DIAGNOSTIC/TROUBLESHOOTING MANUAL

EGES-305-2

2006

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

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Foreword

This manual is part of a series of publications intended to assist service technicians in maintaining International® diesel engines.

Due to a commitment of continuous research and development, some procedures, specifications, and parts may be altered to improve International® products and introduce technological advances.

Periodic revisions may be made to these publications and mailed automatically to “Revision Service” subscribers. When ordering publications, the latest revision will be supplied.

NOTE: International® diesel engines are installed in many different applications. It is not always possible to illustrate the exact surroundings of the working area in photographs.

When ordering additional copies of this publication or any other International® Truck and Engine Corporation publication, refer to the following contact information:

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VT 275 Series Service Literature

Number*	Description
EGES-300-1	*VT 275 Engine Service Manual*
EGES-305-1	*VT 275 Engine Diagnostics Manual*
1171818R3	*VT 275 Operation and Maintenance Manual*
EGED-315	VT 275 Diagnostic Form
EGED-310-1	VT 275 Electronic Control System Diagnostic Form

* - Publication with the latest revision will be furnished.

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

Service Diagnosis

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

The engine is first considered as a complete unit. If it is determined that the problem is application related, see application specific manuals for further diagnostic information.

If the problem is determined to be within the engine, the problem can then be localized to components or systems. Testing procedures will then help analyze the source of the problem.

Prerequisites for effective diagnosis:

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

Effective service diagnosis requires use of the following references:

- *Engine Service Manual*
- *Engine Diagnostic Manual*
- Diagnostics Forms
- Electronic Control Systems Diagnostics Forms
- Technical Service Information (TSI) letters
- Technical Services Frequently Asked Questions (FAQ)

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

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

Safety Information

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

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

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

Most accidents that involve operation, maintenance, and repair are caused by failure to observe basic safety rules or precautions. Read and follow OSHA regulations.

SAFETY TERMINOLOGY

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

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

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

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

SAFETY INSTRUCTIONS

Vehicle

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

Work area

The engine and its components must be kept clean during service or maintenance. Contamination of the engine or components will cause premature wear.

- 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 appropriate protective apparel when working with or around hot liquid, hot engines, or hot engine components
- 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.
- To prevent fire and hazardous fumes, clean and wipe dry all engine surfaces where fluids may have spilled.

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.
- Use suitable eye protection.
- 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, lights, or extension cords.

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 fuel 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 Systems

Engine Serial Number

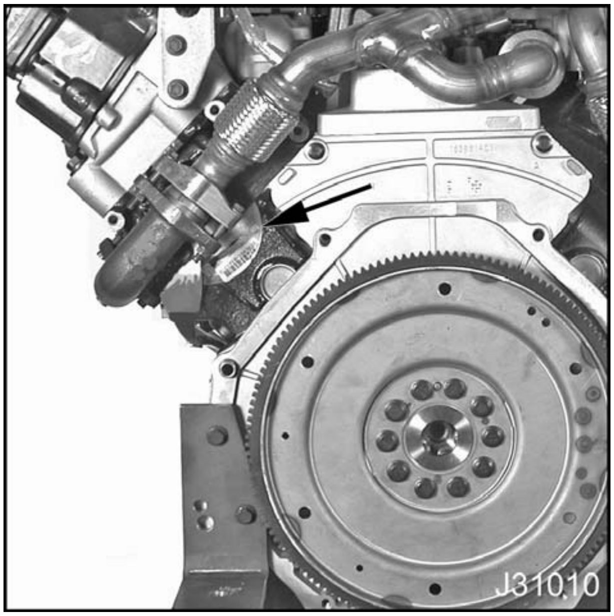

Figure 1 Engine serial number

The engine serial number is in two locations:

- Stamped on the crankcase pad, on the rear left side below the cylinder head.
- Manufacturer’s engine serial number label on the crankcase breather adjacent to the emission label on the left valve cover.

Engine Serial Number Example

4.5HM2Y0101718

4.5 – Engine displacement (liters)
H – Diesel, turbocharged, air intercooled and electronically controlled
M2 – Motor truck
U2 – Power unit and OEM, sold to original equipment manufacturer
Y – United States, Huntsville
7 digit suffix – Sequence number

Emission Labels

An Environmental Protection Agency (EPA) Engine Emission Label is issued for the International® VT 275 diesel engine.

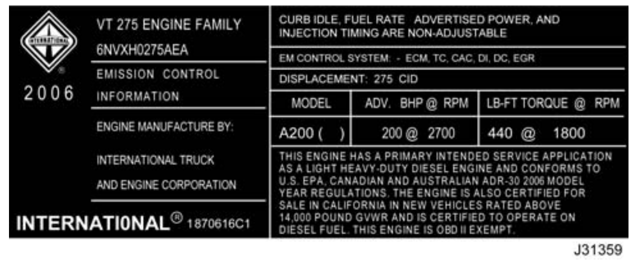

Figure 2 Example of Environmental Protection Agency (EPA) emission label (50 state)

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

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

Engine Accessories

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

- Alternator
- Dual turbocharger assembly
- Power steering pump
- Starter motor

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

Engine Description

International® VT 275 Features and Specifications

Engine configuration	4 stroke V6 diesel, 4 valves/cylinder
Displacement	4.5 liters (275 in^3)
Bore (sleeve diameter)	95 mm (3.74 in.)
Stroke	105 mm (4.134 in.)
Compression ratio	18.0:1
Aspiration	Dual turbocharged and Charge Air Cooled (CAC)
Rated power @ rpm	200 hp @ 2700 rpm[1]
Peak torque @ rpm	440 ft·lbs @ 1800 rpm[1]
Engine rotation (facing flywheel)	Counterclockwise
Combustion system	Direct injection turbocharged
Fuel system	International® electro-hydraulic generation 2 injection
Cooling system capacity (engine only)	11 liters (12 quarts US)
Lube system capacity (including filter)	13 liters (14 quarts US)
Lube system capacity (overhaul only, with filter)	14 liters (15 quarts US)
Firing order	1-2-5-6-3-4

1 Initial rating at the time of manual printing, ratings are subject to change for various application. See EPA emission label for the exact rating for a particular engine.

Engine Features

The engine is designed with the following features:

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

Standard Features

The International® VT 275 is a V6 engine with a displacement of 4.5 liters (275 cubic inches).

The cylinder heads have 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 hydraulic roller cam followers, push rods, rocker arms, and valve bridges to open the dual intake and exhaust valves.

The crankcase assembly has been designed as two major matching components. The upper crankcase half houses the cylinders, main bearing saddles, with oil and coolant passages either cast or machined. The lower crankcase consists of a structural plate with the main bearing caps machined into it for improved load retention and alignment.

The crankshaft is supported by four main bearings with fore and aft thrust controlled at the upper half of the number 3 main bearing. Two connecting rods are attached to each crankshaft rod journal and are offset to minimize vibration. Piston pins are free floating, allowing the pin free lateral movement within the connecting rod as well as the piston. Piston pins and are held in place with retaining rings.

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

The primary balancer shaft fits and turns within the camshaft itself and is driven by the crankshaft flange. A counterweight is bolted to the front of the balancer shaft and is held in place by the thrust plate. The camshaft thrust plate aligns and holds the rear end of the balance shaft in the crankcase.

The Crankshaft Position (CKP) sensor and Camshaft Position (CMP) sensor are used by the Electronic Control Module (ECM) and Injector Drive Module (IDM) to calculate rpm, fuel timing, fuel quantity, and duration of fuel injection.

One piece aluminum-alloy pistons are fitted with one keystone ring, one rectangular intermediate compression ring, and a two piece oil control ring.

The combustion bowl is located in the piston crown to reduce emissions. All pistons are mated to fractured cap joint connecting rods.

The engine lubrication system is pressure regulated, full flow cooled, and full flow filtered. The crankshaft driven gerotor oil pump provides the necessary pressure to protect all the bearings and other wear surfaces. The oil pressure regulator, in the front cover, maintains the desired system pressure. The oil cooler cover and oil filter base assemblies direct oil and coolant flow for purpose of heat exchange.

The International® electro-hydraulic generation 2 injection system includes a cast iron oil rail assembly, fuel injectors, and a high-pressure oil pump. The IDM electronically controls the injectors. The IDM sends voltage pulses to the opening and closing coils of each injector to control fueling. The IDM receives input information from the ECM to determine timing, quantity, and duration of fuel for each injection event.

An electronic Boost Control Solenoid (BCS) in combination with a pneumatic actuator controls the turbocharger.

An open crankcase breather system draws crankcase vapors through a breather element while separating the vapor to the atmosphere and returning oil to the crankcase.

The secondary fuel filter assembly is pressure regulated and incorporates an air bleed orifice allowing air to be automatically purge if it has been introduced to the system.

Optional Features

A coolant heater is available to raise the temperature of the coolant surrounding the cylinders for improved performance during cold weather start-ups.

Chassis Mounted Features

The Horizontal Fuel Conditioning Module (HFCM), mounted on either the vehicle frame rail of the driver’s side (CF) or on the passenger side near the transmission and frame rail (stripped chassis), contains a fuel pump, filter, water separator with a drain valve, Water In Fuel (WIF) sensor, and Diesel Thermo Recirculation Module (DTRM).

Diamond Logic® engine control has three electronic control modules that monitor and control the engine:

Electronic Control Module (ECM)

Injector Drive Module (IDM)

Exhaust Gas Recirculation (EGR) drive module

The Inlet Air Heater (IAH) relay controls the IAH. The IAH is mounted under and through the intake manifold in the inlet air stream. The IAH warms the incoming air during cold start-up.

The glow plug relay controls the six glow plugs, one for each cylinder. The glow plugs warm the cylinders during start-up.

The inlet air heater and glow plug relays work together during start-up.

A Charge Air Cooler (CAC) is an air-to-air heat exchanger which increases the density of the air charge.

Typical Engine Component Locations

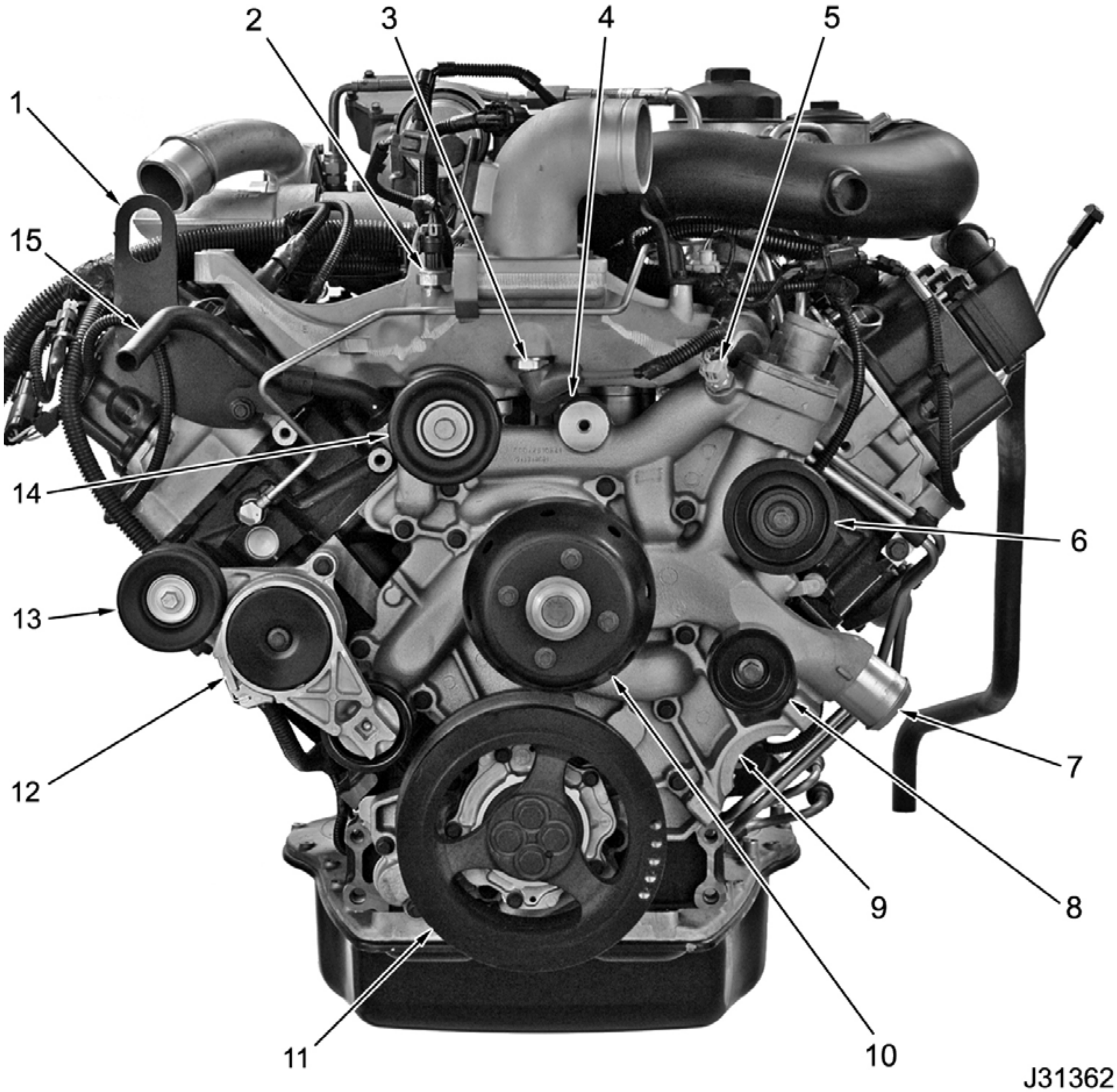

Figure 3 Front

1. Lifting eye (right front)
2. Manifold Absolute Pressure (MAP) sensor
3. Inlet Air Heater (IAH)
4. Diagnostic port (not shown, behind IAH)
5. Engine Coolant Temperature (ECT) sensor
6. Grooved idler
7. Coolant inlet
8. Flat idler
9. Front cover assembly
10. Water pump pulley
11. Vibration damper
12. Belt tensioner assembly
13. Grooved idler
14. Flat idler
15. Heater supply

