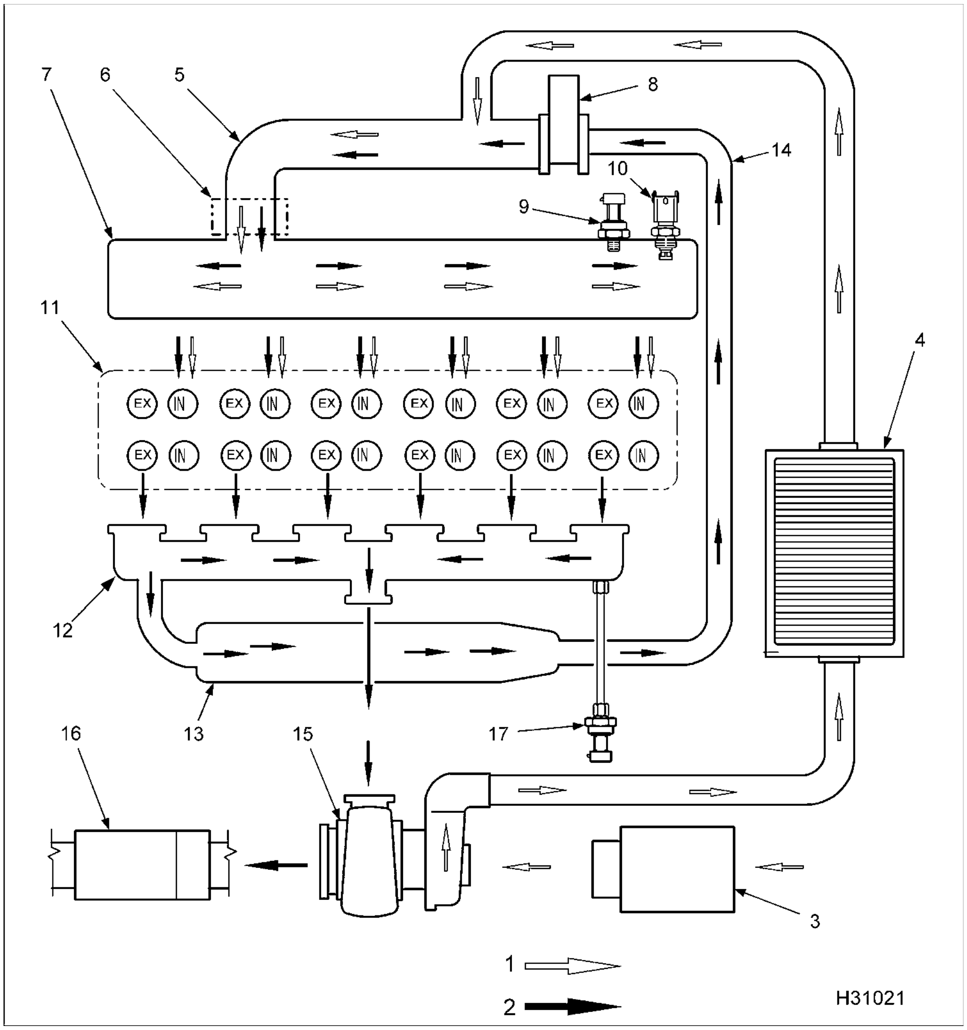

Figure 10 Air Management System (AMS)

1. Intake air
2. Exhaust gas
3. Air cleaner
4. Charge Air Cooler (CAC)
5. Inlet and EGR mixer duct
6. Air intake heater assembly (optional)
7. Intake manifold
8. EGR valve
9. Manifold Absolute Pressure (MAP) sensor
10. Manifold Air Temperature (MAT) 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)
- Intake air heater assembly (optional)
- 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)

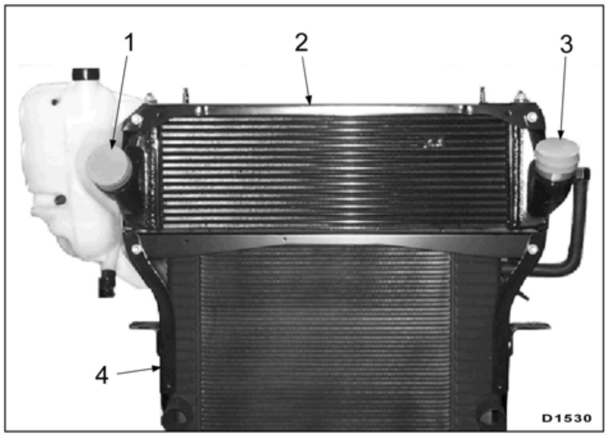

Figure 11 Charge Air Cooler (typical)

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)

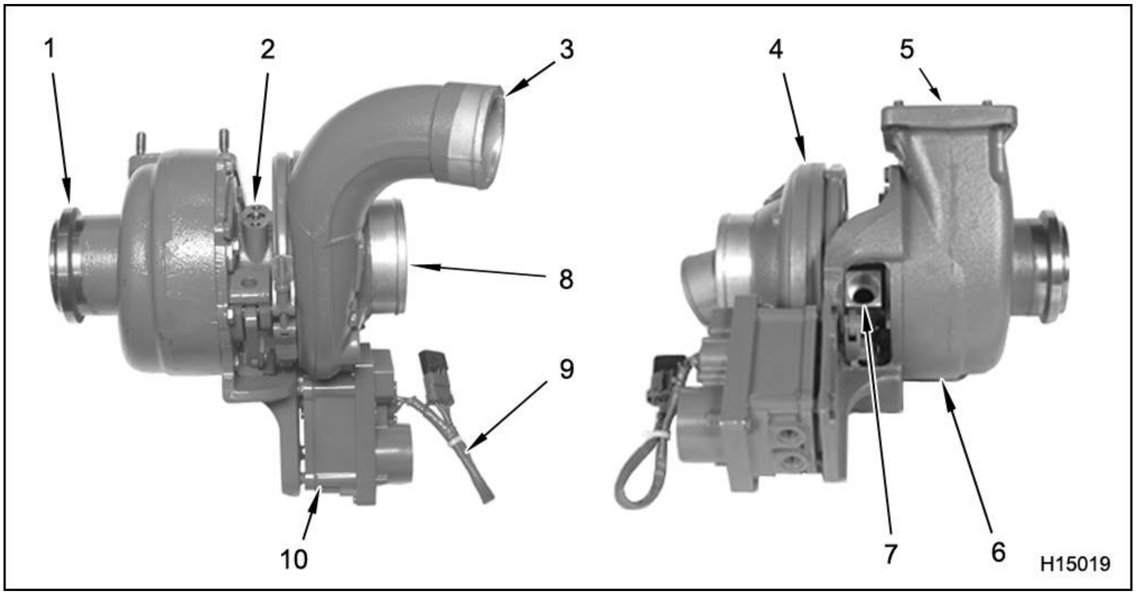

Figure 12 Variable Geometry Turbocharger (VGT)

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 key feature of the Variable Geometry Turbocharger (VGT) is 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

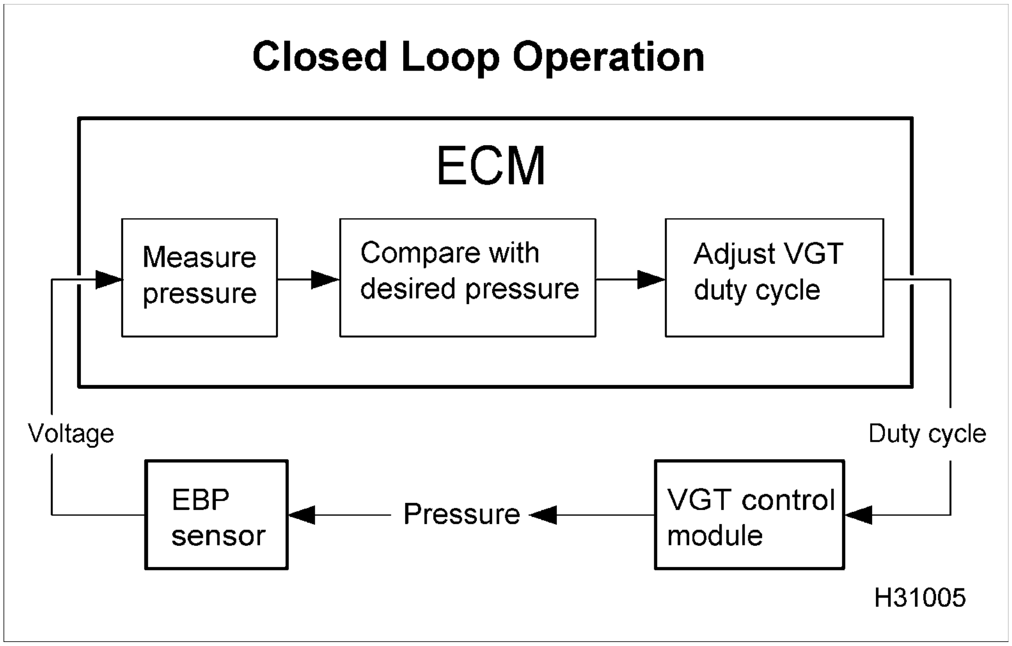

Figure 13 VGT closed loop system

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

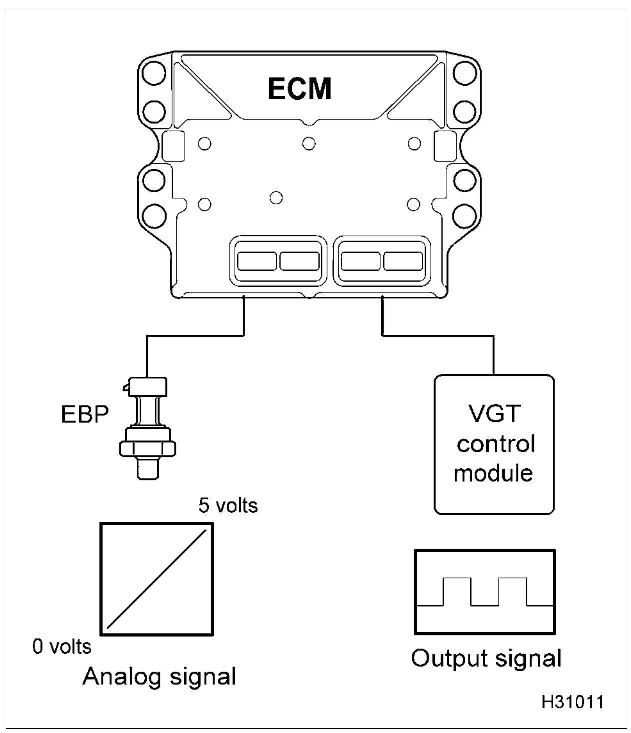

Figure 14 VGT control

The VGT control module receives a pulse width modulated signal from the ECM. A microchip controls the DC motor to a desired position. The DC motor rotates a crank lever, controlling vane position.

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.

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

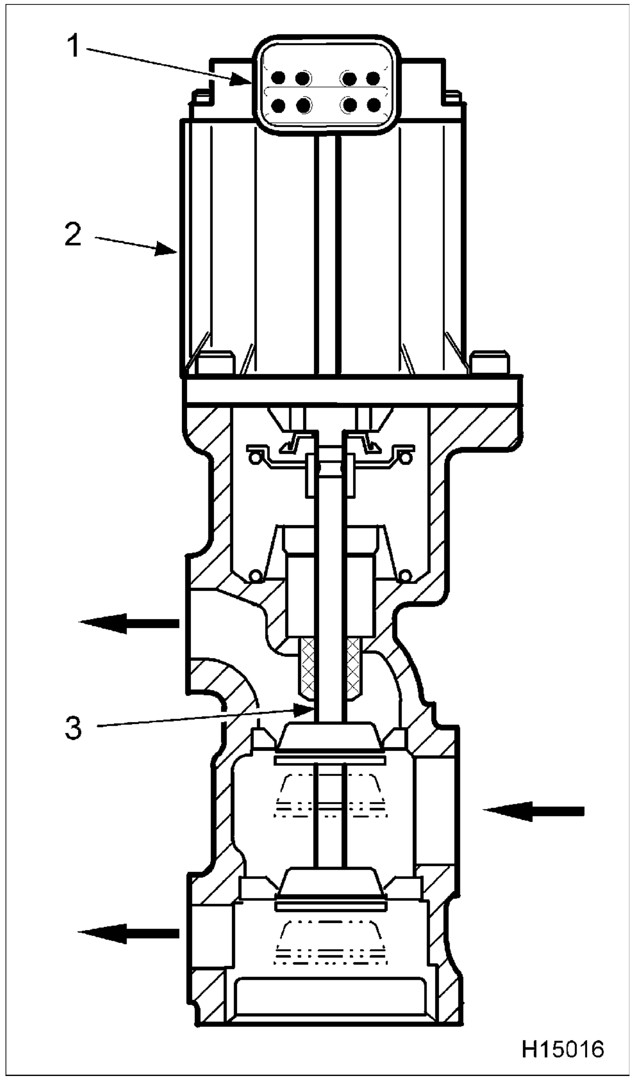

Figure 15 EGR control valve

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.