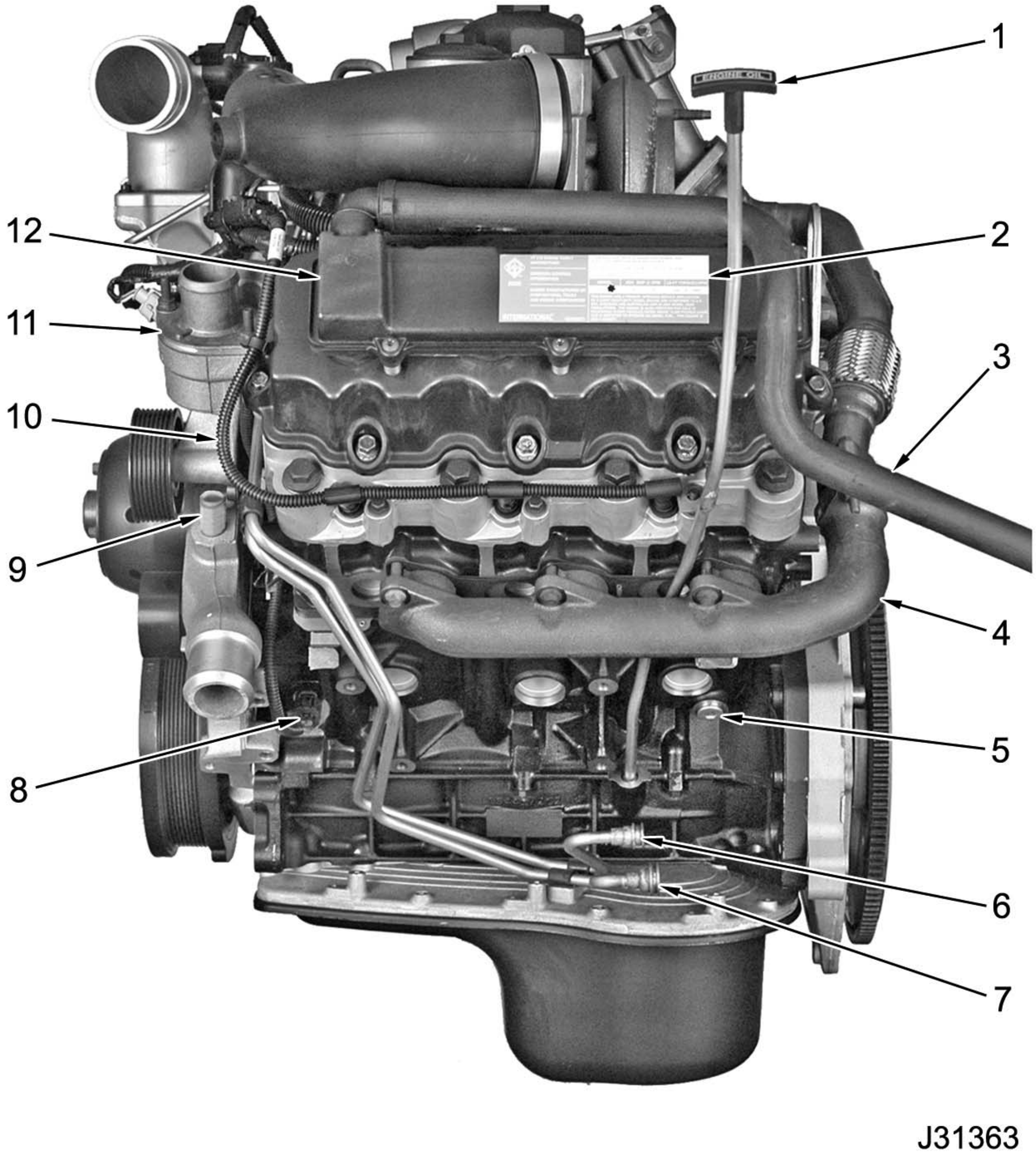

Figure 4 Left

1. Oil level gauge tube assembly
2. Exhaust emission label
3. Crankcase vent hose assembly
4. Exhaust manifold (left)
5. Crankcase coolant drain plug (left)
6. Fuel return to fuel pump
7. Fuel supply from fuel pump
8. Camshaft Position (CMP) sensor
9. Heater return port
10. Glow plug harness assembly (left)
11. Thermostat (to radiator)
12. Crankcase breather assembly

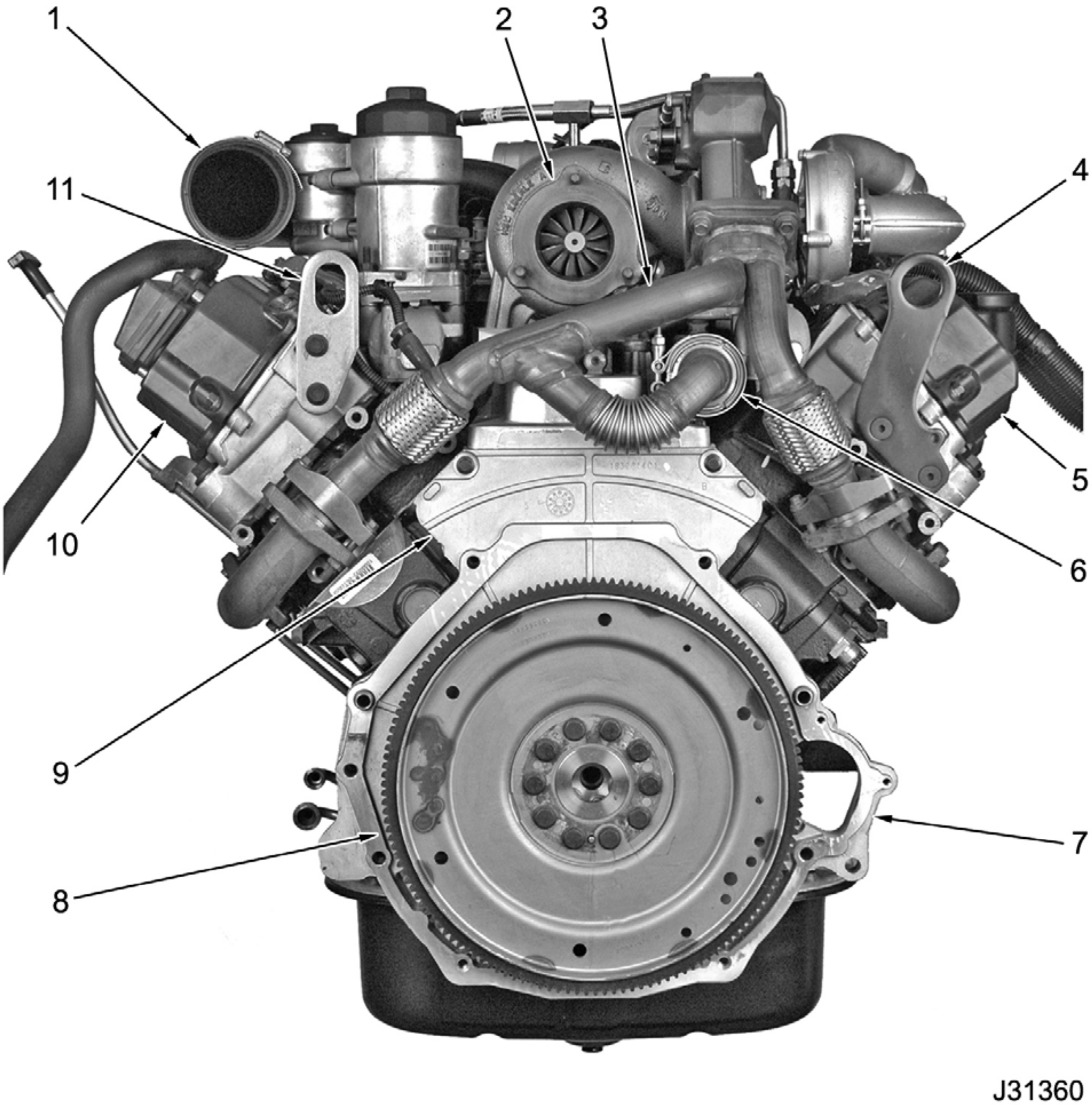

Figure 5 Rear

1. Inlet air (to turbocharger)
2. Turbocharger/exhaust outlet
3. Exhaust tube assembly
4. Lifting eye (right rear)
5. Valve cover assembly (right)
6. Exhaust tube to EGR cooler
7. Starter mount (rear cover)
8. Flywheel assembly
9. Rear cover
10. Valve cover assembly (left)
11. Lifting eye (left rear)

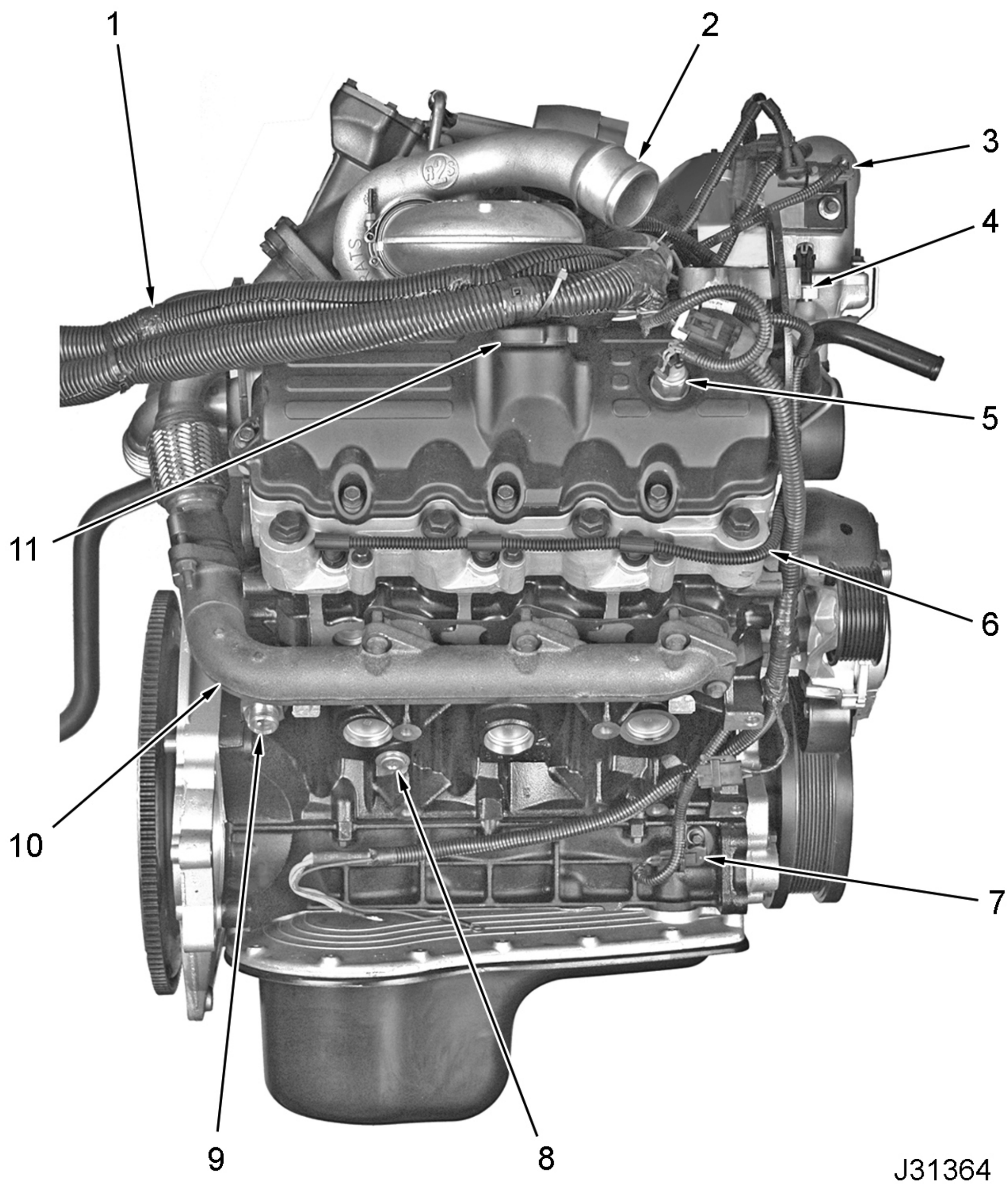

Figure 6 Right

1. Wiring harnesses to chassis mounted ECM, IDM, IAH and glow plug relays
2. Turbocharger compressed air to CAC
3. Boost Control Solenoid (BCS)
4. Manifold Air Pressure (MAP) sensor
5. Injection Control Pressure (ICP) sensor
6. Glow plug harness assembly (right)
7. Crankshaft Position (CKP) sensor
8. Crankcase coolant drain plug (right)
9. Coolant heater
10. Exhaust manifold (right)
11. Oil fill cap

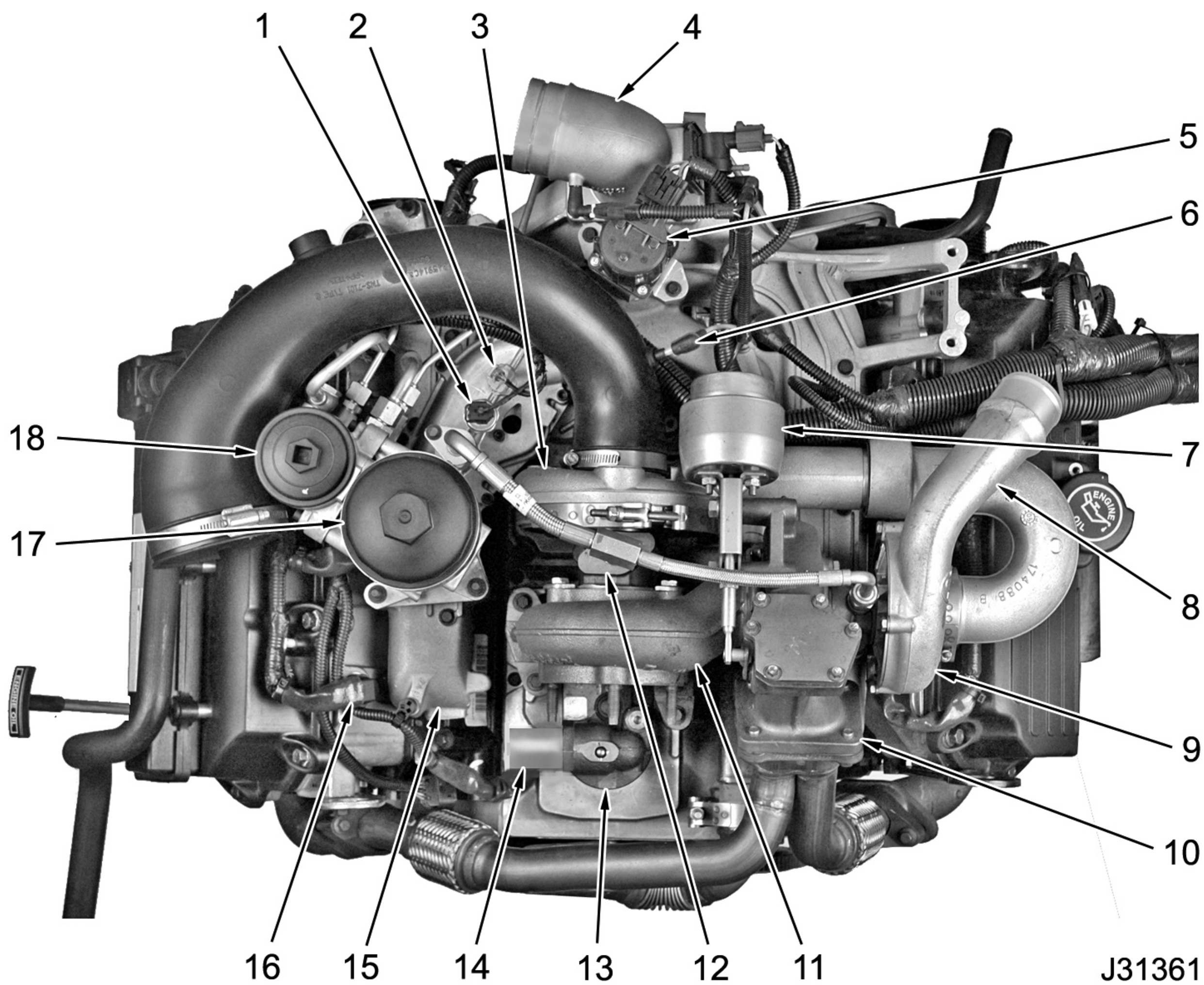

Figure 7 Top

1. Engine Oil Pressure (EOP) switch
2. Engine Oil Temperature (EOT) sensor
3. Turbocharger low-pressure compressor
4. Intake elbow
5. Exhaust Gas Recirculation (EGR) valve
6. BCS tube assembly
7. Turbocharger pneumatic actuator
8. Turbocharger compressed air to CAC
9. Turbocharger high-pressure compressor
10. Turbocharger high-pressure turbine
11. Turbocharger low-pressure turbine
12. Oil supply to dual turbocharger assembly
13. High-pressure oil pump assembly
14. Injection Pressure Regulator (IPR) valve
15. Intake manifold (left side)
16. Injector connection (6)
17. Oil filter
18. Secondary fuel filter

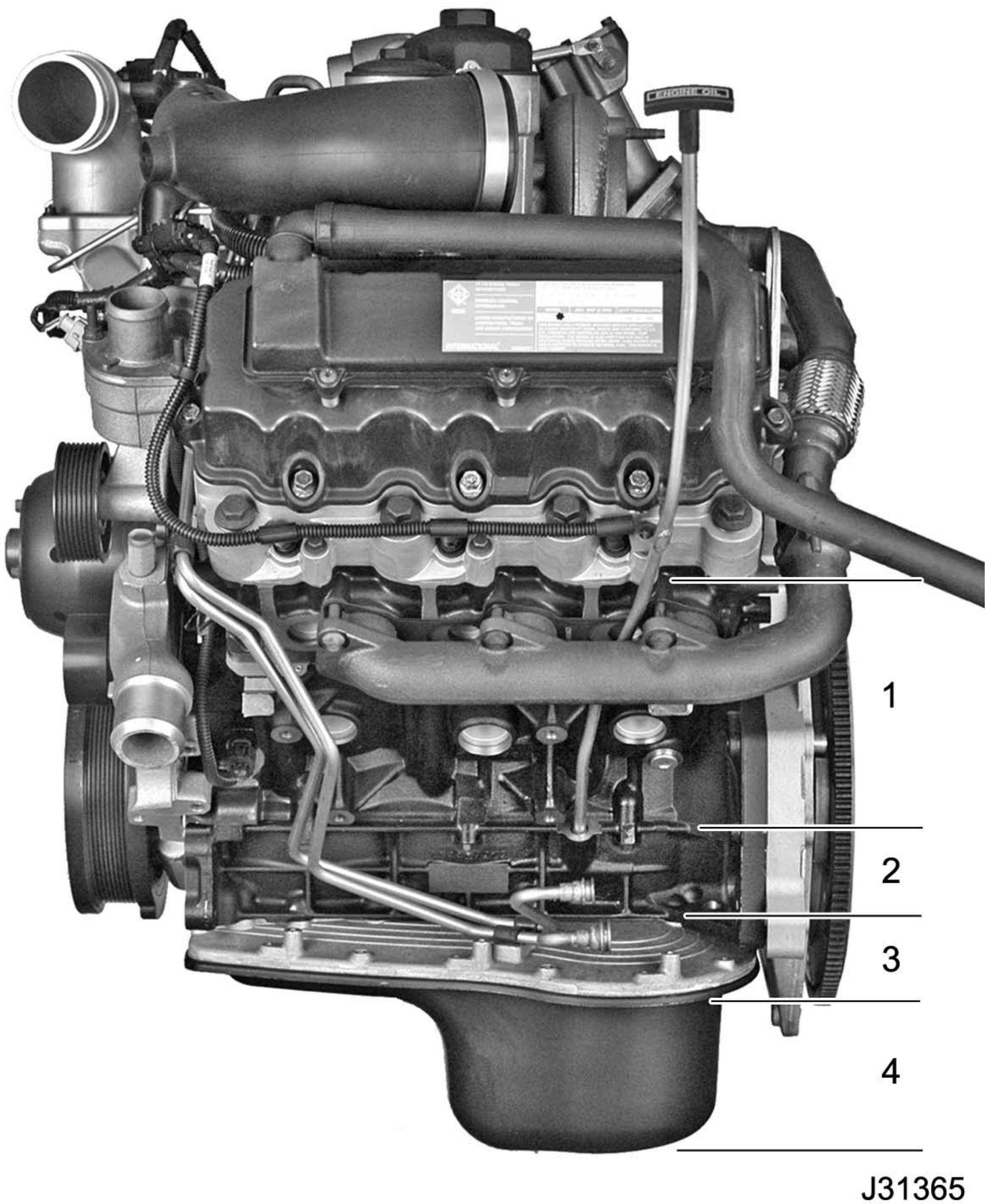

Figure 8 Crankcase assembly and oil pan assembly

1. Upper crankcase
2. Lower crankcase
3. Upper oil pan
4. Lower oil pan

Engine Systems Interaction Diagram

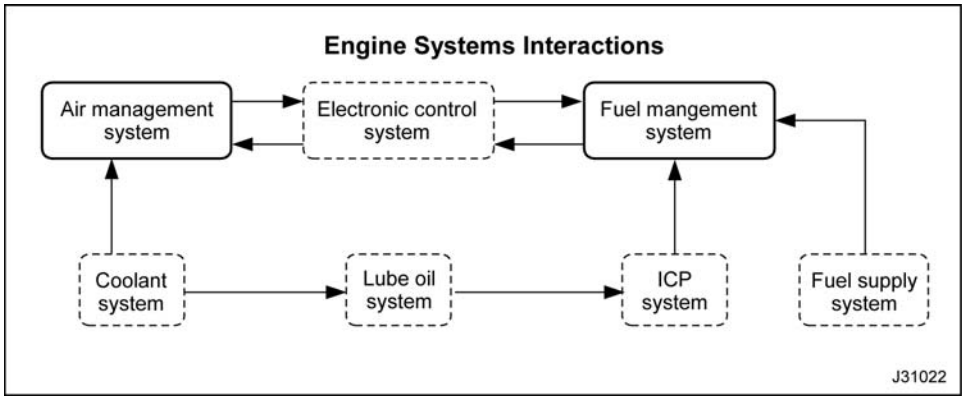

Figure 9 Engine systems interactions

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 Injection Control Pressure (ICP) system uses engine oil to actuate the fuel injectors.

The fuel supply system pressurizes fuel to the fuel injectors.

Air Management System

Air Management Components and Air Flow

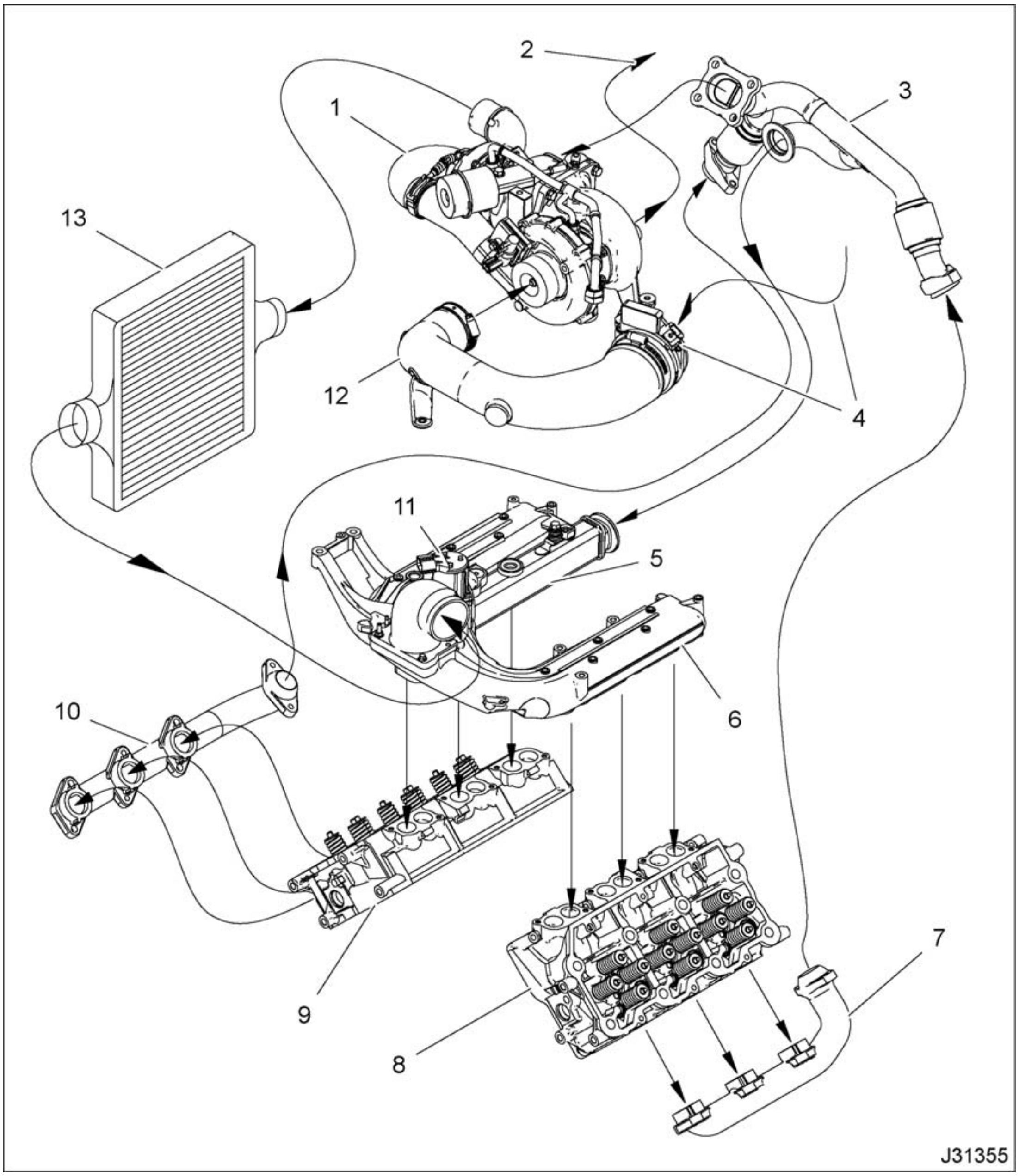

Figure 10 Air induction/exhaust system diagram

1. Dual turbocharger assembly
2. Exhaust outlet (to atmosphere)
3. Exhaust tubing
4. MAF/IAT sensor, air inlet (from air filter assembly)
5. EGR cooler
6. Intake manifold
7. Exhaust manifold (left)
8. Cylinder head (left)
9. Cylinder head (right)
10. Exhaust manifold (right)
11. EGR valve assembly
12. Air inlet duct
13. Charge Air Cooler

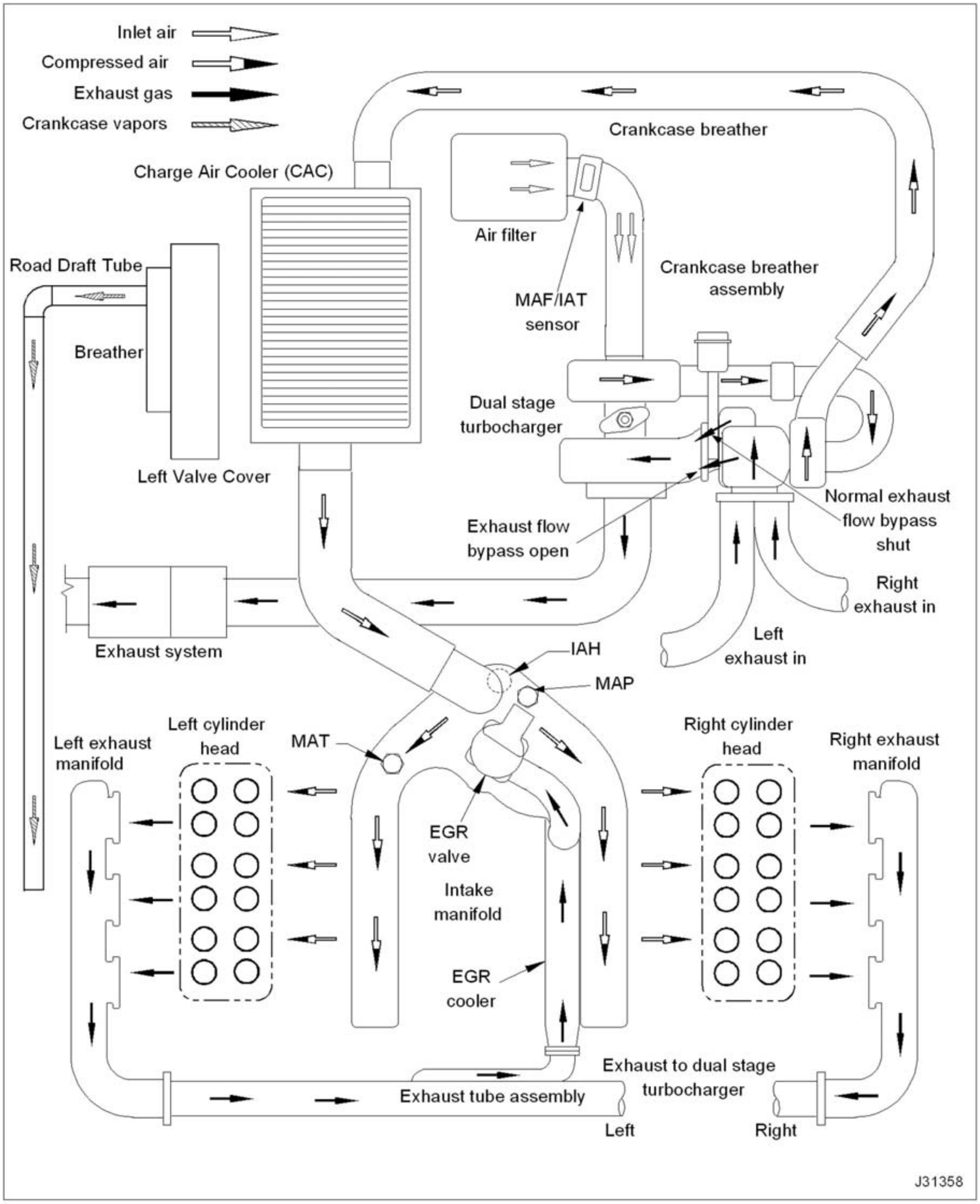

Figure 11 Air Management System (AMS)