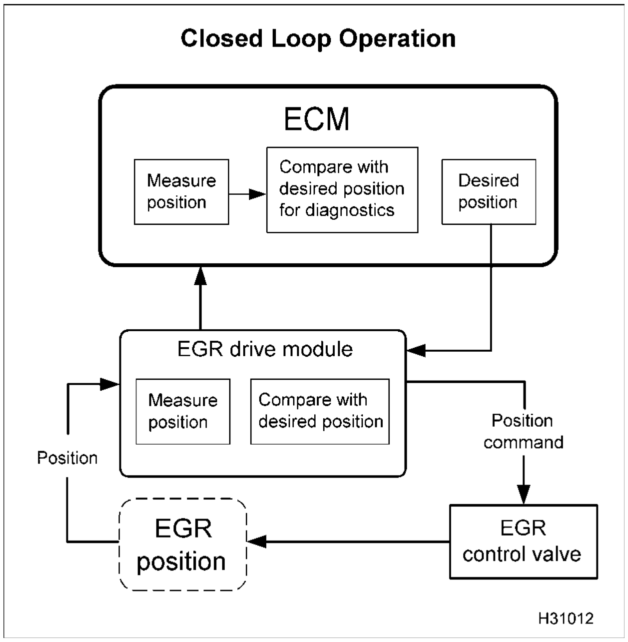

Figure 16 EGR closed loop operation with fault management

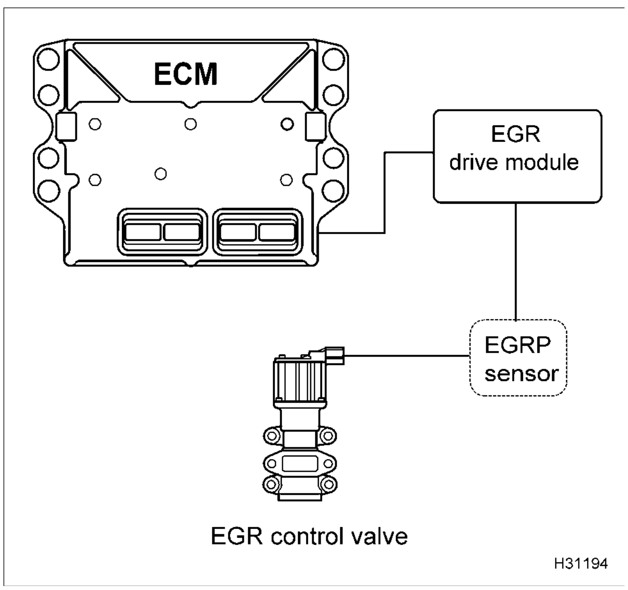

Figure 17 EGR control

Based on position sensor feedback, a micro-chip drives a three-phase DC motor to a desired position. The DC motor rotates a threaded shaft that moves the valve assembly in a linear motion.

The DC motor includes a built-in valve position sensor to provide the EGR drive module with feedback information . The output signals provide the information on the valve position relative to its seat.

The EGR is a closed loop system that uses exhaust gas recirculation position to provide feedback to the EGR drive module.

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

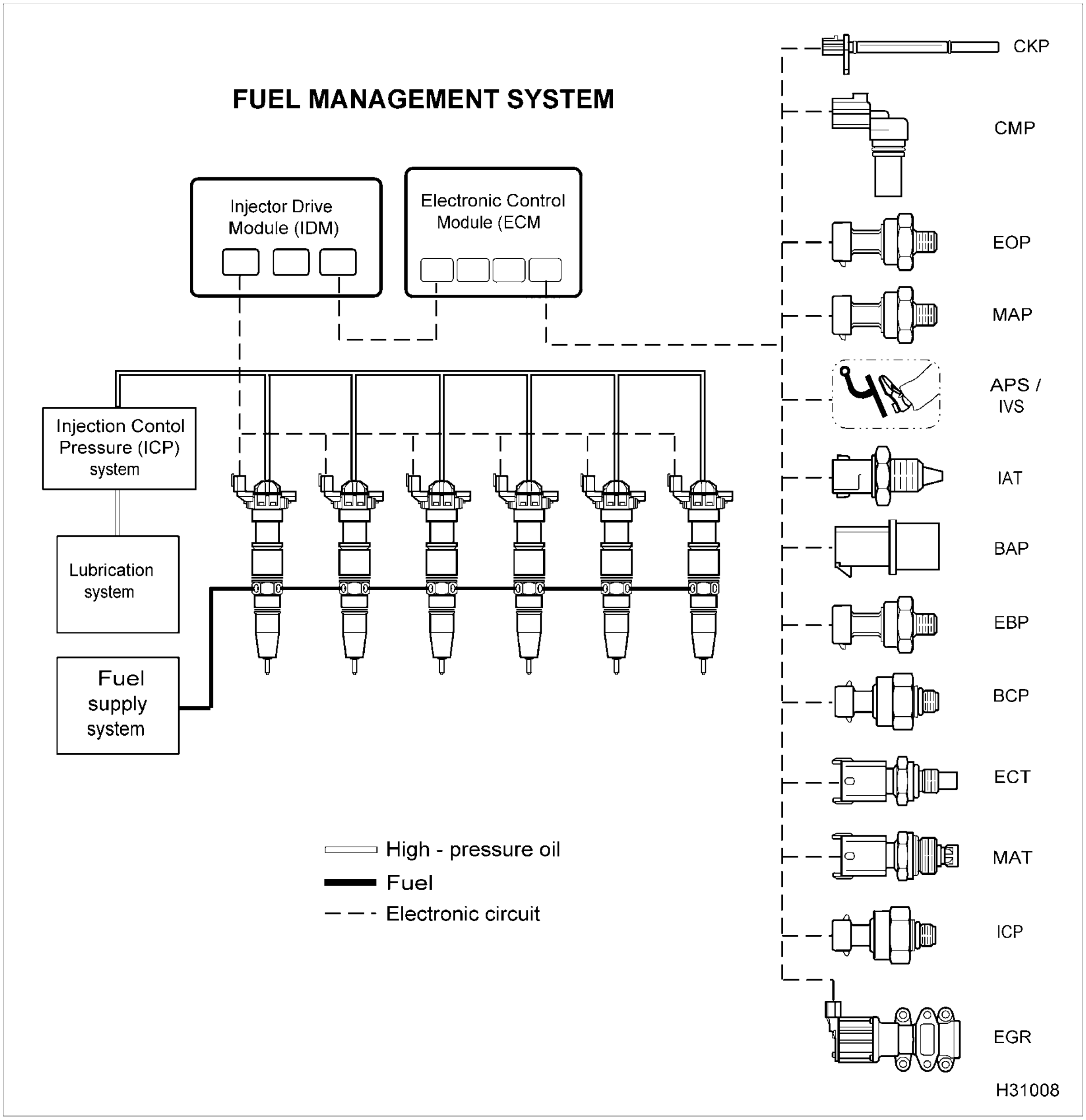

Figure 18 Fuel management system

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

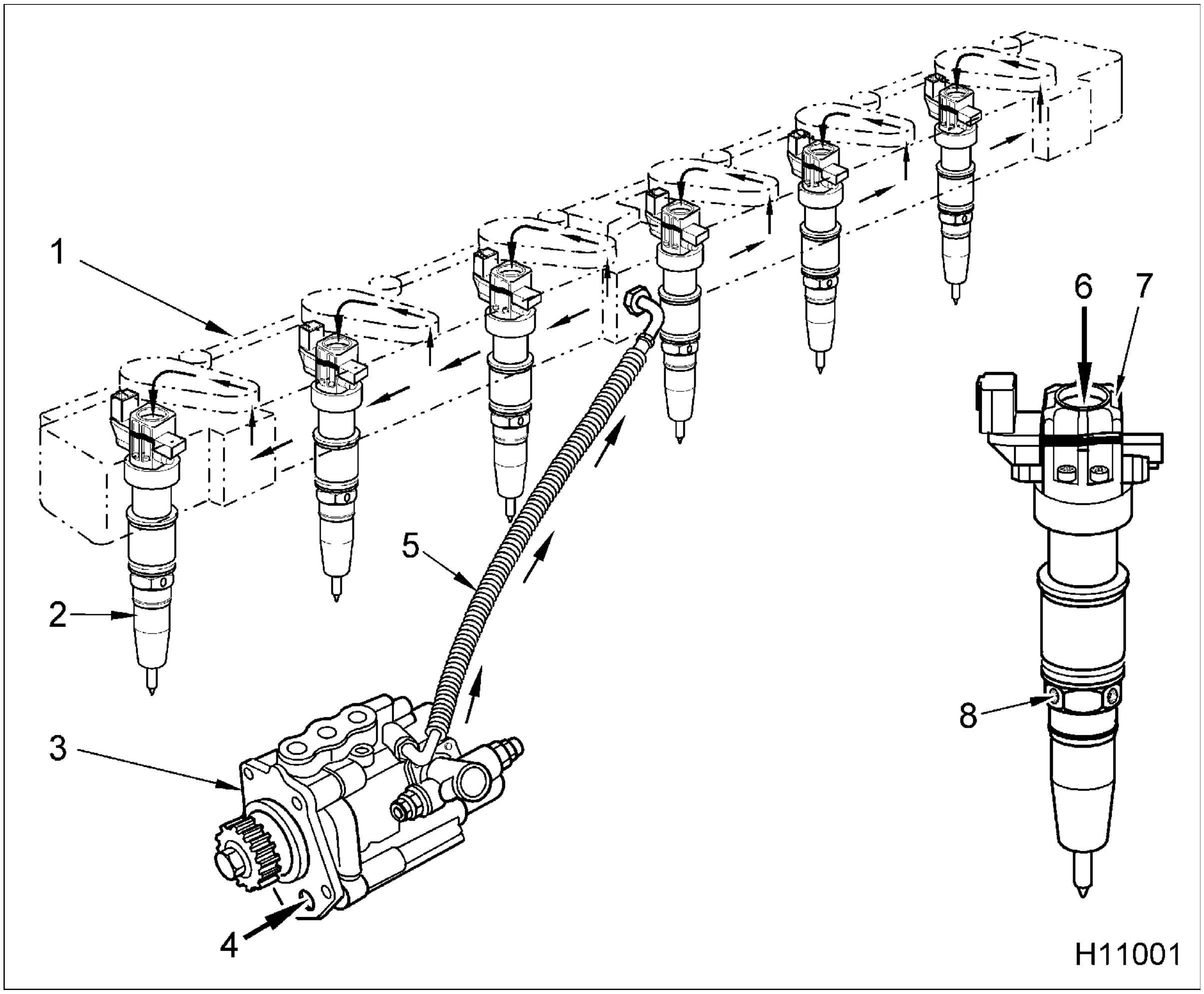

Figure 19 Injection Control Pressure (ICP) system

1. High-pressure oil manifold assembly
2. Fuel injector
3. High-pressure pump assembly
4. High-pressure oil inlet (pump)
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. After injection, the CLOSE coils are energized to end injection. Exhaust oil exits through two ports in the top of the fuel injectors and then drains back to sump.