The Air Management System (AMS) includes the following:
Air filter assembly
Dual stage turbocharger with pneumatic actuator
Charge Air Cooler (CAC)
MAF/IAT sensor
MAP sensor
Intake manifold
Intake valves
Exhaust Gas Recirculation (EGR) system
Exhaust valves
Exhaust manifolds
Exhaust tube assembly
Catalytic converter - if equipped
Catalyzed Diesel Particulate Filter (CDPF) - if equipped

Air Flow

The following series of statements trace the path of air as it flows through the engine.

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

   During cold weather startups, an inlet air heater warms the incoming air. An inlet air heater relay controls the operation of the heating element depending upon ambient temperature, atmospheric pressure and altitude.

B. The air continues to flow through the low-pressure impeller (larger turbo), where it is compressed and discharged to the high-pressure impeller (smaller turbo).

C. The high-pressure impeller compresses discharge air to a considerably higher pressure and temperature before it enters the CAC.

D. As the discharge air (heated) flows through the CAC, ambient air flows across the CAC tubes and fins providing an exchange of heat to the atmosphere. The heat exchange that takes place allows cooled air (denser) to enter the engine with enough pressure to give a correct air to fuel ratio.

E. The cooled air from the CAC continues into the intake manifold, past the intake valves and into the cylinders. After combustion has taken place, hot exhaust gases are forced through the exhaust manifolds and into the exhaust piping.

   - Most of the hot exhaust gas flows into the turbocharger high-pressure turbine (smaller turbo), spinning the high-pressure turbine wheel. Exhaust continues to flow onto the low pressure turbine (larger turbo), spinning the low-pressure turbine wheel before exiting the turbocharger and into the engine exhaust pipe.
   - A portion of the hot exhaust gas is routed through the EGR cooler and into the EGR valve where it is metered into the intake manifold to blend with incoming filtered air. This helps reduce combustion temperatures and Oxides of Nitrogen (NO_x).

F. Exhaust flows through the exhaust piping, muffler and catalytic converter or CDPF (depending on rating), and out the exhaust pipe.

G. A breather and crankcase vent hose assembly draw crankcase vapors from the engine.

Dual Stage Turbocharger

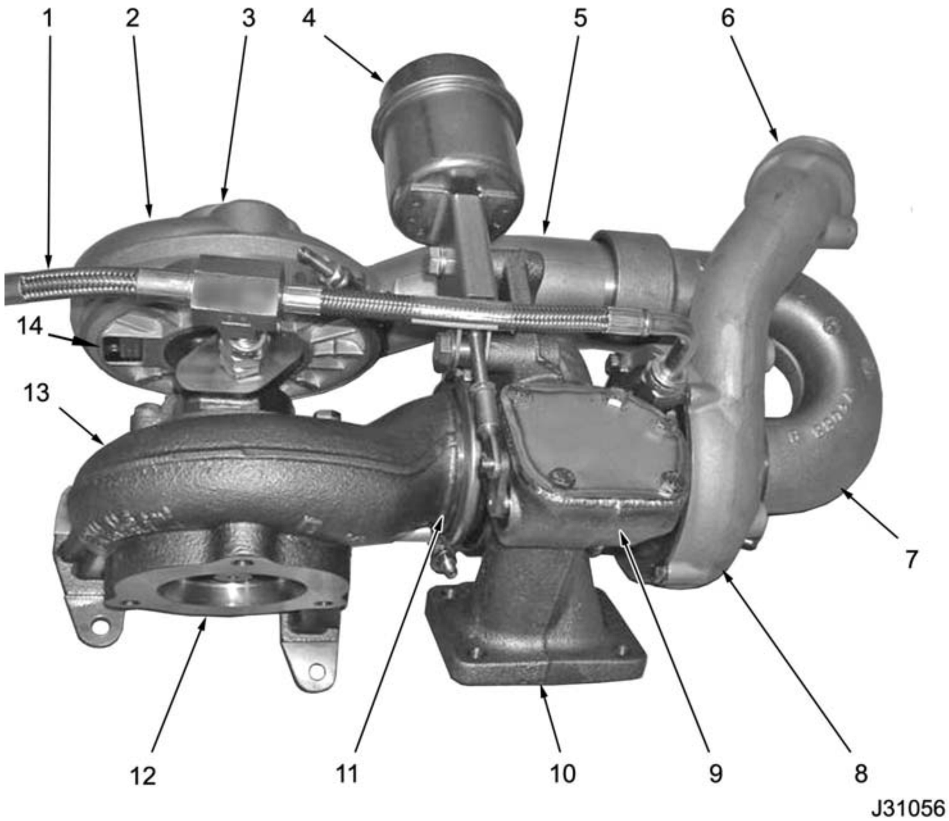

Figure 12 Dual stage turbocharger

1. Oil supply tube
2. Low-pressure compressor
3. Air inlet
4. Pneumatic actuator
5. Low-pressure compressor outlet
6. High-pressure compressor discharge
7. Crossover tube
8. High-pressure compressor
9. High-pressure turbine
10. Exhaust inlet
11. High-pressure turbine outlet/low-pressure turbine inlet
12. Exhaust outlet
13. Low-pressure turbine
14. Equipment serial number tag

The dual stage turbocharger responds directly to engine loads. Different engine loads affect exhaust energy that determines turbocharger speed. Turbocharger speed controls boost pressure for various engine loads. The dual stages of the turbocharger contribute to the lowering of exhaust emissions.

At engine low idle, engine load and boost are low. As engine rpm increase, more fuel and air enter the cylinders. Exhaust temperature and pressure increase; higher exhaust energy increases turbine and compressor speed that raises the pressure and temperature of inlet boost air.

As engine rpm and load decrease, less fuel and air enter the cylinders. Exhaust temperature and pressure decrease; lower exhaust energy decreases turbine and compressor speed that lowers the pressure and temperature of boost air.

Dual Stage Turbocharger Flow

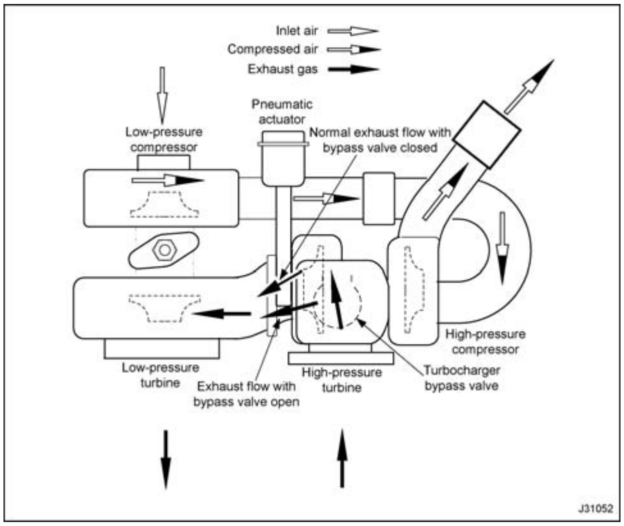

Figure 13 Dual stage turbocharger flow

During light loads, all exhaust flows through the high-pressure turbine and low-pressure turbine.

The filtered air, mixed with crankcase vapors, is drawn to the low-pressure compressor. The air mixture is compressed and discharged to the high-pressure compressor. The high-pressure compressor compresses the discharge air at higher pressure, temperature, and density before it enters the Charge Air Cooler (CAC).

When boost pressure reaches a predetermined value, a pneumatic actuator opens a valve, allowing some exhaust to bypass the high-pressure turbine and flow directly to the low-pressure turbine; maximum boost pressure is limited.

Exhaust Gas Recirculation (EGR) System

The EGR system includes the following:
Exhaust tube assembly
EGR cooler
EGR valve
EGR drive module
Intake manifold

The EGR system reduces Nitrogen Oxide (NO_x) emissions.

NO_x gas forms during a reaction between nitrogen and oxygen at the high temperatures of combustion. By mixing exhaust with the inlet air, NO_x gas formation is reduced.

EGR Flow

Some exhaust from the exhaust tube assembly flows into the EGR cooler. Exhaust from the EGR cooler flows into a passage in the intake manifold that intersects with the EGR valve.

When the EGR is commanded, the EGR valve opens allowing cooled exhaust gases to enter the intake manifold to be mixed with filtered intake air then is recycled through combustion process.

EGR Valve

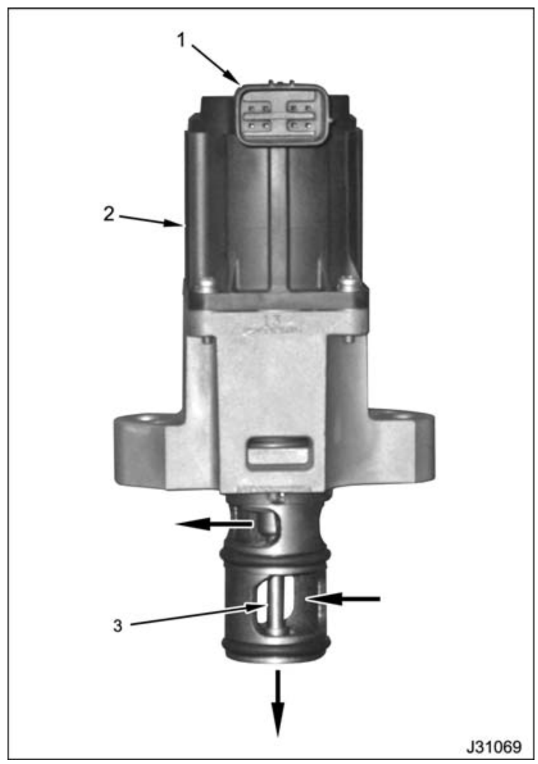

Figure 14 EGR valve

1. Connector
2. DC motor with position sensor
3. Poppet 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.

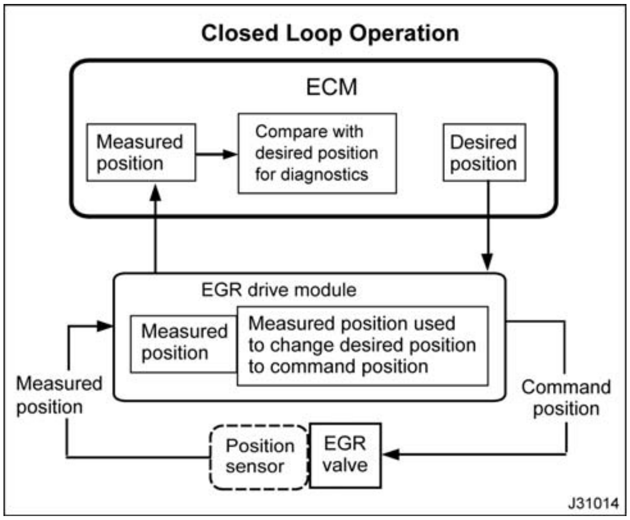

Figure 15 EGR closed loop operation

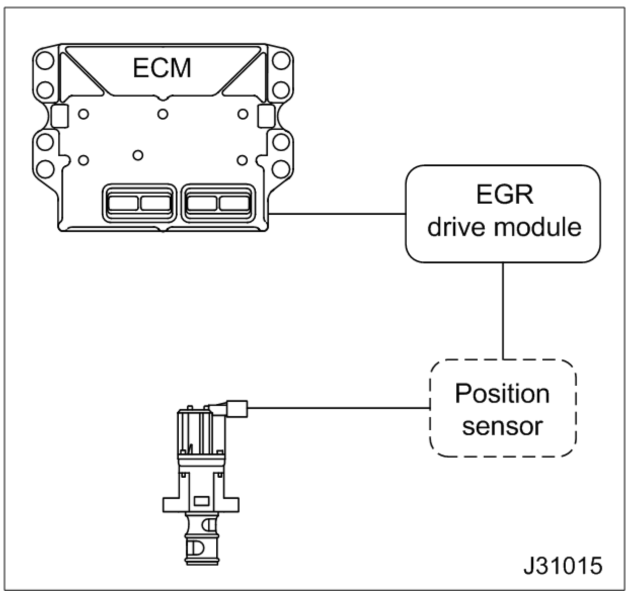

Figure 16 EGR control

The EGR actuator consists of three major components; a valve, an actuator motor, and an Integrated Circuit (IC). The IC has three Hall effect position sensors to monitor valve movement. The EGR valve is located at the front of engine in the intake manifold.

The EGR drive module controls the actuator motor and is chassis mounted in the electrical control area on the right side behind the cab.

The EGR drive module receives the desired EGR position from the ECM across the CAN2 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 actuator motor.

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

Fuel Management System

Fuel Management Components

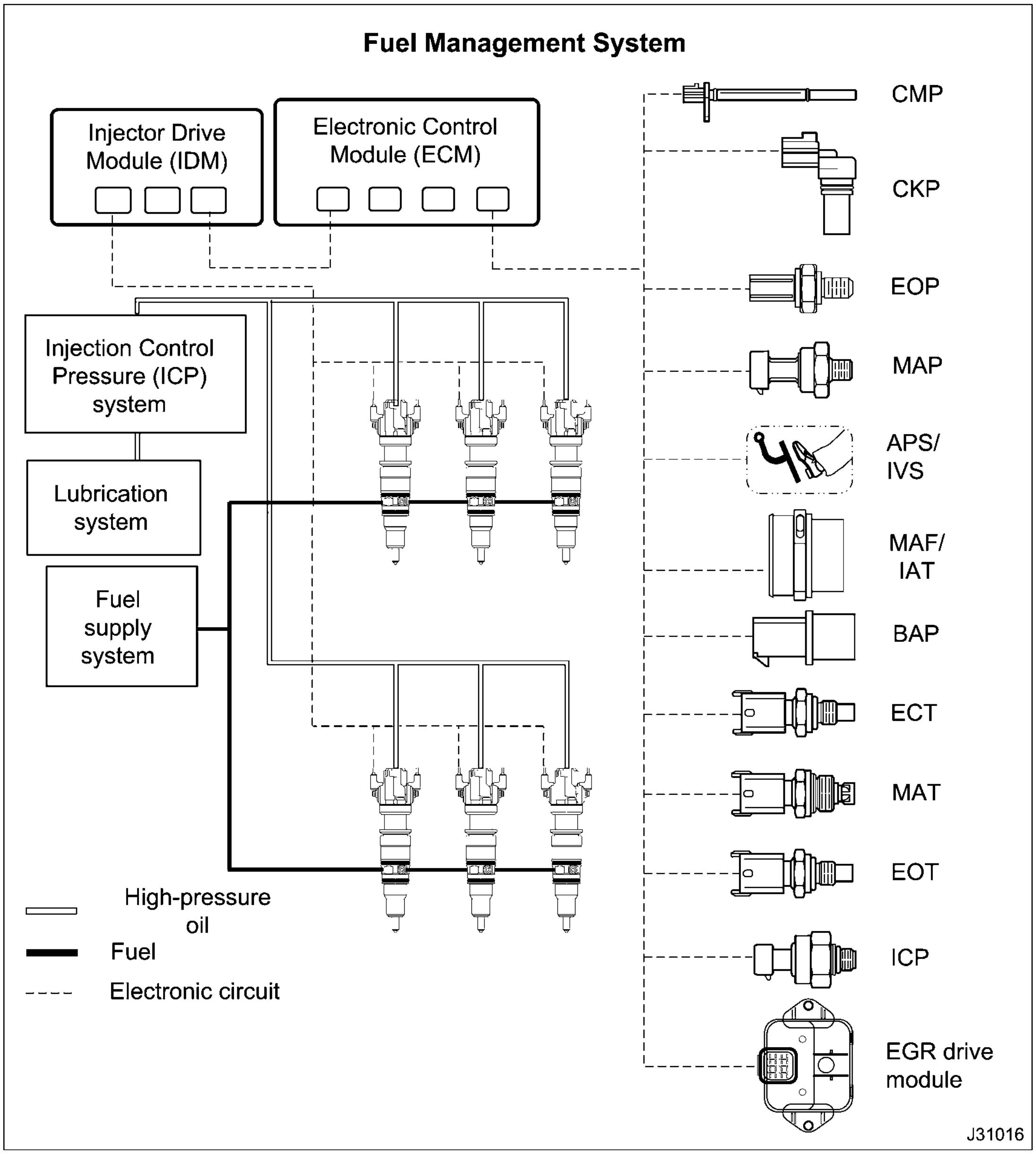

Figure 17 Fuel management system

The fuel management system includes the following:
Injection Control Pressure (ICP) system
Fuel supply system
Fuel injectors
Lubrication system
Electronic control system

High-pressure Oil Flow

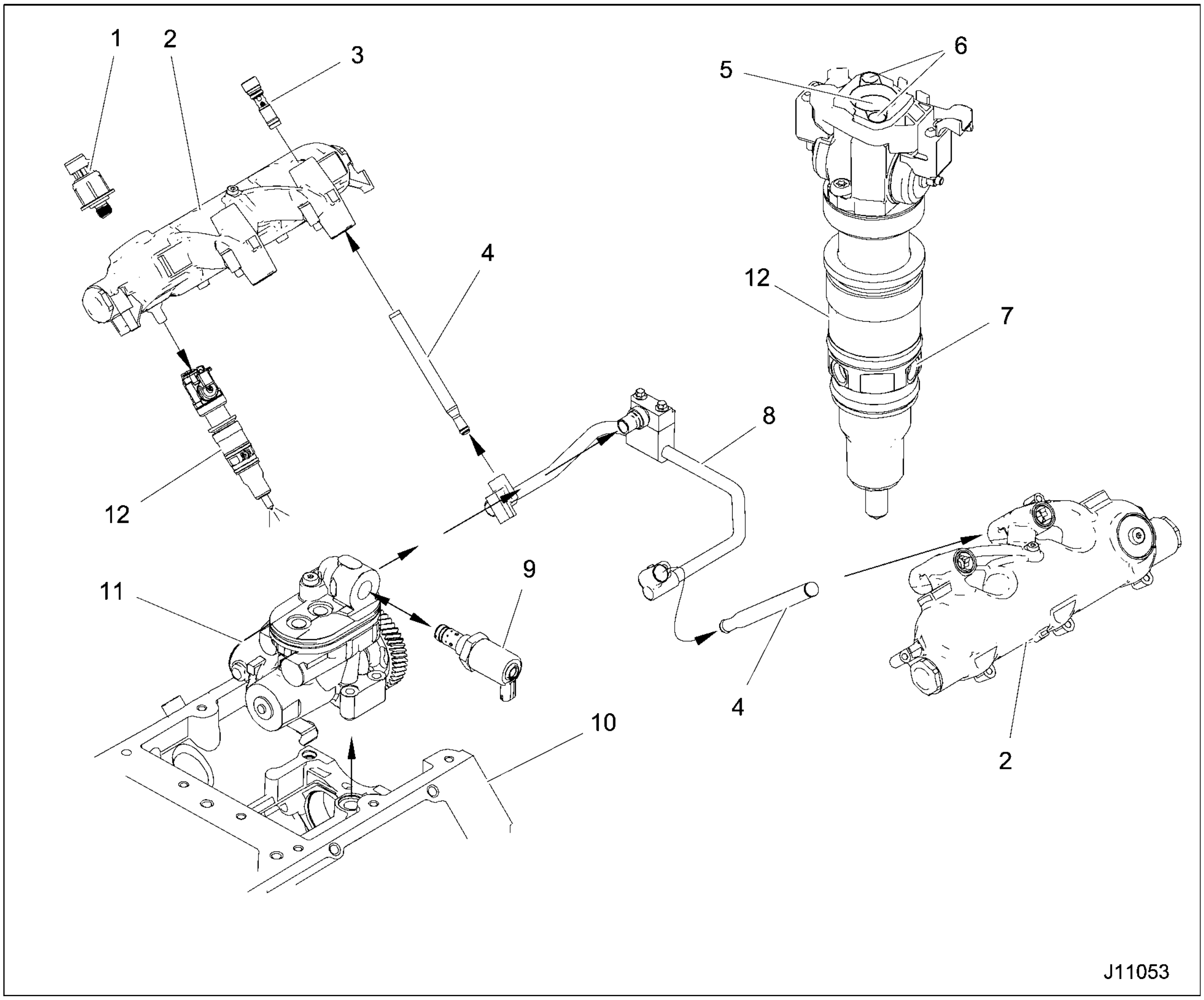

Figure 18 High-pressure oil flow

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

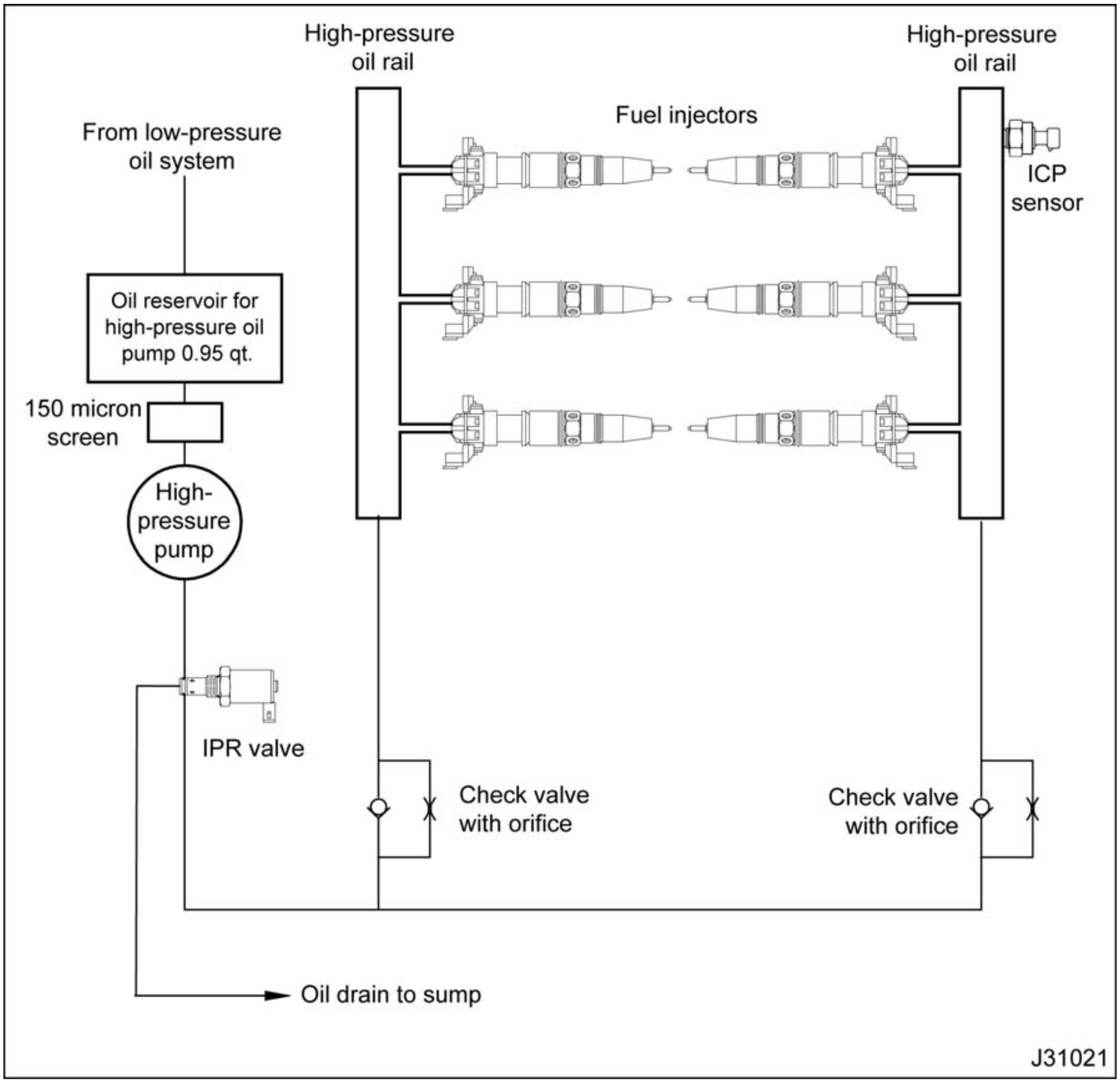

Figure 19 High-pressure oil flow schematic

The high-pressure oil system includes the following:

- High-pressure oil pump
- Injection Pressure Regulator (IPR) valve
- 150 micron screen
- Oil reservoir for the high-pressure oil pump
- Branch tube assembly
- Case-to-head tube assemblies
- High-pressure oil rails
- Fuel injectors
- Injection Control Pressure (ICP) sensor

A gear-driven, high-pressure oil pump draws oil through a screen in the oil reservoir for the high-pressure oil pump. The oil reservoir, in the top of the crankcase below the oil cooler, is kept full by the engine lubrication system.

The IPR valve maintains the ICP pressure by dumping excess oil back to the crankcase.

High-pressure oil from the pump flows through a branch tube assembly to each case-to-head tube assembly to each high-pressure oil rail.

High pressure oil in the oil rails enter the fuel injectors through sealed ports in the top of the fuel injectors.

When the OPEN coil for each injector is energized, the injector uses high-pressure oil to inject and atomize fuel into the combustion chamber. The CLOSE coils are energized to end injection. Exhaust oil exits through two ports in the top of the injector and drains back to the crankcase.

Injection Control Pressure (ICP) System

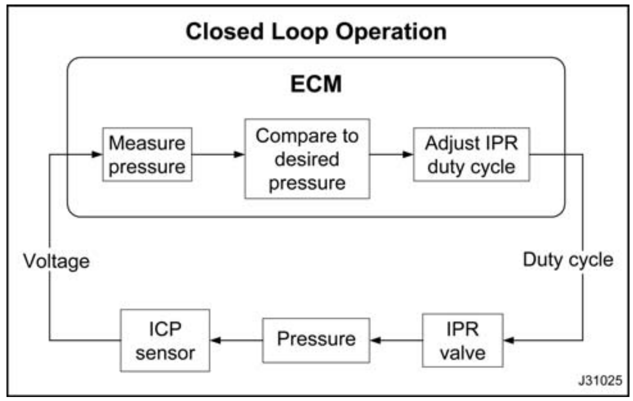

Figure 20 ICP closed loop system

The ICP is a closed loop system that uses the ICP sensor to provide feedback to the Electronic Control Module (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

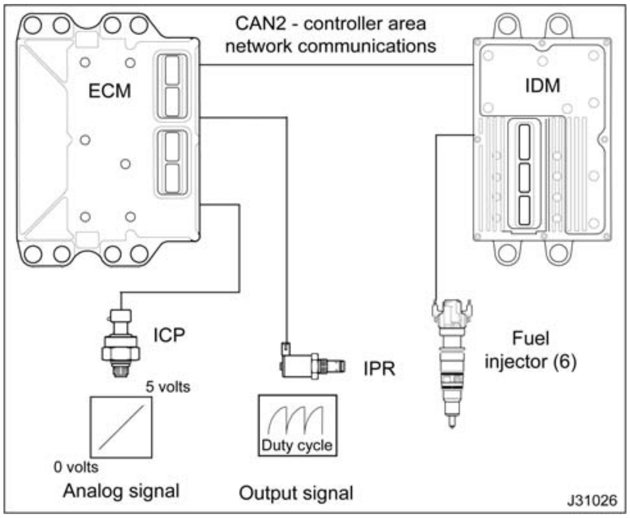

Figure 21 ICP control

ICP System 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 modulated 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 an Open Loop operation.