Injection Control Pressure (ICP) Closed Loop System

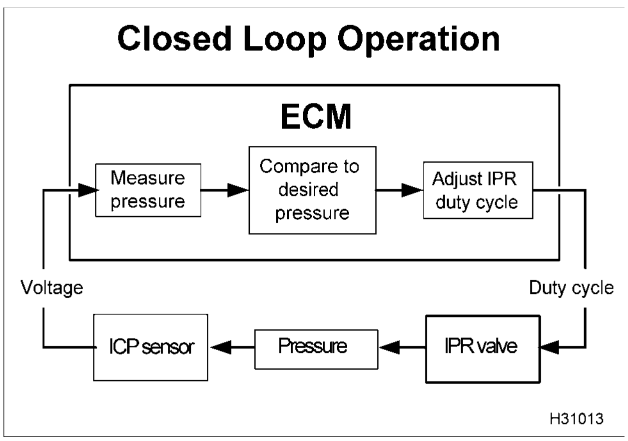

Figure 20 ICP closed loop system

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

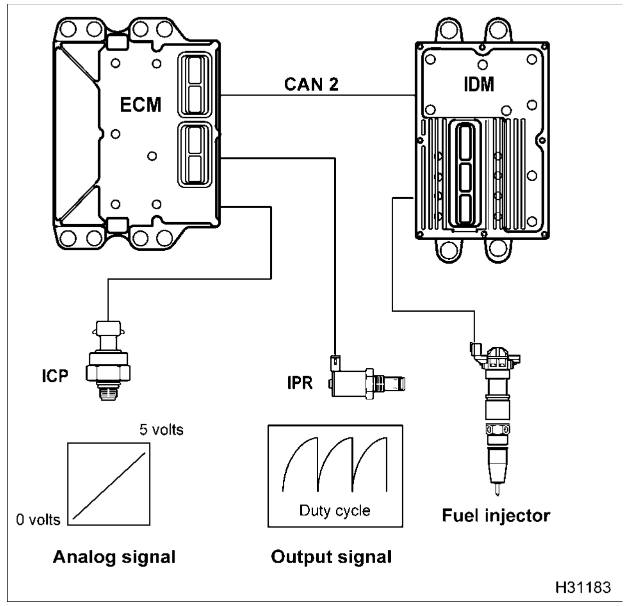

Figure 21 ICP control

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 left of the engine brake shutoff valve in the high-pressure oil rail.

Fuel Injectors

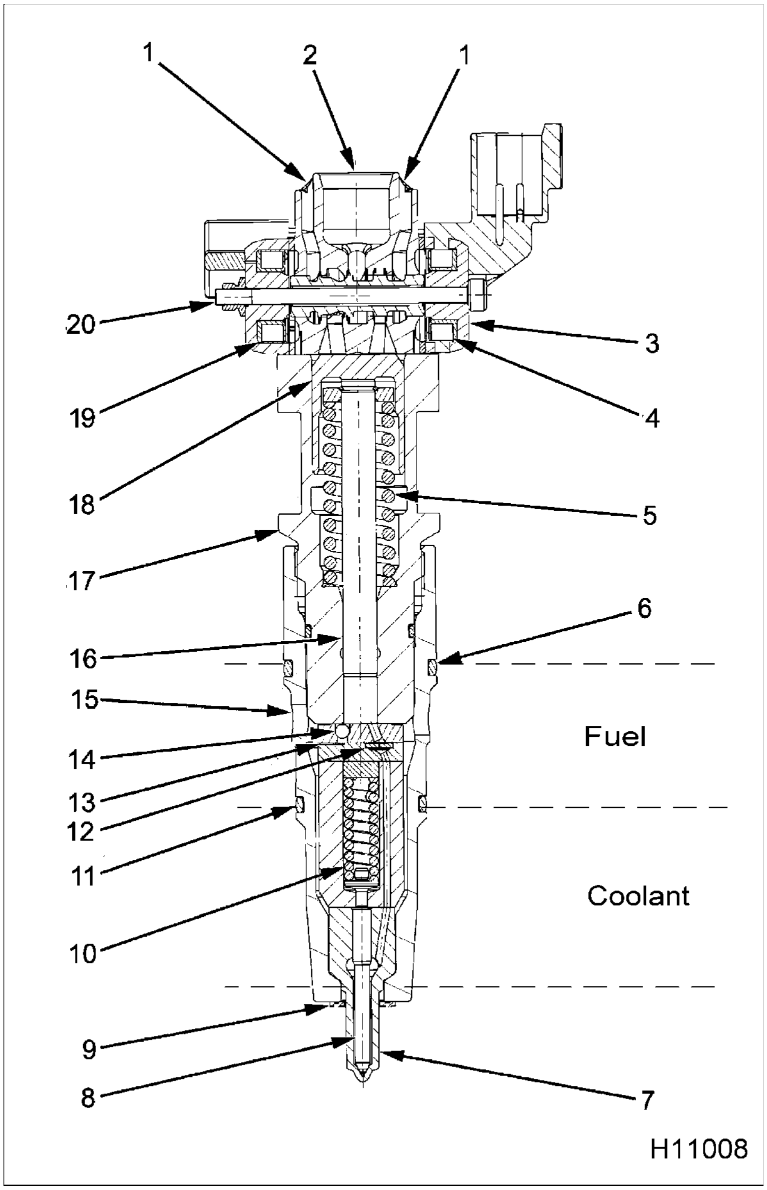

Figure 22 Fuel injector assembly

1. Exhaust port (oil)
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 tungsten carbide 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

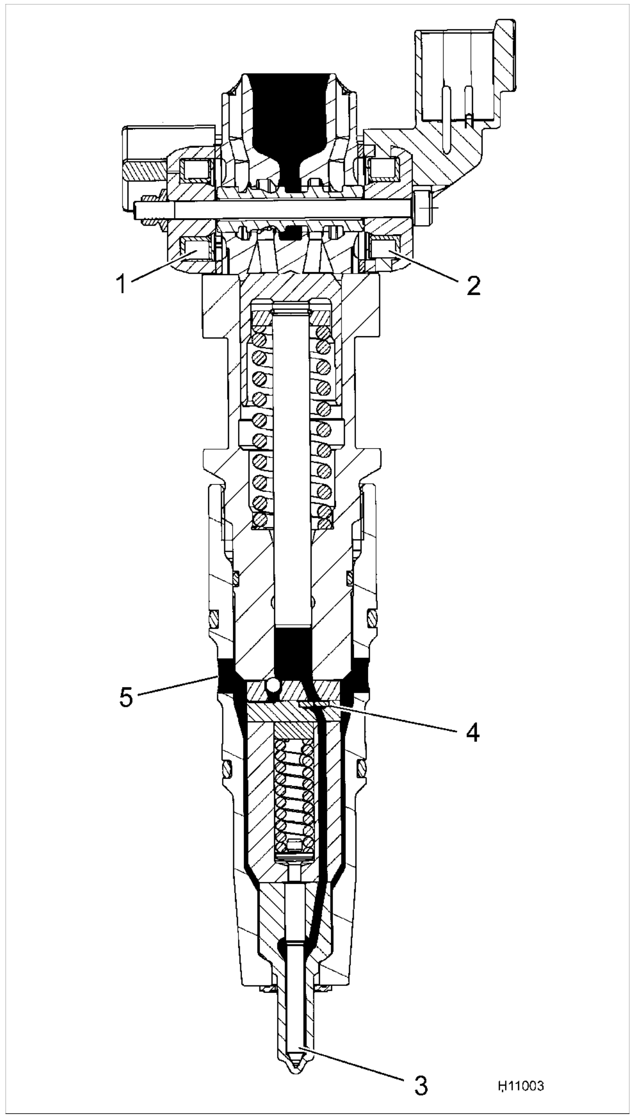

Figure 23 Fill stage

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)

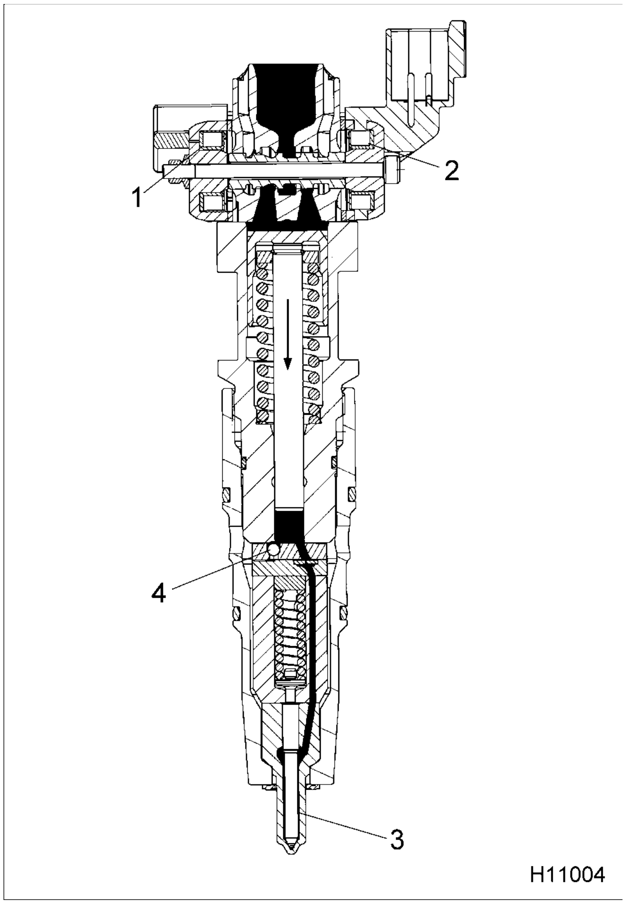

Figure 24 Main injection (Step 1)

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

A pulse width 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)

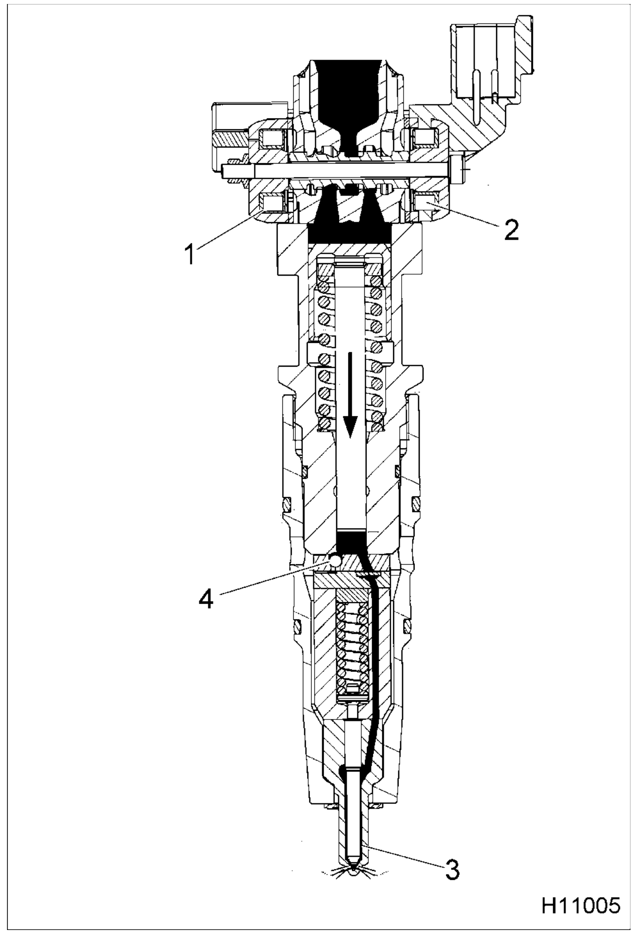

Figure 25 Main injection (Step 2)

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

End of main injection (Step 1)

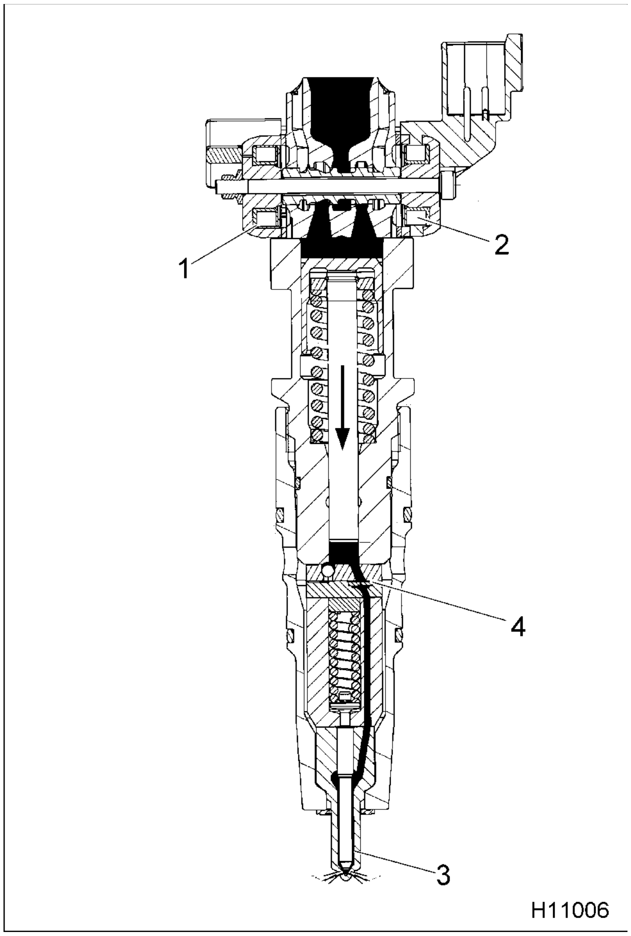

Figure 26 End of main injection (Step 1)