Fuel Injectors

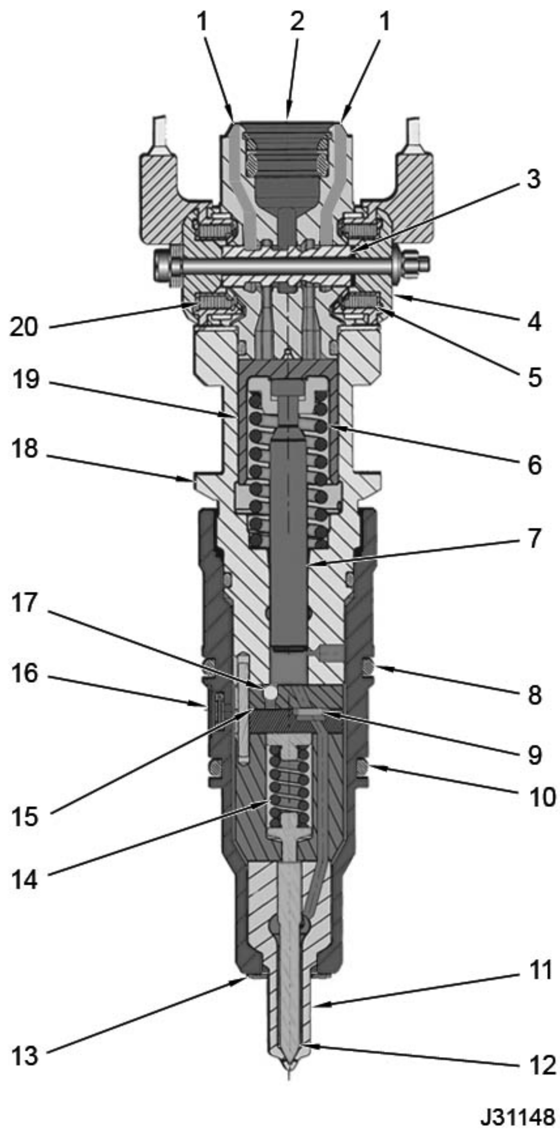

Figure 22 Fuel injector assembly

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

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 passes through its rocker arm carrier.

Injector Coils and Spool Valve

An OPEN coil and a CLOSE coil in 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 20 MPa (2900 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

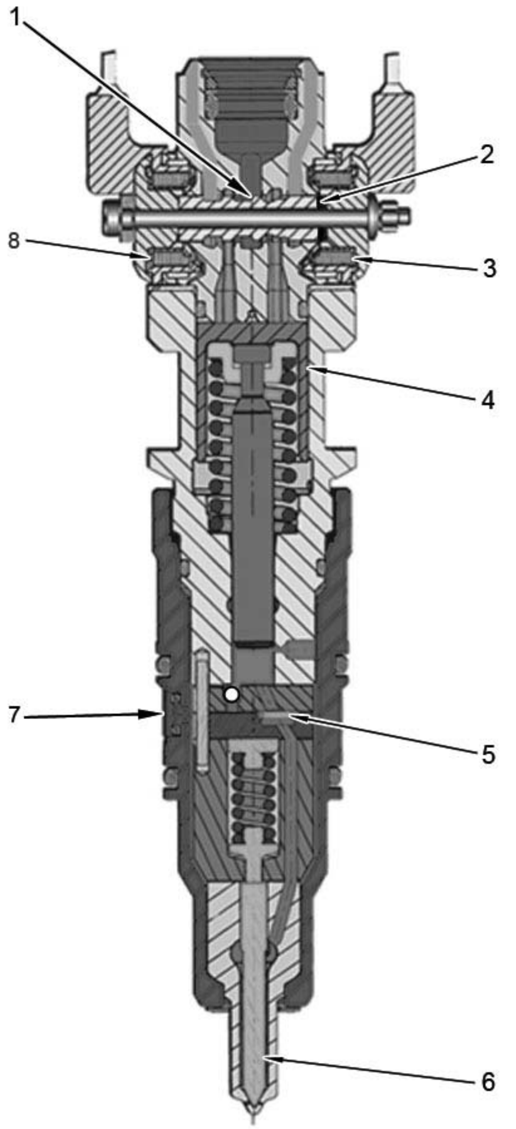

Figure 23 Fill stage

1. High-pressure oil deadheaded at spool valve
2. Spool valve (closed)
3. OPEN coil (off)
4. Intensifier piston (at rest)
5. Disc check (seated)
6. Needle (seated)
7. Low-pressure fuel in through four inlet ports
8. CLOSE coil (off)

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 VOP spring holds the needle on its seat to prevent fuel from entering the combustion chamber.

Main Injection (Step 1)

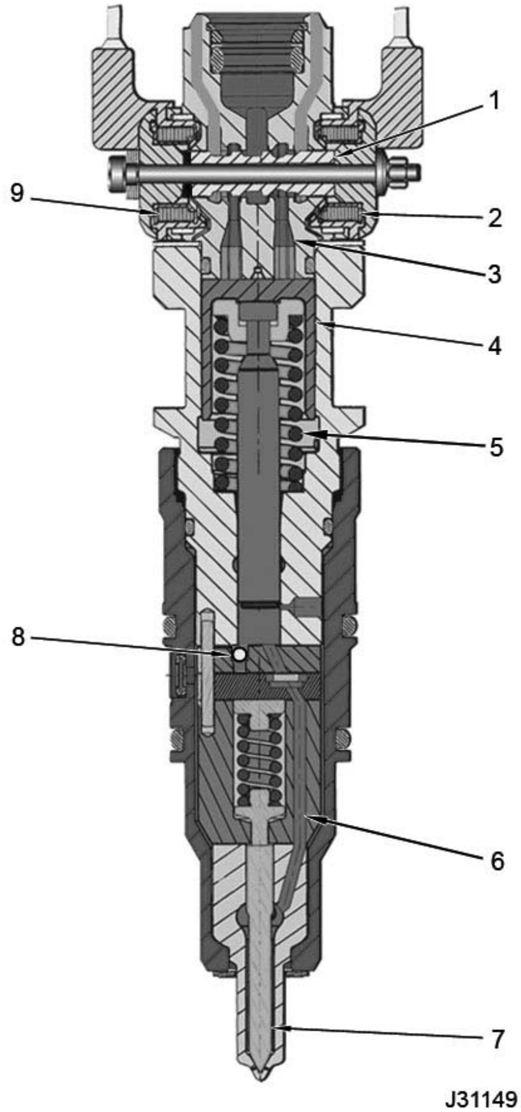

Figure 24 Main injection (step 1)

1. Spool valve (open - moves to coil)
2. OPEN coil (on)
3. High-pressure oil starts to flow
4. Intensifier piston (moving down)
5. Intensifier piston spring begins compressing
6. Fuel pressure builds
7. Needle (seated)
8. Fuel inlet check ball (seated)
9. Close coil (off)

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)

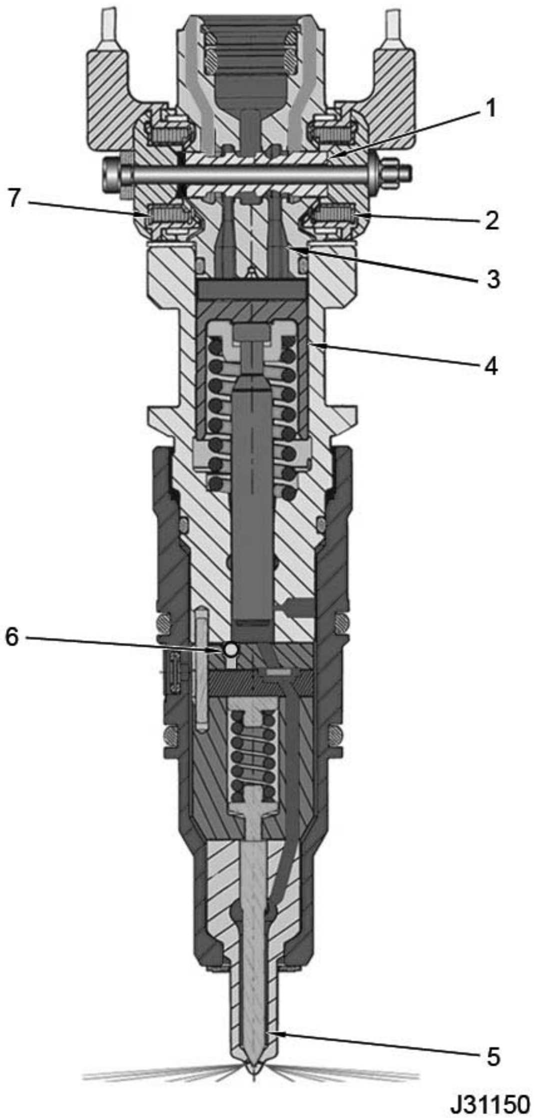

Figure 25 Main injection (step 2)

1. Spool valve (still at open coil)
2. OPEN coil (off)
3. High-pressure oil flows to push intensifier piston down
4. Intensifier piston (moving down)
5. Needle (unseated - VOP)
6. Fuel inlet check ball (seated)
7. CLOSE coil (off)

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 20 MPa (2900 psi), the needle lifts of its seat and injection begins.

End of Main Injection (Step 1)

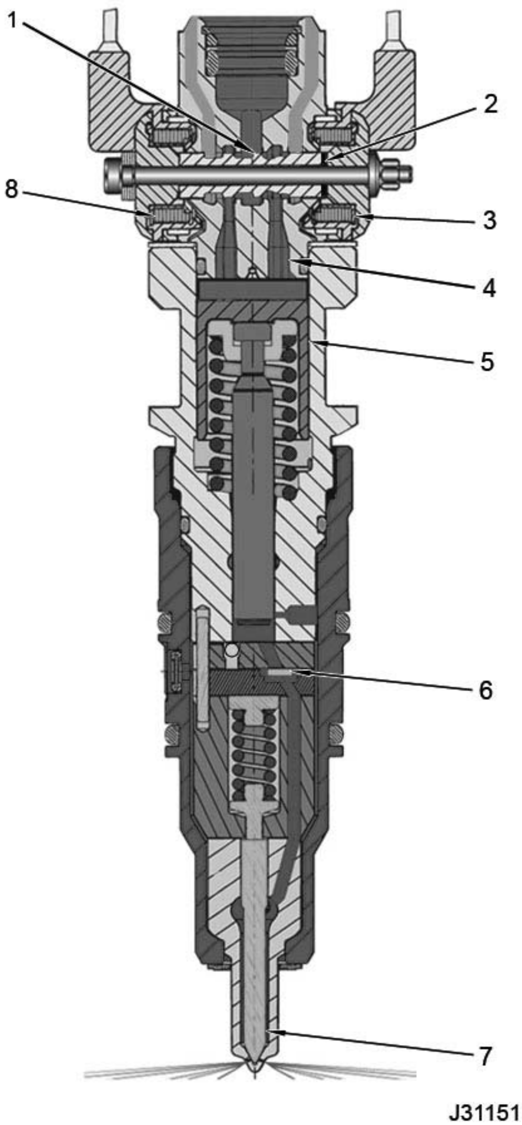

Figure 26 End of main injection (step 1)

1. High-pressure oil deadheaded at spool valve
2. Spool valve (closed - moved to close coil)
3. OPEN coil (off)
4. High-pressure oil flow stops
5. Intensifier piston (moving up)
6. Check disc (seated)
7. Needle (unseated/closing)
8. CLOSE coil (on)

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)

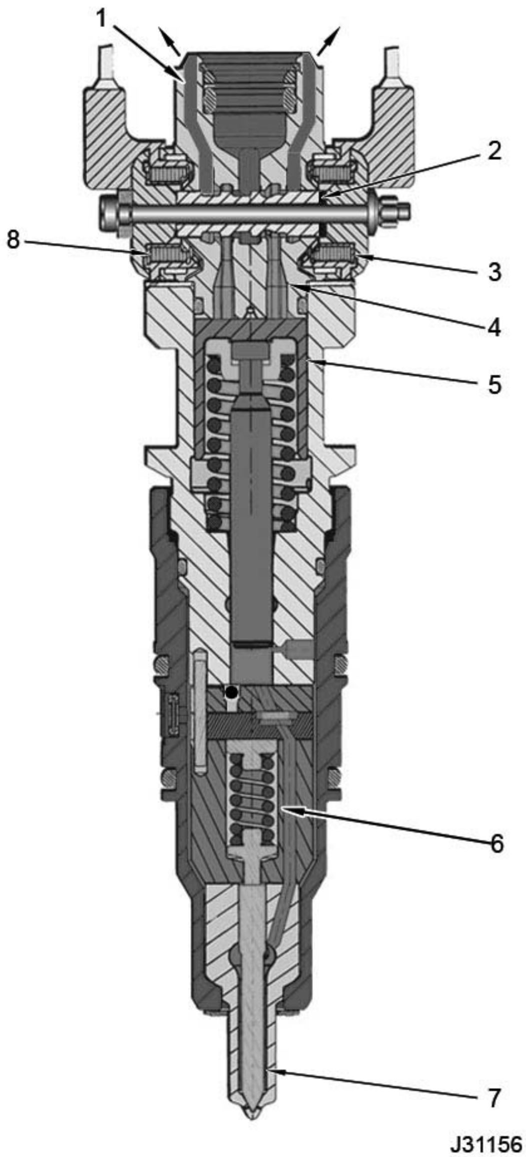

Figure 27 End of main injection (step 2)

1. Exhaust port (oil) (2)
2. Spool valve (closed - still at close coil)
3. OPEN coil (off)
4. High-pressure oil bleeds out exhaust oil port
5. Intensifier piston (at rest)
6. VOP spring (returns needle)
7. Needle (seated)
8. CLOSE coil (off)

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 VOP spring forces the needle back onto its seat.