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)

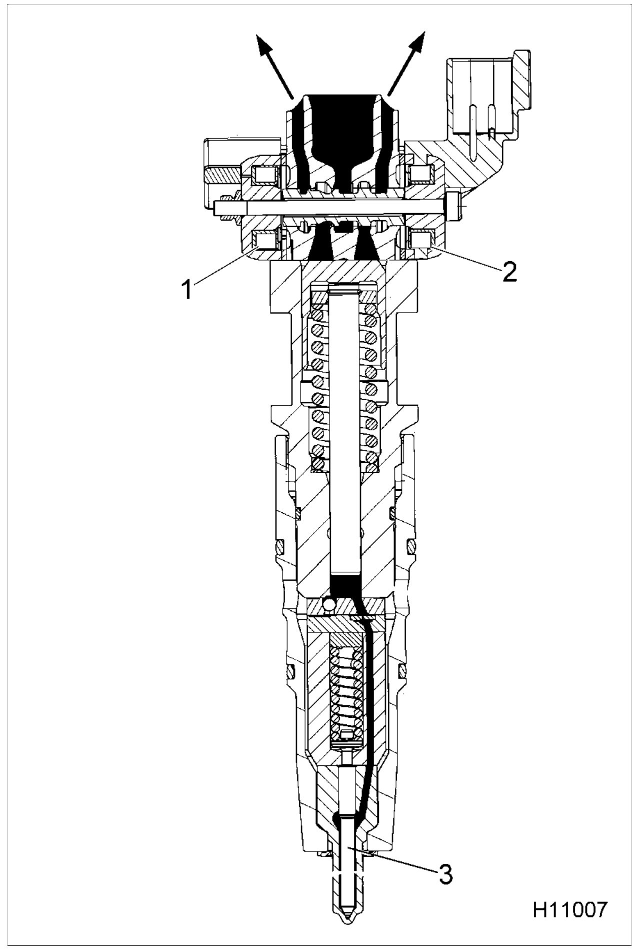

Figure 27 End of main injection (Step 2)

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

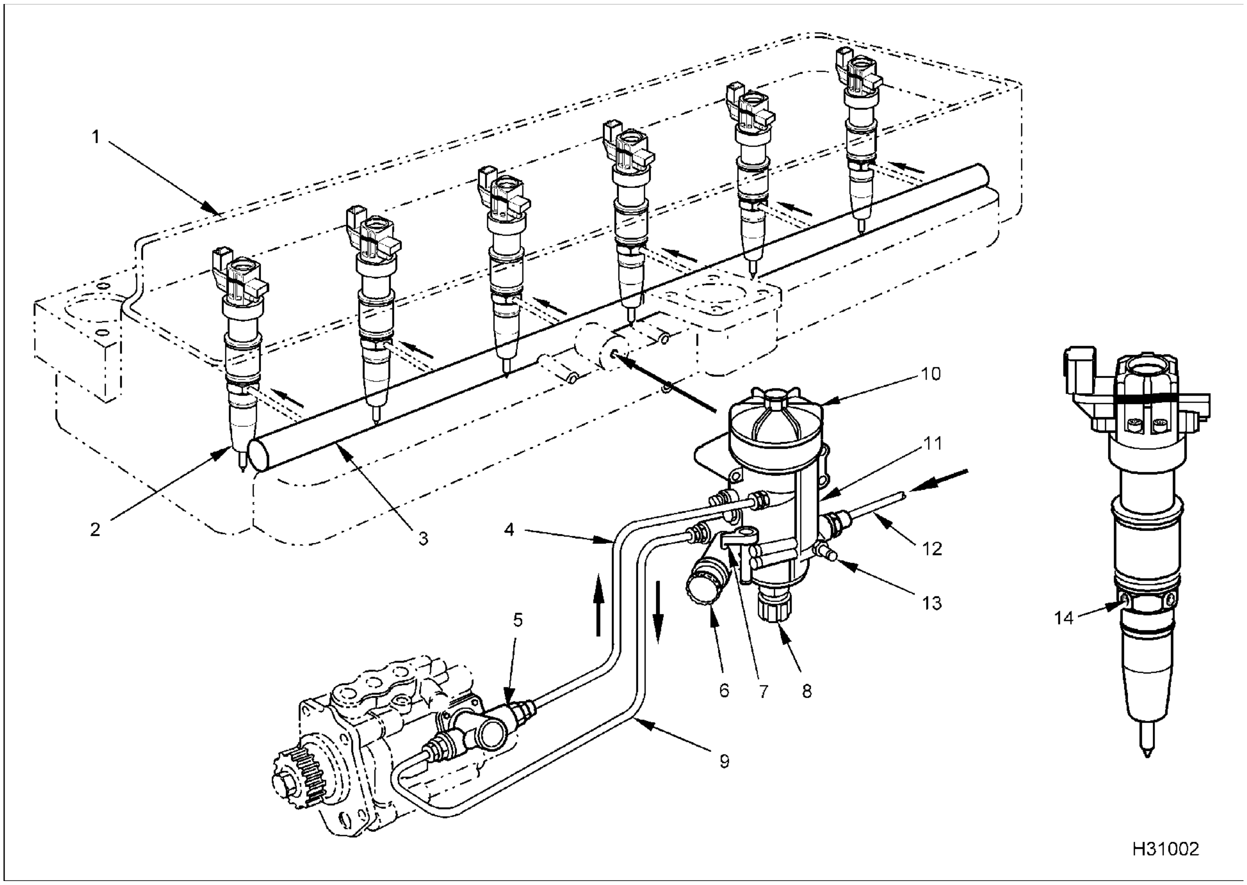

Figure 28 Fuel supply system

1. Cylinder head assembly
2. Fuel injector
3. Low-pressure fuel rail
4. Transfer pump outlet tube assembly
5. Low-pressure 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 assembly
12. Fuel line from tank
13. Test fitting
14. Fuel inlet (4)

Fuel Flow Schematic

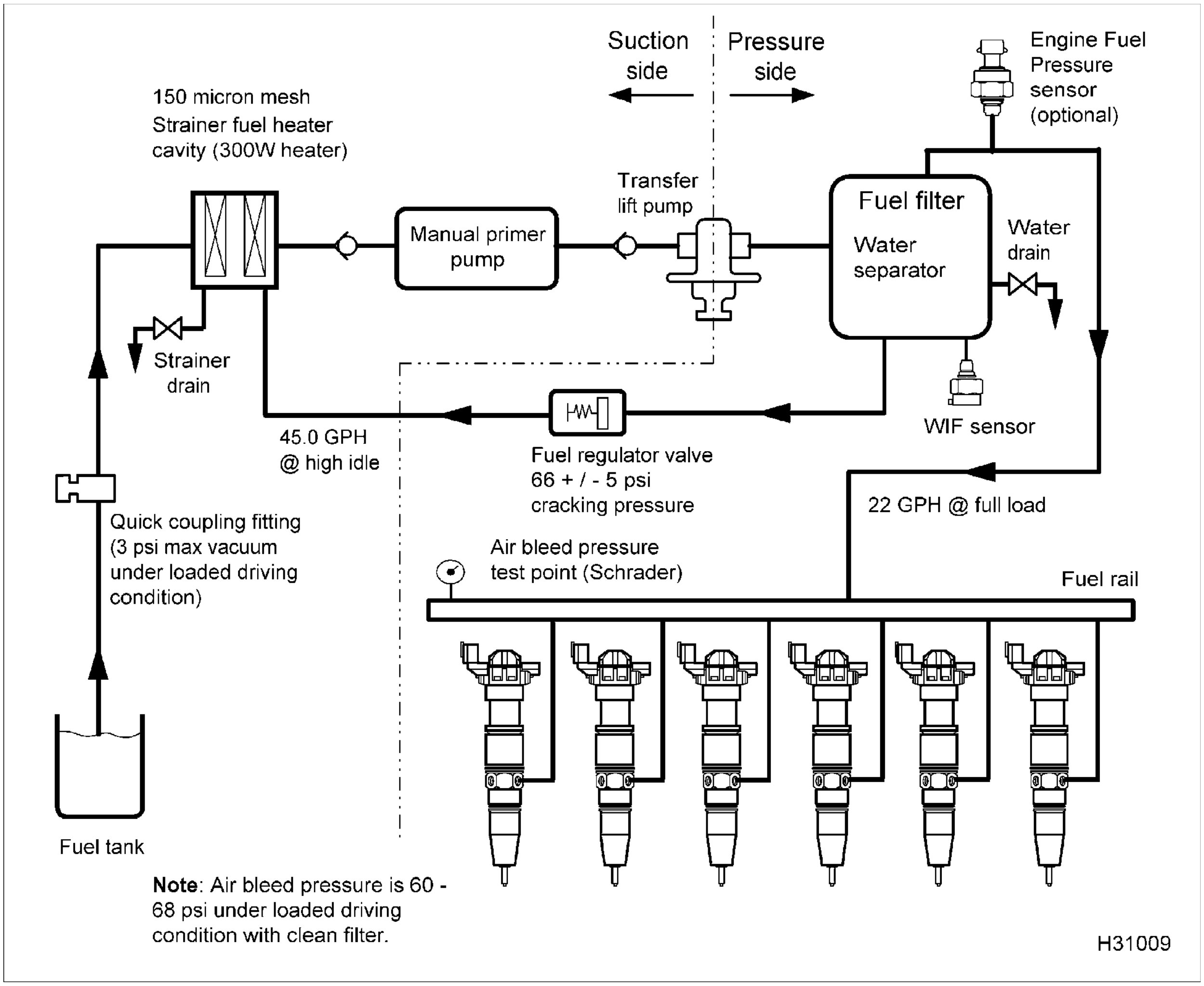

Figure 29 Fuel flow

The fuel filter housing includes the following components:

- 150 micron fuel strainer
- 300W 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

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 sends a signal to the Electronic Control Module (ECM); the ECM illuminates the amber WATER IN FUEL lamp on the instrument panel. 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 cycled between the fuel filter housing and low-pressure fuel pump. When engine demand increases, engine fuel consumption increases resulting in less fuel cycling. Under heavy loads fuel flows through the filter with little or no cycling.