Fuel Supply System

Fuel Supply System Schematic and Flow

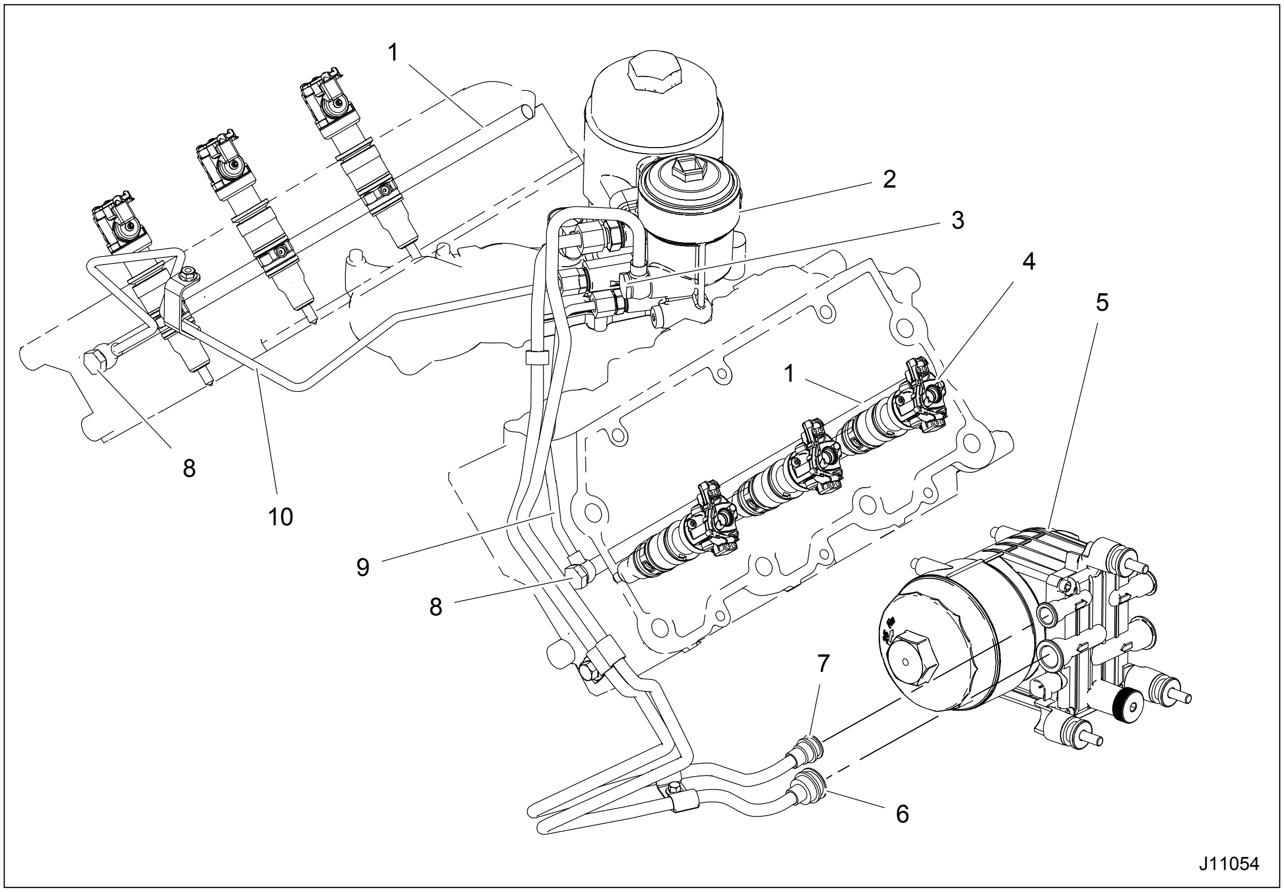

Figure 28 Fuel supply system

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

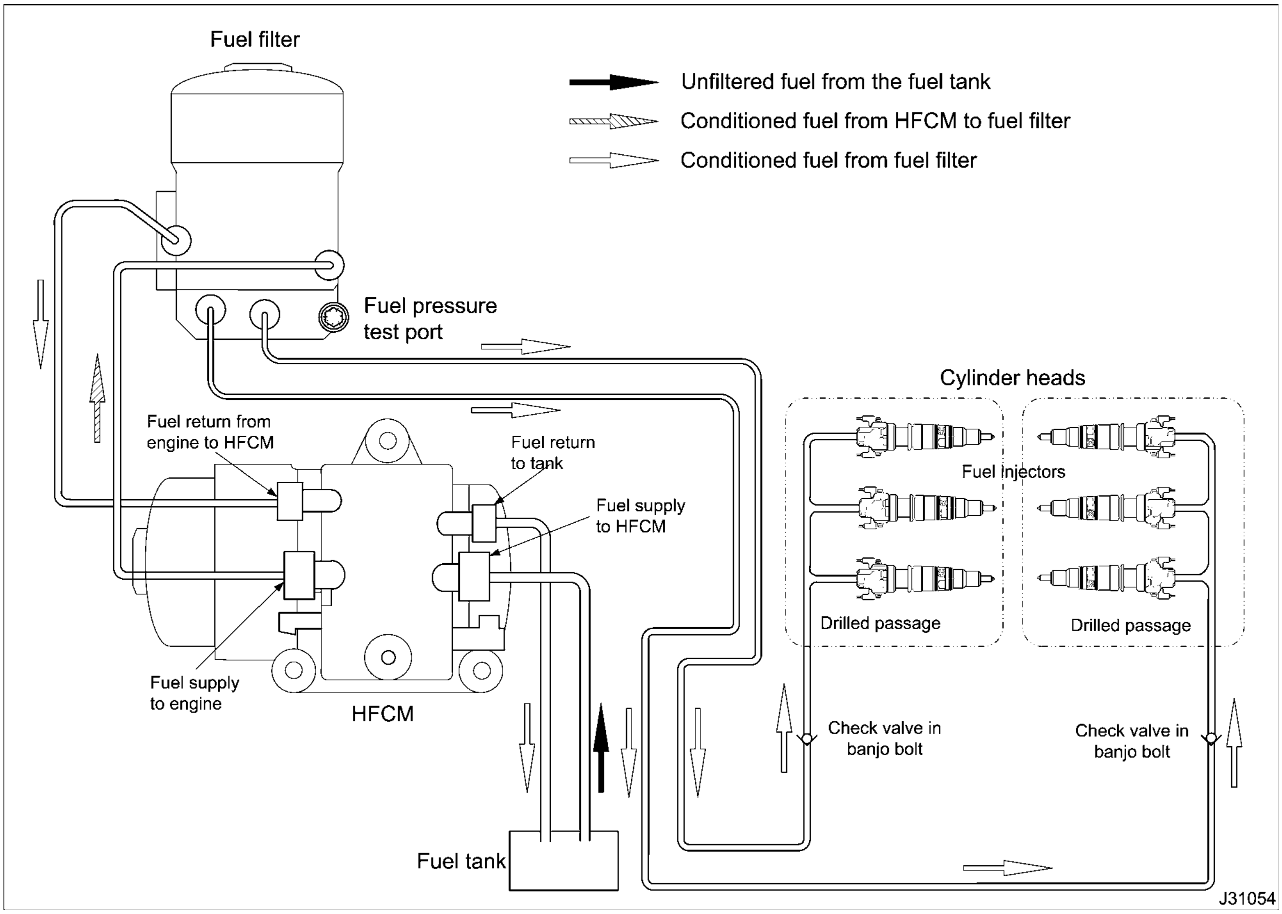

Figure 29 Fuel supply system

The fuel supply system includes the following:
Fuel tank
Fuel lines (tank to HFCM)
Horizontal Fuel Conditioning Module (HFCM)
Secondary fuel filter assembly
Fuel lines (HFCM to secondary fuel filter)
Fuel lines (secondary fuel filter to cylinder heads)
Drilled passages in cylinder heads

Fuel Flow

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

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

Horizontal Fuel Conditioning Module (HFCM)

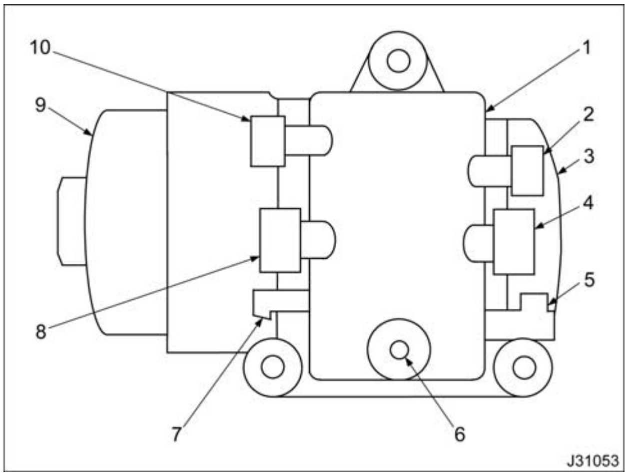

Figure 30 HFCM

1. Cover plate assembly
2. Fuel return to tank
3. Fuel pump access cover
4. Fuel supply to HFCM
5. Water In Fuel (WIF) sensor connector
6. Fuel drain valve
7. Fuel heater connector
8. Fuel supply to engine
9. Fuel filter cover
10. Fuel return from engine to HFCM

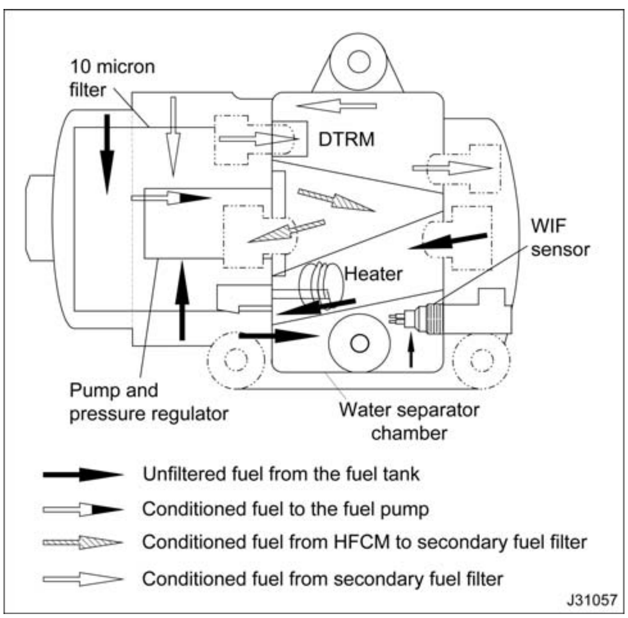

Figure 31 HFCM - fuel flow

The following parts or features in the HFCM condition and regulate fuel pumped to the secondary fuel filter assembly.
Fuel pump and pressure regulator
Fuel heater
Water In Fuel (WIF) sensor
Water separator
Fuel filter
Diesel Thermo Recirculation Module (DTRM)

The fuel pump draws fuel from the fuel tank, past the fuel heater and through a 10 micron filter. A pressure regulator, controls fuel to the suction side of the fuel pump. The fuel heater is activated at 10 °C (50 °F) and shuts off at 27 °C (80 °F).

A 10 micron filter separates particles and a water separator eliminates water from the fuel drawn into the pump. If large amounts of water are separated, a Water In Fuel (WIF) sensor will send a signal to the Electronic Control Module (ECM) to illuminate the amber WATER IN FUEL lamp. Conditioned fuel is pumped to the secondary fuel filter assembly.

A DTRM recirculates fuel returned from the secondary fuel filter assembly back to the unfiltered side of the filter or back to the fuel tank. Depending on returning fuel temperature the DTRM diverts return fuel flow to the fuel tanks or back through the HFCM and back to the secondary fuel filter. Above 27 °C (80 °F) all fuel goes back to the fuel tank. Below 10 °C (50 °F) all fuel goes through the HFCM and back to the secondary fuel filter. Between 10 °C (50 °F) and 27 °C (80 °F) fuel will flow both directions through the HFCM to the secondary filter and back to the fuel tank.

Secondary Fuel Filter Assembly

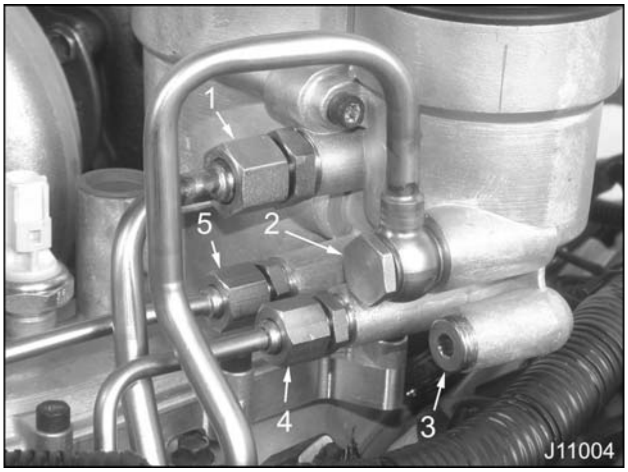

Figure 32 Fuel lines

1. Fuel return to fuel pump
2. Fuel supply from fuel pump
3. Fuel pressure test port plug
4. Conditioned fuel to left cylinder head
5. Conditioned fuel to right cylinder head

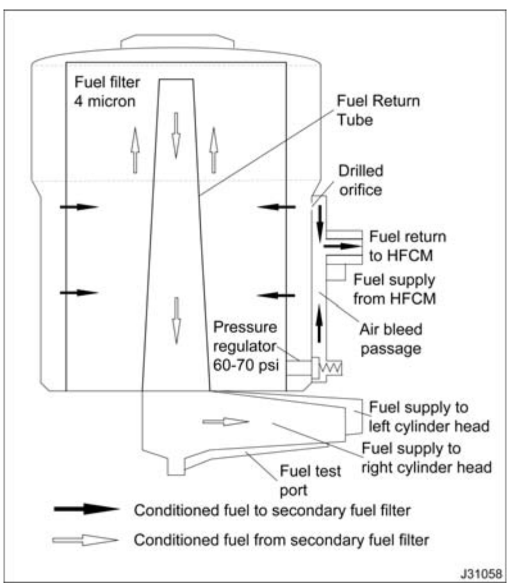

Figure 33 Secondary fuel filter assembly - fuel flow

A four micron filter element in the fuel filter separates particles in the fuel.