Fuel is conditioned as it flows through a main filter and central post. The post 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 filter header assembly under low pressure – less than 482 kPa (70 psi) – into the low-pressure fuel rail for distribution to the fuel injectors. Fuel flows from the fuel filter housing into the fuel rail, through the fuel rail into six drilled holes (one for each injector) to 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

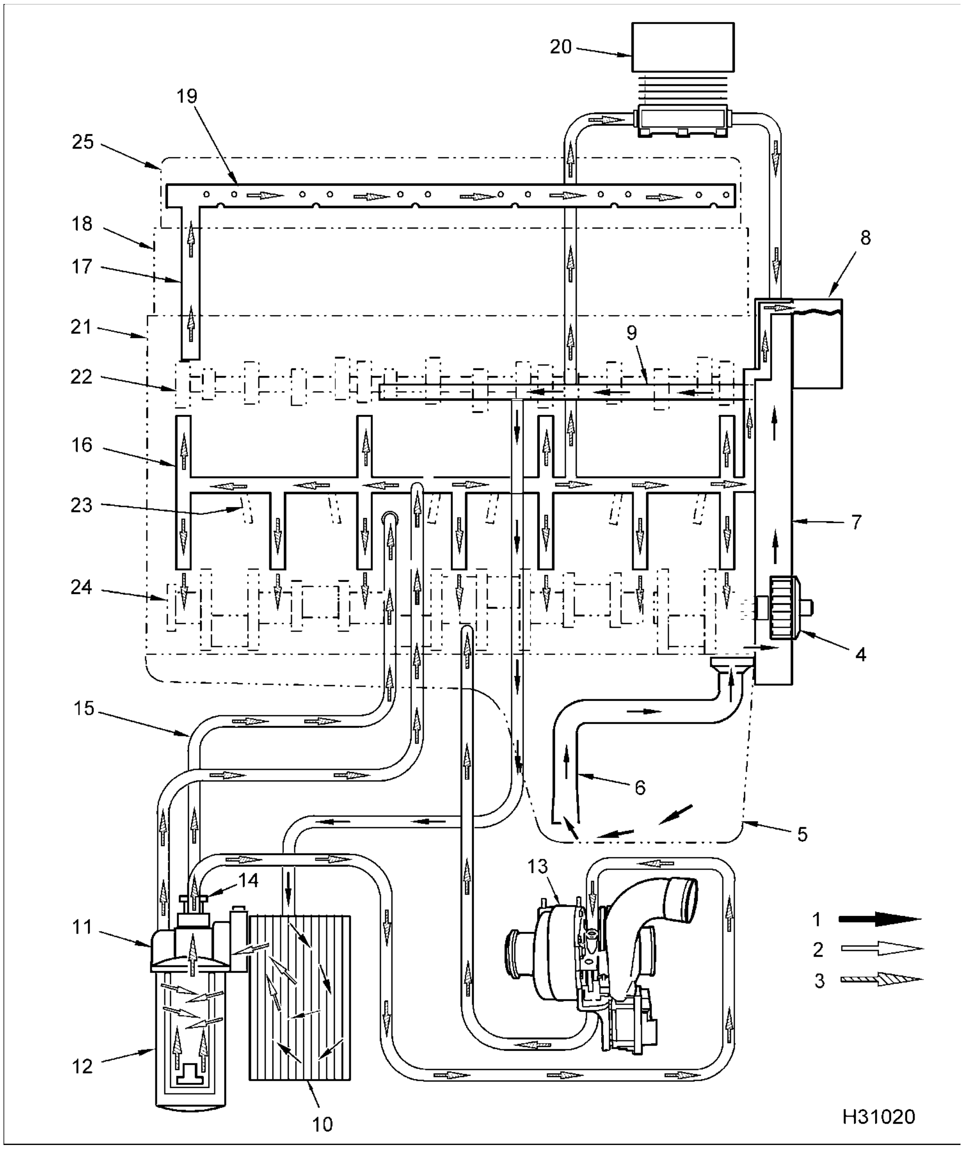

Figure 30 Lubrication system

1. Unfiltered oil
2. Cooled unfiltered oil
3. Filtered oil
4. Secondary filtration filter
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 jet (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

Oil Flow Diagram

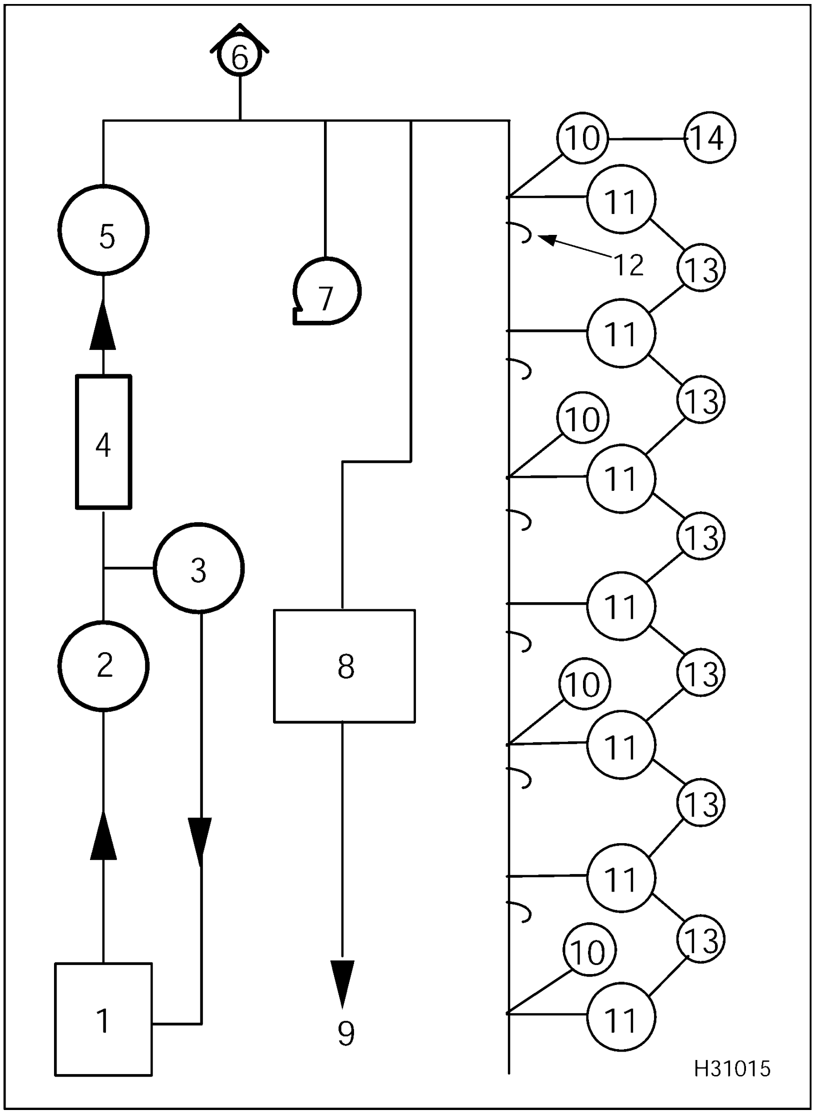

Figure 31 Lubrication system

1. Sump
2. Oil pump
3. Secondary filtration (if equipped)
4. Oil cooler
5. Oil filter
6. Regulator valve
7. Variable Geometry Turbocharger (VGT)
8. Oil reservoir for high-pressure pump
9. To high-pressure oil system
10. Cam bearings
11. Main bearings
12. Piston cooling tubes (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 bypassed in 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 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 to rod journals, receiving 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 jets, 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 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 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 back to the crankcase through an elbow connected to the bottom of the compressor.

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

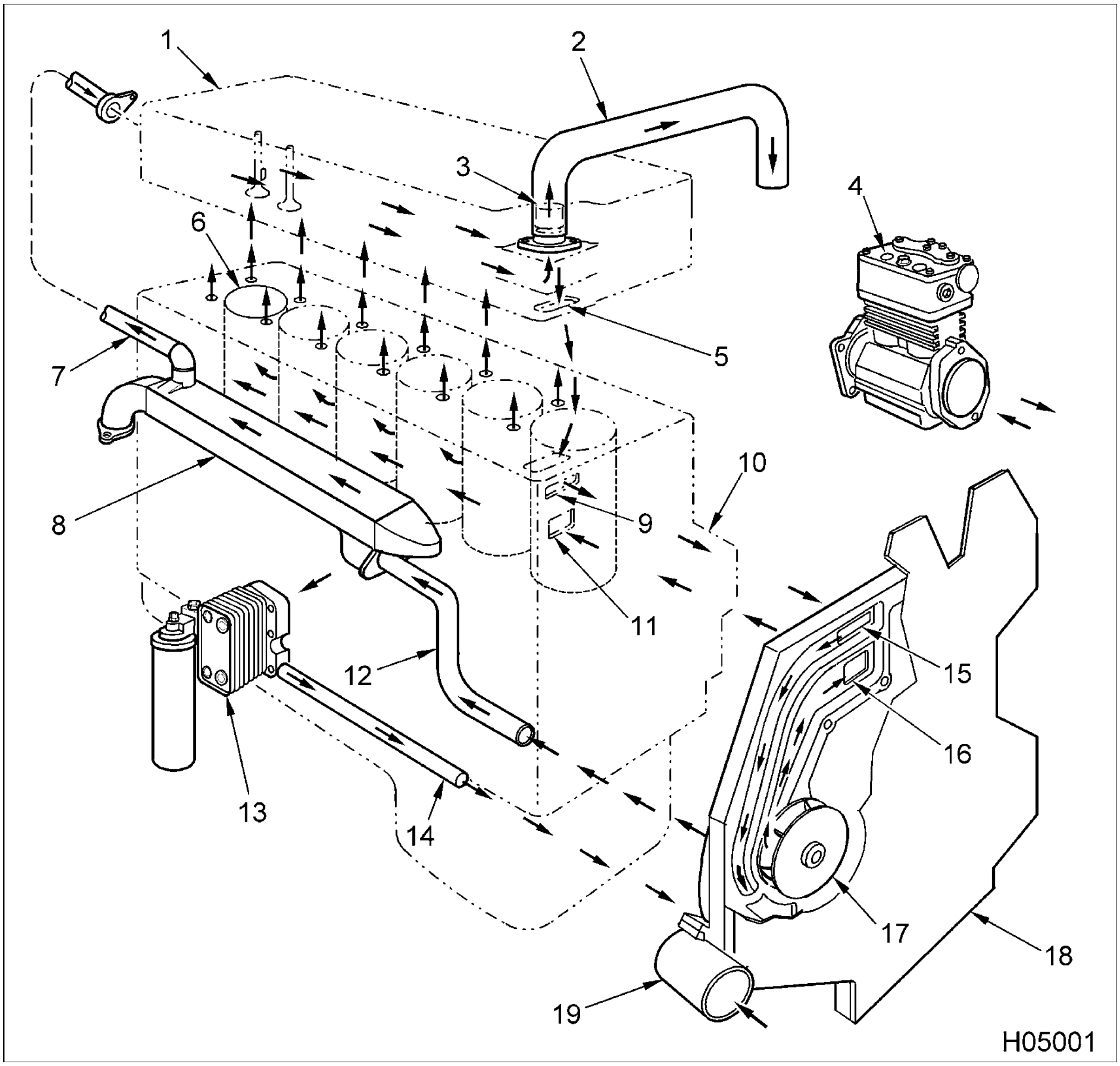

Figure 32 Engine cooling system

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 coolant return tube assembly
8. EGR cooler
9. Water outlet from crankcase to front cover
10. Crankcase
11. Water inlet to crankcase
12. EGR cooler supply tube
13. Oil system 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 set into the front cover has three 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, distributed evenly through metering holes in the cylinder head. 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).

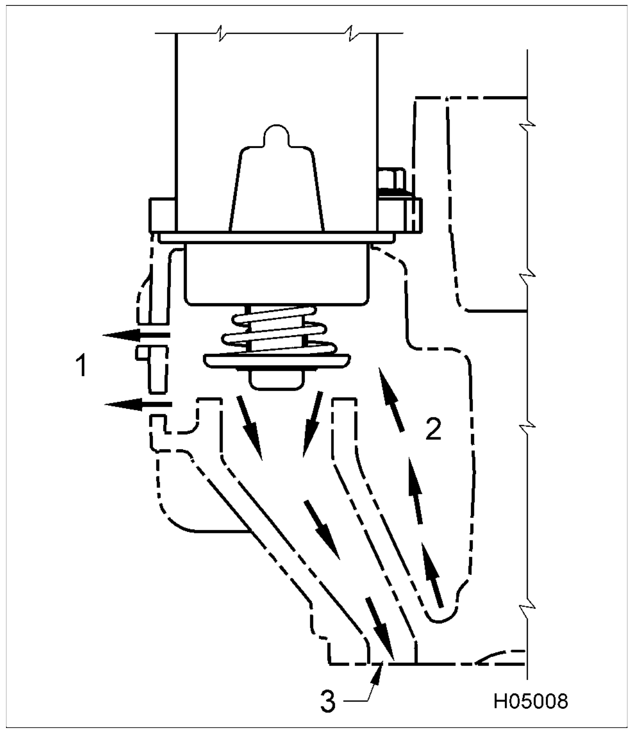

Figure 33 Thermostat closed

1. Coolant flow to heater port
2. Coolant in from engine
3. By-pass 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.

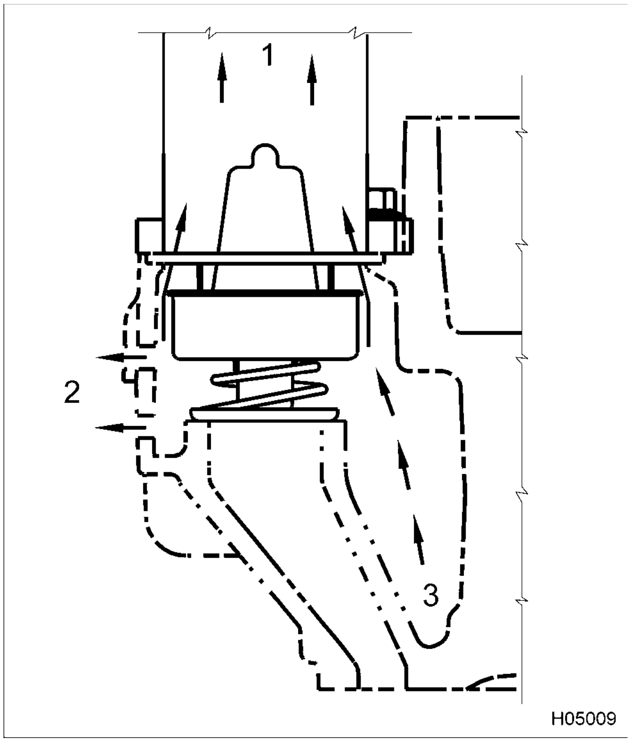

Figure 34 Thermostat open

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

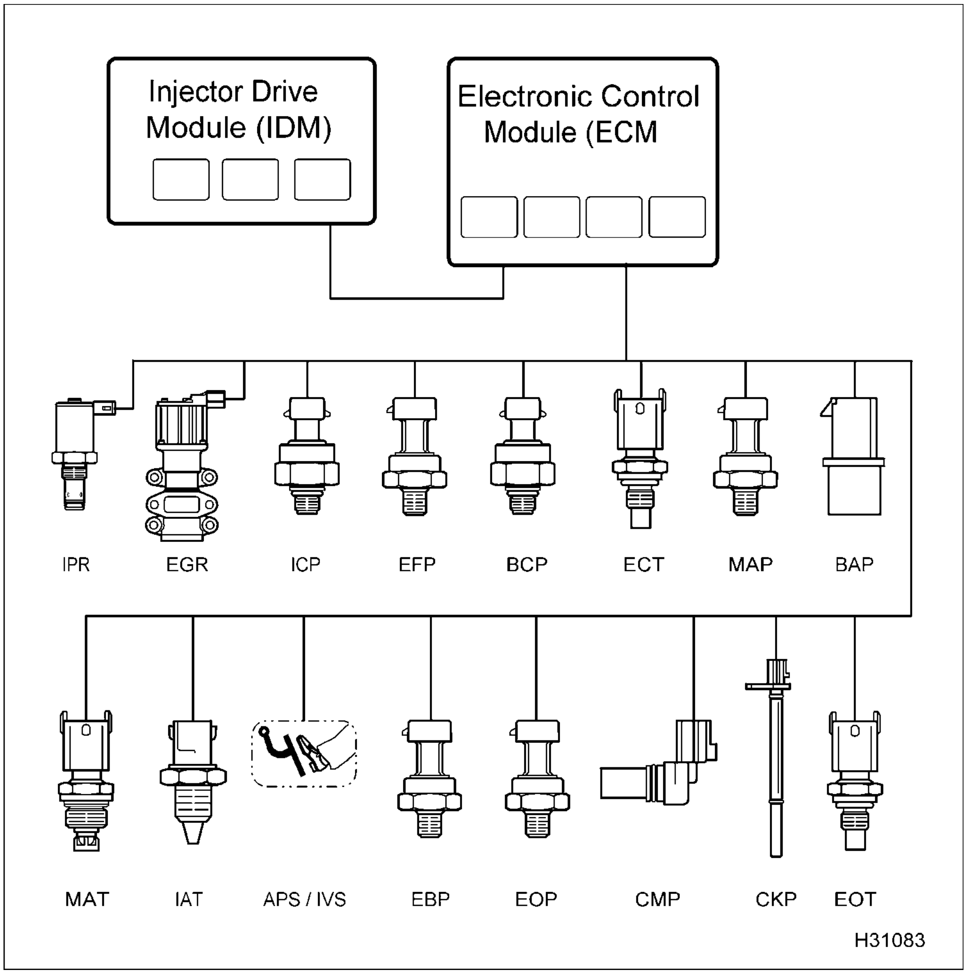

Figure 35 Electronic Control System

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:

- Provides Reference Voltage (V_{REF})
- Conditions input signals
- Processes and stores control strategies
- Controls actuators

1. Reference voltage (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 a 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 key 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 key 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, both 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 control module and control valve
- Diamond Logic™ engine brake
- IPR valve
- Air intake heater assembly (optional)

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 control valve has a DC motor to control the valve position and a position sensor to provide a feedback signal to EGR drive module. The voltage source is supplied by the ECM power relay through a 12 way connector. DC motor control is achieved through the EGR drive module from a command from the ECM to match engine requirements.

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.

Injection Drive Module (IDM)

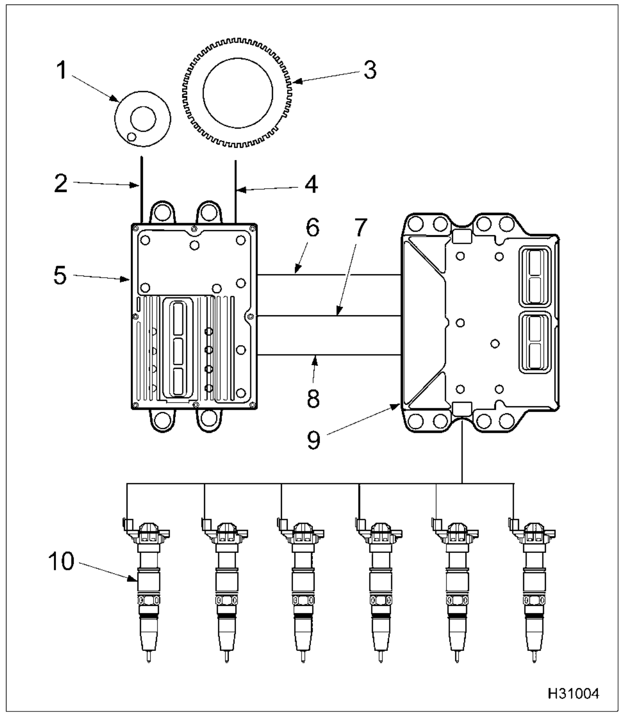

Figure 36 Injection Drive Module (IDM)

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

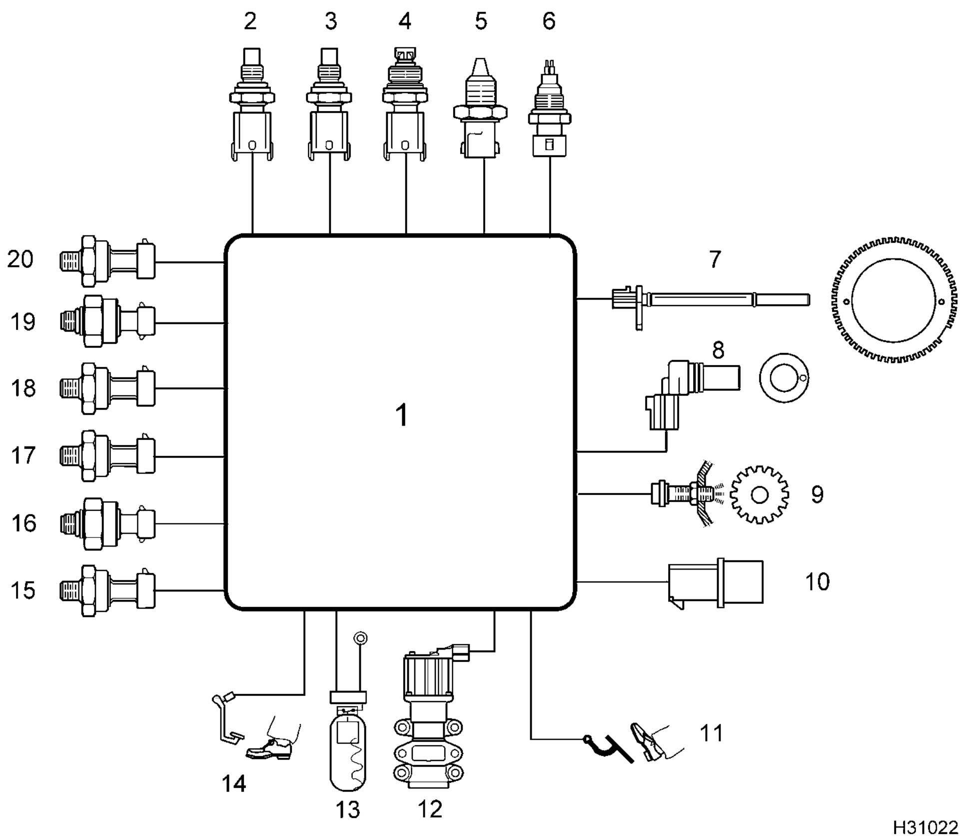

Figure 37 Engine and vehicle sensors

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) sensor
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) sensor
19. Injection Control Pressure (ICP)
20. Exhaust Back Pressure (EBP)

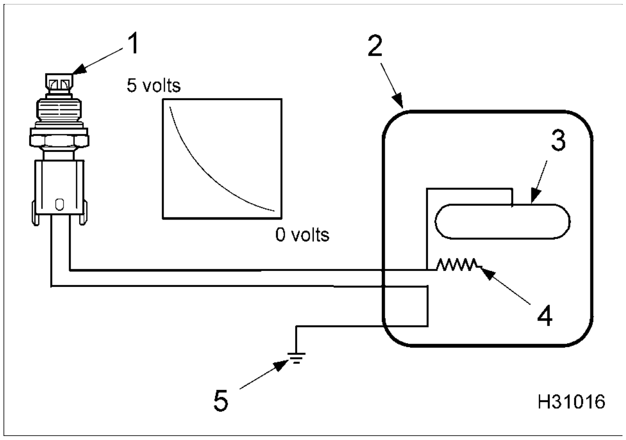

Figure 38 Thermistor

1. Temperature sensor
2. Electronic Control Module (ECM)
3. Microprocessor
4. Voltage Reference (Vref)
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 intake 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), left 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.

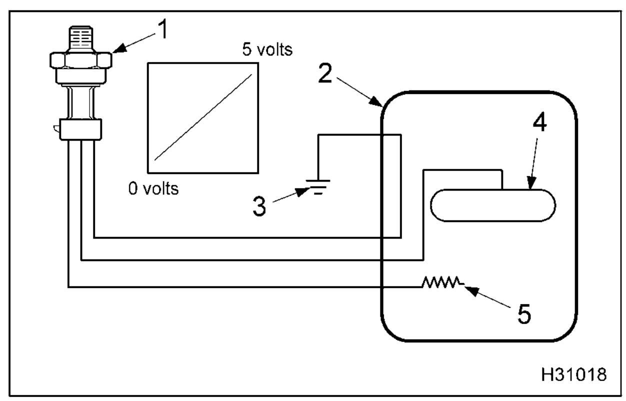

Figure 39 Variable capacitance sensor

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

Variable Capacitance Sensors

- BAP
- BCP

- EBP
- EFP
- EOP
- ICP
- MAP

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 preprogrammed 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 air heater operation. The BAP sensor is installed in the cab.

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 installed right of the engine brake shutoff valve in the high-pressure oil rail.

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 ECM monitors the EBP signal to determine exhaust back pressure. This 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 monitors the EFP signal to determine correct fuel pressure for efficient engine operation. The EFP sensor is installed in the rear of the fuel filter assembly (crankcase side).

Injection Control Pressure (ICP) sensor

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 installed left of the engine brake shutoff valve in the high-pressure oil rail.

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.

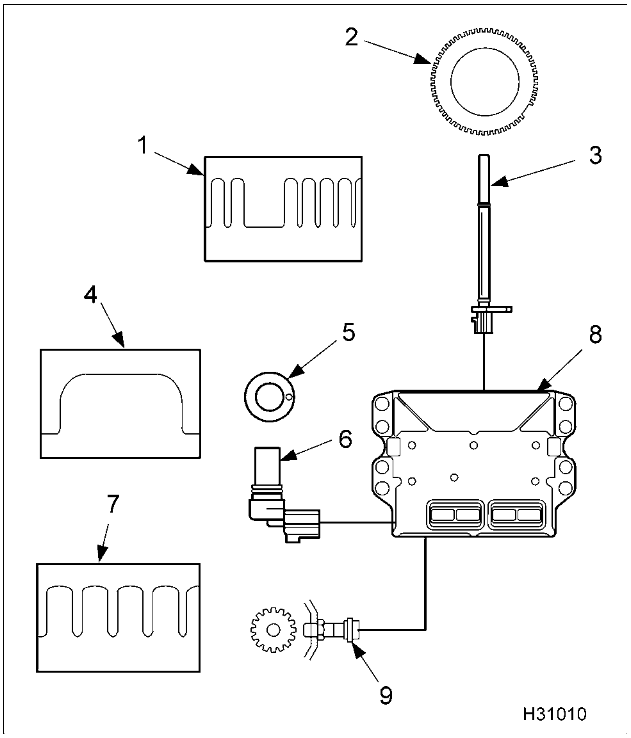

Figure 40 Magnetic pickups

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) sensor

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

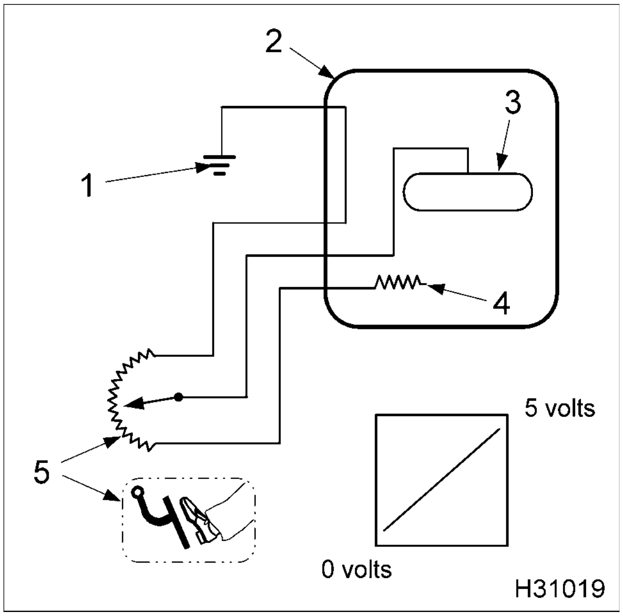

Figure 41 Potentiometer

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. A remote accelerator or throttle device can be used in addition to the accelerator pedal.

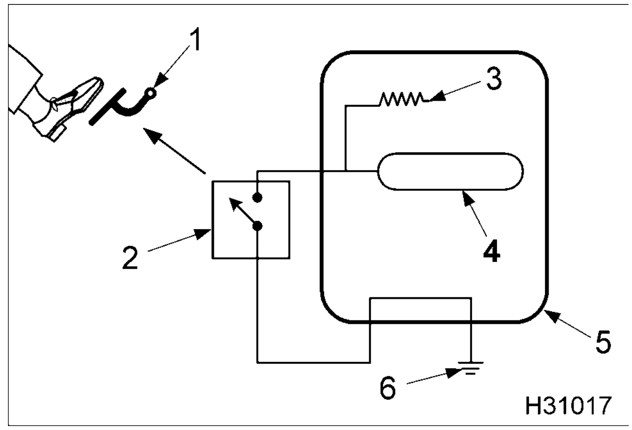

Figure 42 Switch

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. 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 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 tank. 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 detects water in the fuel. When enough water accumulates at the bottom of the housing, the WIF sensor sends a signal to the Electronic Control Module (ECM); the ECM sets a Diagnostic Trouble Code (DTC) and illuminates the amber WATER IN FUEL lamp on the instrument panel. The WIF is installed in the base of the fuel filter housing.

Diamond Logic™ Engine Brake

Engine Brake Components

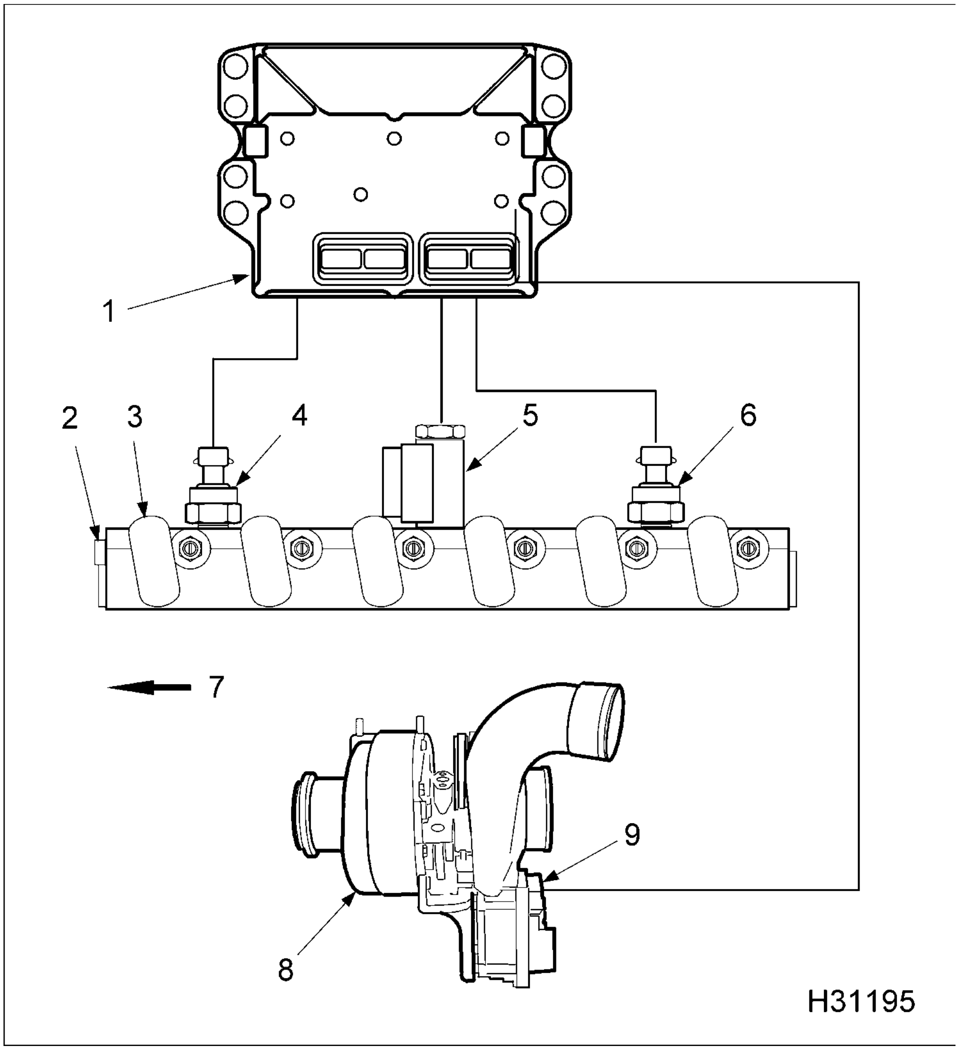

Figure 43 Diamond Logic™ engine brake – system

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

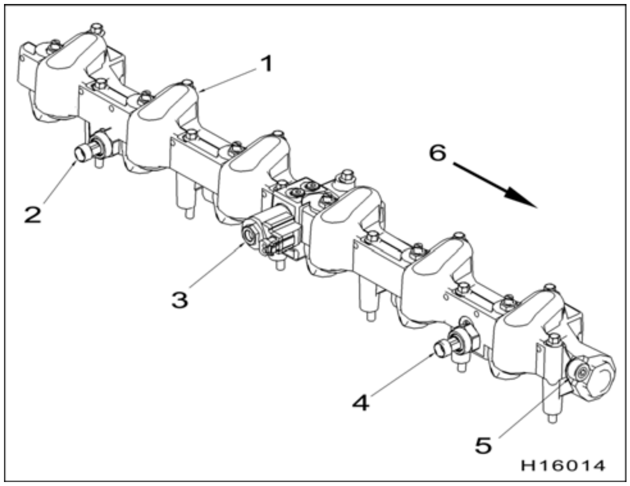

Figure 44 High-pressure oil rail

1. High-pressure oil rail
2. ICP sensor
3. Brake shutoff 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.

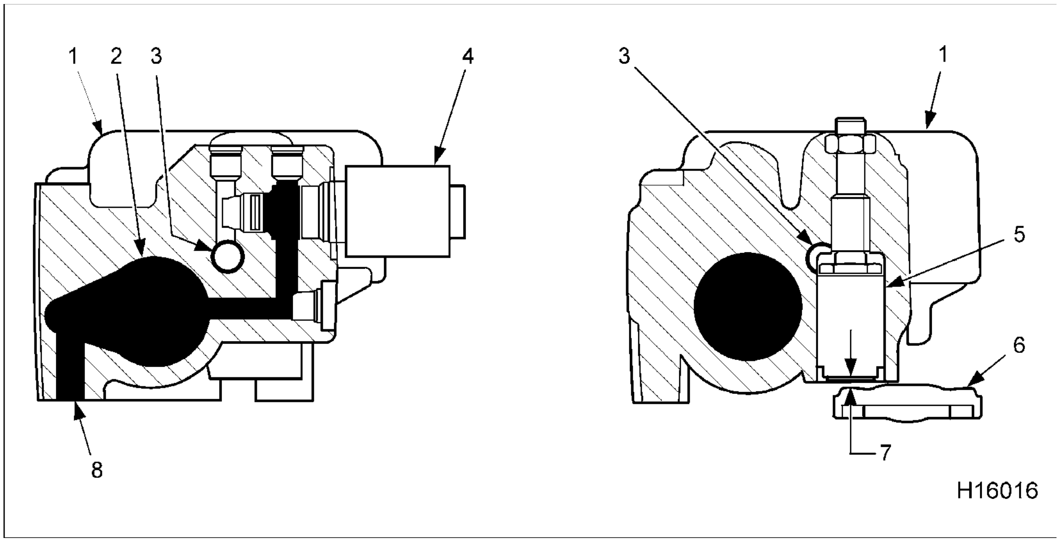

Figure 45 Brake shutoff valve and brake actuator– OFF

1. High-pressure oil rail
2. Injector oil gallery
3. Brake oil gallery
4. Brake shutoff 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 shutoff 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

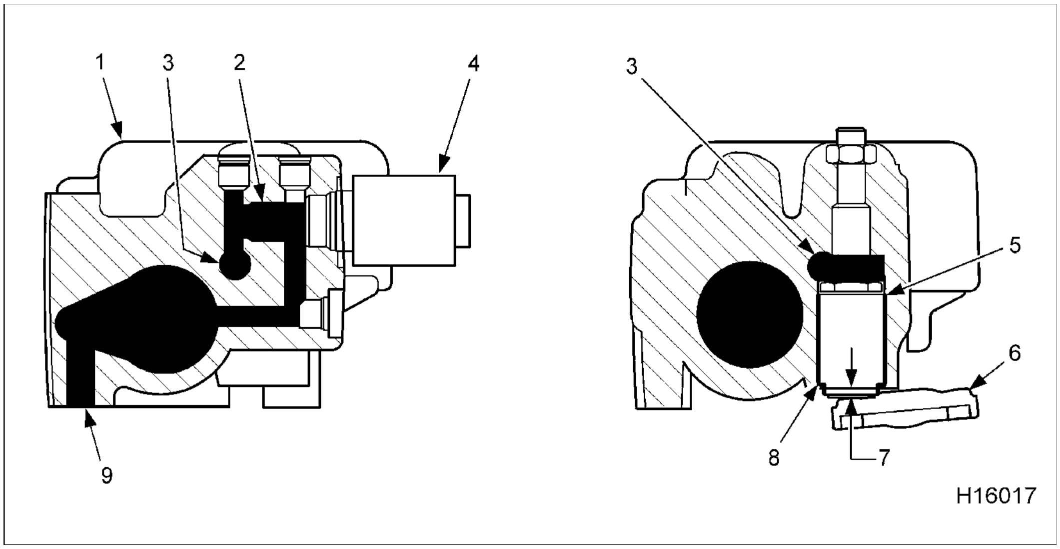

Figure 46 Brake shutoff valve and brake actuator– ON

1. High-pressure oil rail
2. High-pressure oil flow to brake oil gallery
3. Brake oil gallery
4. Brake shutoff 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 1000)
- APS (less than 5%)
- Idle validation
- Operator input switches (On/Off) (power selection – Low, Med, High)

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

When the engine brake is activated, the ECM provides the ground to activate the brake shutoff 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.

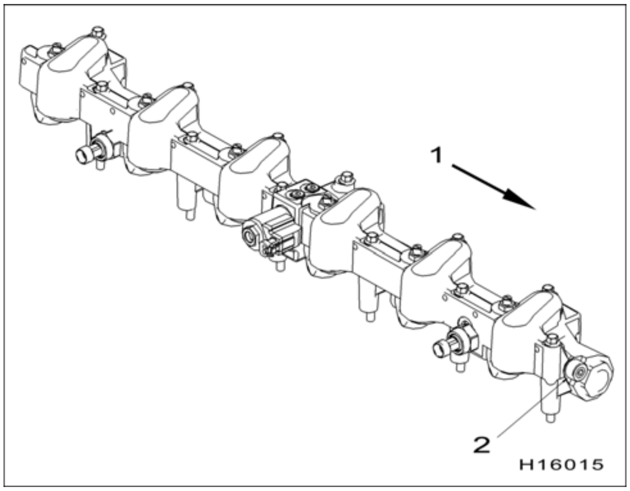

Figure 47 Brake pressure relief valve in high-pressure oil rail

1. Front of engine
2. Brake pressure relief valve

The ECM removes the ground source from the brake shutoff valve to deactivate the engine brake. Residual brake gallery pressure initially bleeds from the actuator bore. When brake gallery pressure reaches 1000 psi, the brake pressure relief valve opens, and oil drains back to sump.

Table of Contents

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

Engine Preparation

Clean Engine

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

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

1. Cap all openings to prevent water and degreased agents from entering any engine components internally.
2. Cover any exposed electrical pin connectors and ECM, IDM, and EGR modules using plastic and duct tape.
3. Use an appropriate detergent mixed in the correct ratio of water and apply to engine using a hot water pressure washer or similar cleaning equipment.

Drain Engine Fluids

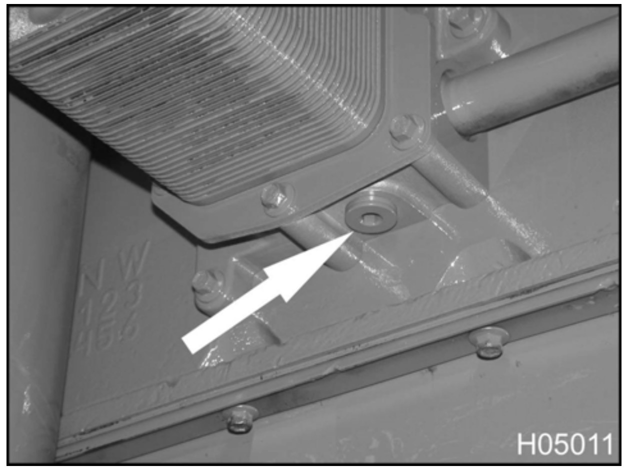

Figure 48 Coolant drain plug location

1. Place a coolant drain pan beneath the coolant drain plug. Remove coolant drain plug (M18) and O-ring from the bottom of the oil system module. Open radiator cap to allow system to drain quicker. After draining coolant, install new O-ring on plug and install in module. Torque plug to the standard torque value (See General Torque Guidelines, page 409). Dispose of used coolant according to applicable laws.

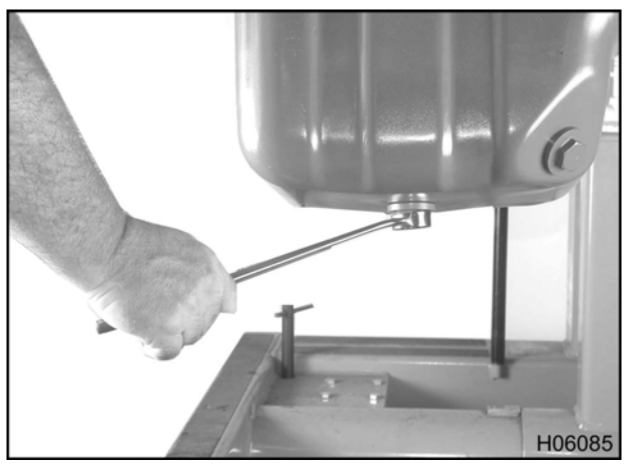

Figure 49 Draining the oil

2. Place a oil drain pan beneath the oil drain plug to collect the oil.

3. Remove oil pan drain plug (M25) and O-ring. Drain engine oil and dispose of used engine oil according to applicable laws.
4. Discard O-ring, inspect drain plug and replace if necessary. Place a new O-ring onto drain plug and install to oil pan. See special torque value (Table 3).

Component Removal

Turbocharger Oil Inlet Tube

1. Loosen turbocharger oil inlet tube assembly nut from fitting on top of oil filter header.
2. Remove two mounting bolts (M8 x 20) securing the turbocharger and oil inlet tube assembly to the top of the turbocharger central housing. Remove turbocharger oil inlet tube assembly. Discard flange O-ring.
3. Remove turbocharger oil drain tube bracket and bolt (M8 x 16) at crankcase.

Turbocharger

WARNING: To avoid serious personal injury, possible death, or damage to the engine or vehicle, support turbocharger assembly during the removal of mounting hardware.

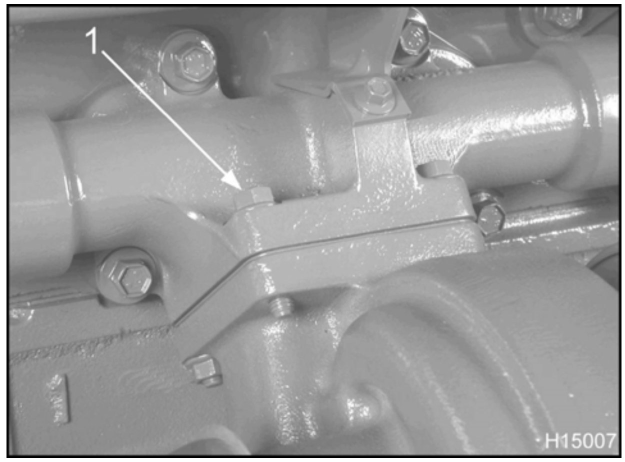

Figure 50 Turbocharger mounting nuts

1. Nuts, M10 (4)

NOTE: To aid in the disassembly of the turbocharger, loosen four nuts (M10) between ⅛ and ¼ of a turn then tap each nut using a socket or flat punch and hammer. This will knock the “peaks” of the stud threads off the “ramps” of the special Spiralock® nuts, thus allowing the nuts to unthread with considerable ease.

NOTE: Remove turbocharger and oil drain tube as an assembly. The oil drain tube is trapped between the turbocharger and crankcase.

1. Remove four nuts (M10 flange head) securing turbocharger assembly to exhaust manifold flange.
2. Remove turbocharger assembly, oil drain tube, and turbo mounting O-ring from engine. Discard oil drain tube O-rings.
3. Cap all openings on turbocharger assembly.

NOTE: If plastic caps are not available, use duct tape to cover openings.

Oil Filter

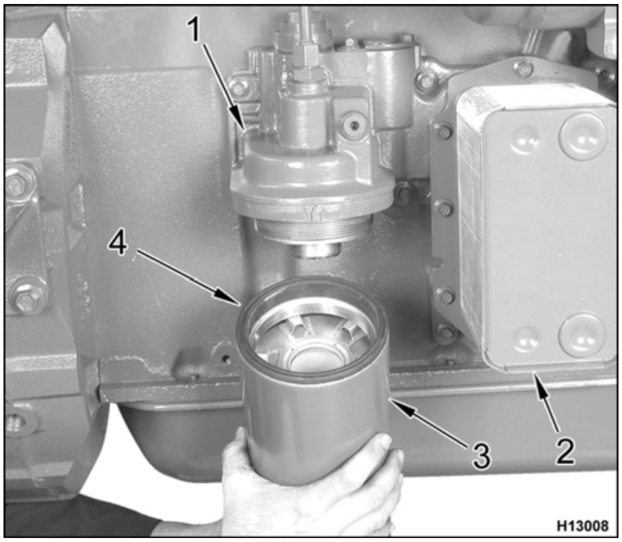

Figure 51 Removing the oil filter

1. Oil filter header
2. Oil cooler
3. Oil filter (spin-on)
4. Oil filter gasket

Remove oil filter from oil cooler filter header. Discard oil filter.

Oil System Module

1. Remove one bolt (M8 x 16) securing oil cooling drain tube assembly to crankcase.
2. Remove eight bolts (M8 x 30) securing oil system module to crankcase.
3. Remove oil system module and oil cooler drain tube as an assembly from crankcase and discard O-rings. The oil cooler drain tube is trapped between the oil system module and the front cover.

Mounting Adapter Plate and Engine

Adapter Plate

WARNING: To avoid serious personal injury, possible death or damage to the engine or vehicle use a minimum 3 ton chain hoist, equipped with safety hooks to lift the engine at designated lifting eyes.

WARNING: To avoid serious personal injury, possible death or damage to the engine or vehicle, use only metric grade 10.9 or SAE grade 8 bolts when mounting adapter plate to engine as well as the engine stand. See instructional literature included with adapter plate for specific directions of its safe use.

1. Visually match up adapter plate with bolt holes on right side of engine to determine adapter plate orientation to the engine stand.

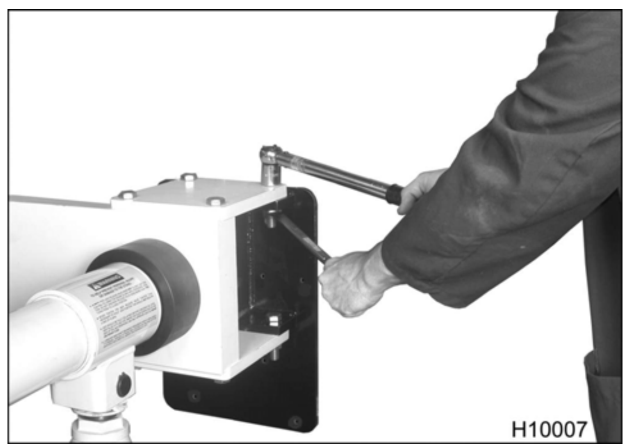

Figure 52 Installing the adapter plate to engine stand

2. Install recommended adapter plate to engine stand and secure by using eight (grade 8) bolts and nuts. Tighten bolts to the standard torque value (See General Torque Guidelines, page 409).

Engine

1. Raise engine to approximate height of engine stand.
2. Align engine stand and adapter plate to engine, rotating stand and / or raising engine to match adapter plate. Secure one bolt and rotate stand if necessary to thread remaining bolts.
3. Use metric grade 10.9 bolts to secure engine to adapter plate. Tighten bolts to the standard torque value (See General Torque Guidelines, page 409). Remove safety chain hooks from engine lifting eyes.

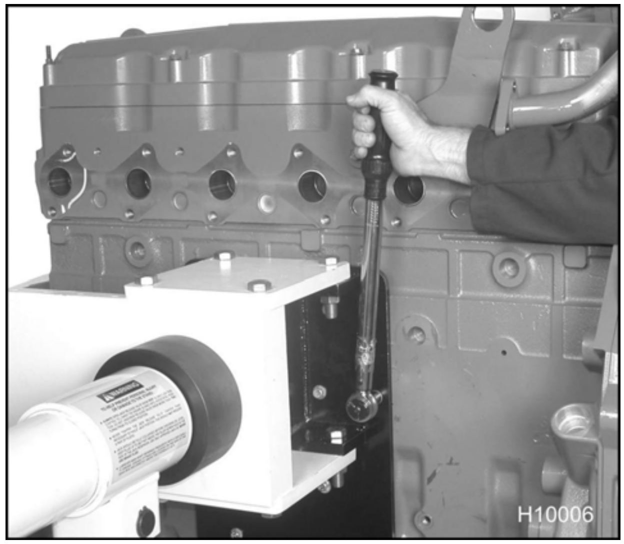

Figure 53 Torquing engine mounting bolts

Special Torque

Table 3 Engine Mounting Special Torques

Oil pan drain plug (M25)	68 N·m (50 lbf·ft)

SPECIAL SERVICE TOOLS

Table 4 Special Tools

Engine mounting plate	ZTSE4649
Engine stand	OTC1750A