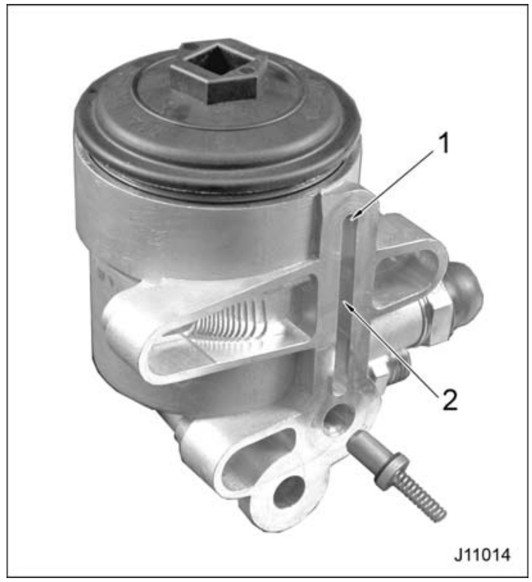

Figure 34 Fuel pressure regulator

1. Orifice
2. Return fuel passage

The fuel pressure regulator is a spring loaded poppet valve. It is used to regulate and relieve excessive fuel pressure. Fuel that passes through the pressure regulator returns to the HFCM. Conditioned fuel flows through a fuel return tube to the two fuel supply ports to the cylinder heads and the fuel test port.

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

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

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

Engine Lubrication System

Lubrication System Components and Oil Flow

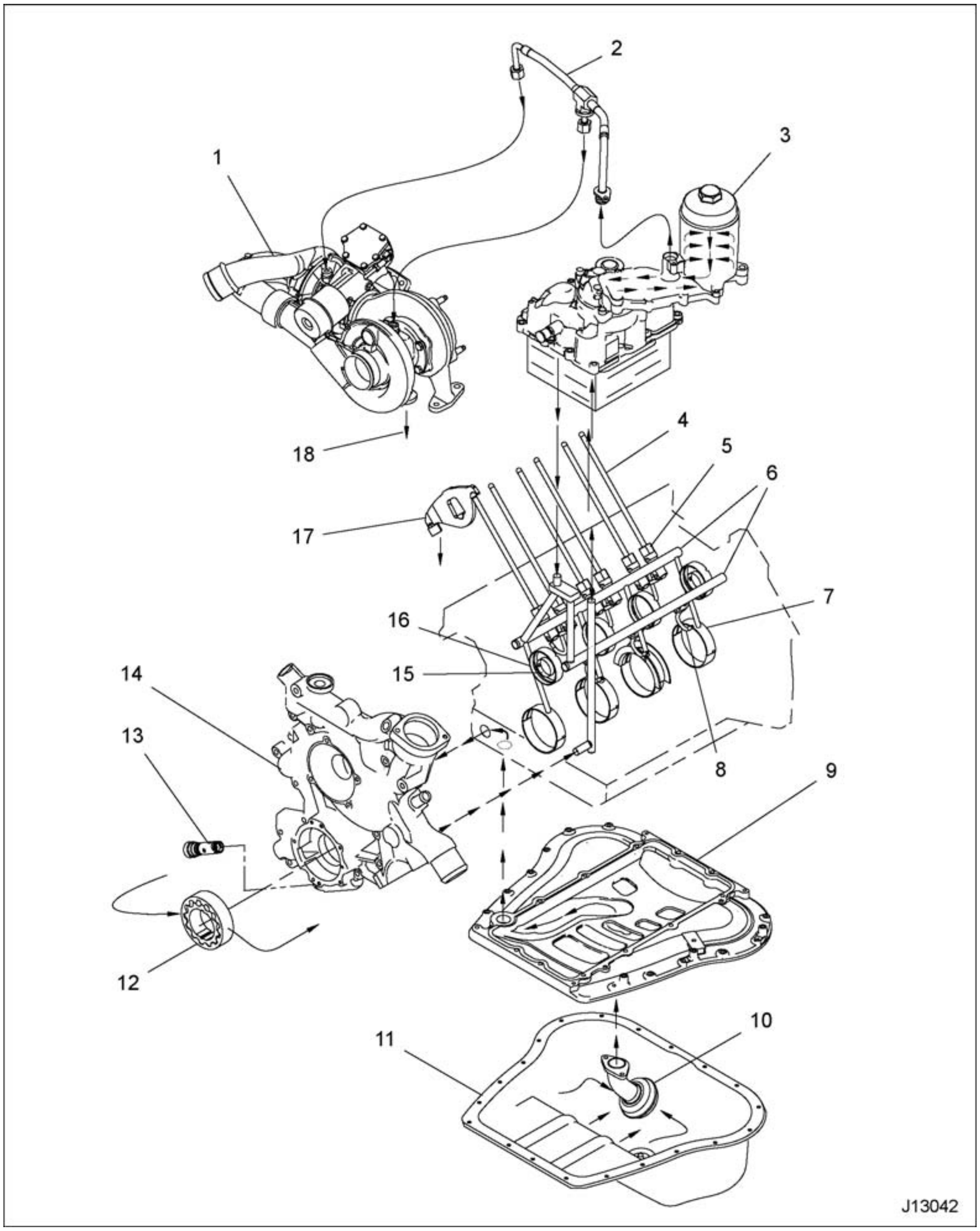

Figure 35 Lubrication system

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

Oil Flow Diagram

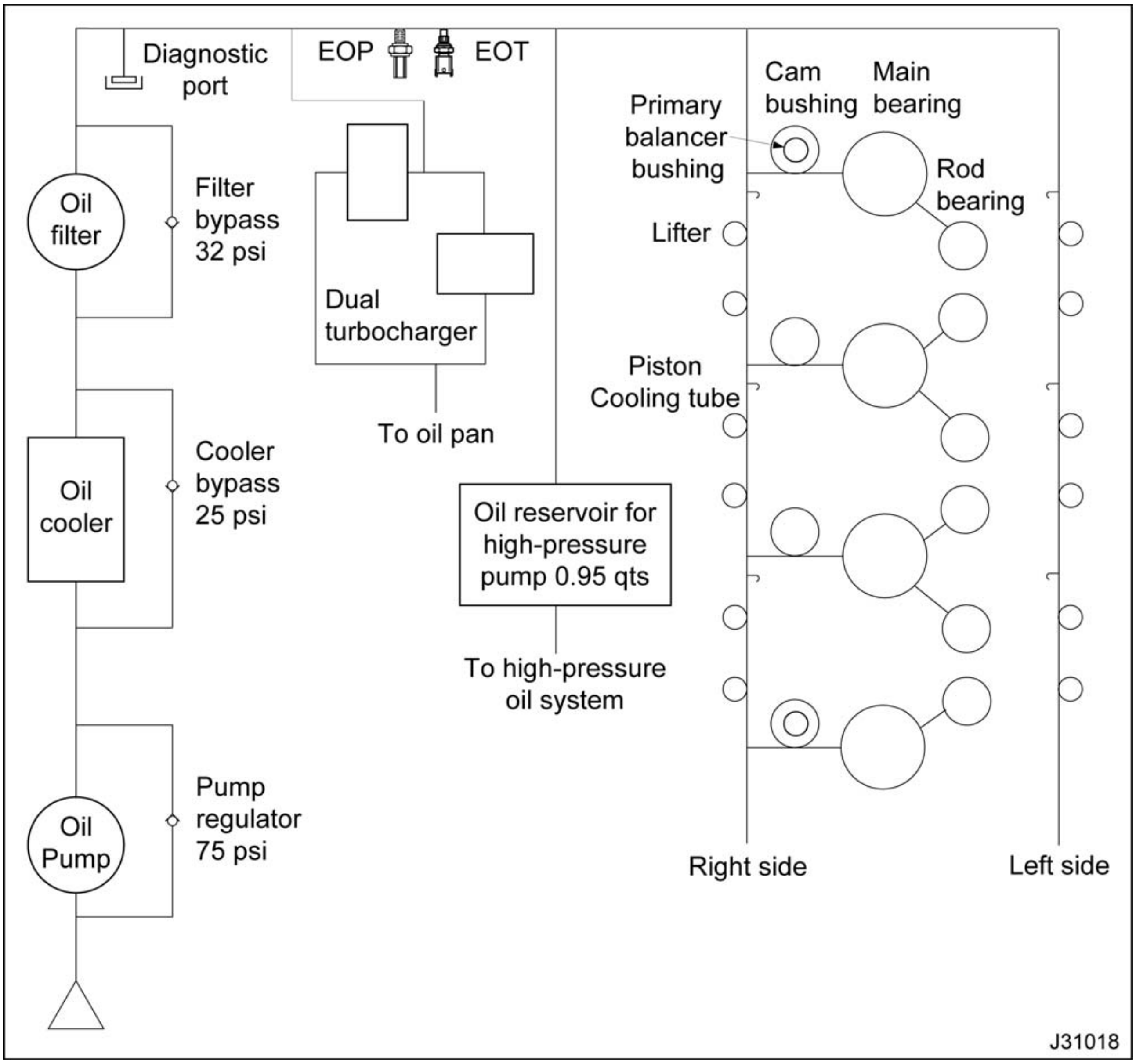

Figure 36 Lubrication system schematic

The lubrication system includes the following:

Oil pan assembly

Gerotor oil pump

Front cover

Oil pressure regulator valve

Crankcase assembly

Oil cooler cover assembly

Oil filter base assembly

Engine Oil Pressure (EOP) switch

Engine Oil Temperature (EOT) sensor

Piston cooling tubes

Lifters

Push rods

The lubrication system is pressure regulated, full flow cooled, and full flow filtered.

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

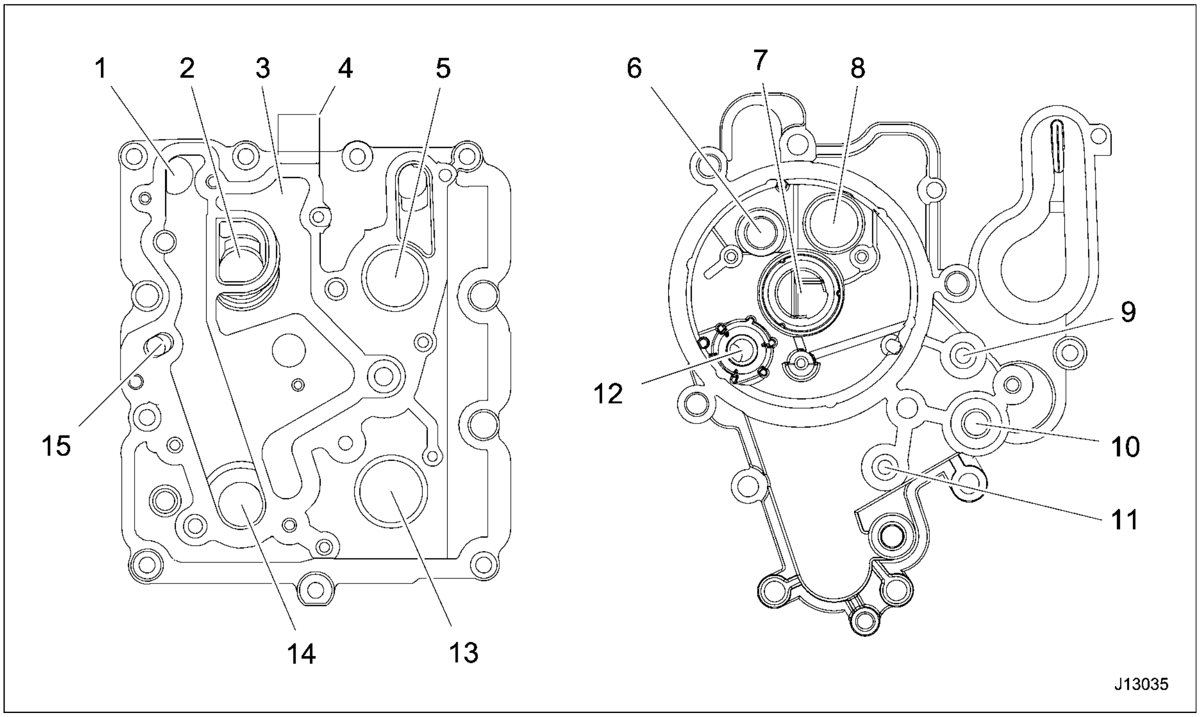

Figure 37 Oil cooler cover and oil filter base location details

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

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

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

Oil flows through the oil filter base to the oil filter element outside to inside, up the outside of the filter stand pipe and down the inside of the stand pipe, and back to the oil filter base.

- If the oil filter element is restricted, a bypass valve in the oil filter return line opens, oil bypasses the oil filter element, and flows to the oil filter base.
- Both bypass valves ensure full flow of oil to the engine, if the filter or cooler is restricted.

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

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

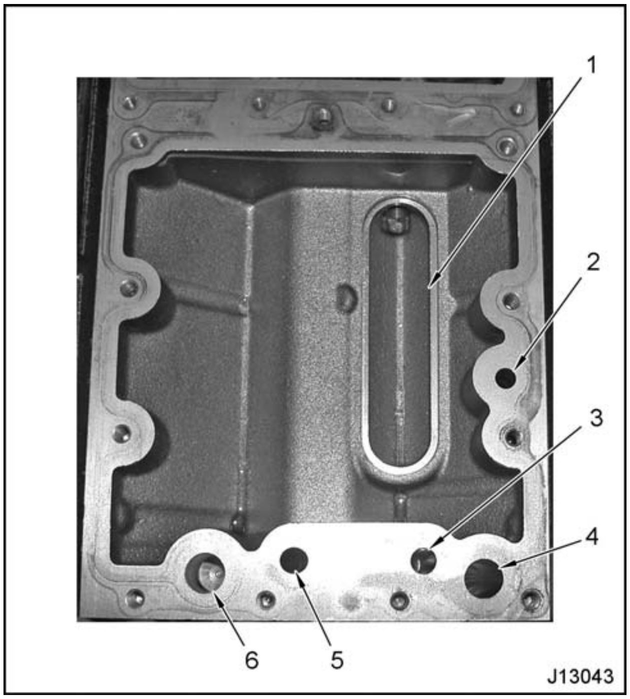

Figure 38 Oil reservoir in crankcase

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

Oil cooler cover and the oil cooler base direct filtered oil in three ways:

One passage supplies oil to the reservoir in the crankcase for the high-pressure oil pump and ICP system. A screen in the oil reservoir catches debris before oil goes to the high-pressure oil pump.

Two other passages supply filtered oil for the following:

Left Side	**Right Side**
Main lube oil gallery	Main lube oil gallery
Push rod and rocker arms	Push rod and rocker arms
Piston cooling tubes	Piston cooling tubes
Lifters	Camshaft bushings
	Crankshaft main bearings
	Connecting rod bearings
	Primary balancer shaft bushings
	Lifters

Cooling System

Cooling System Components and Flow

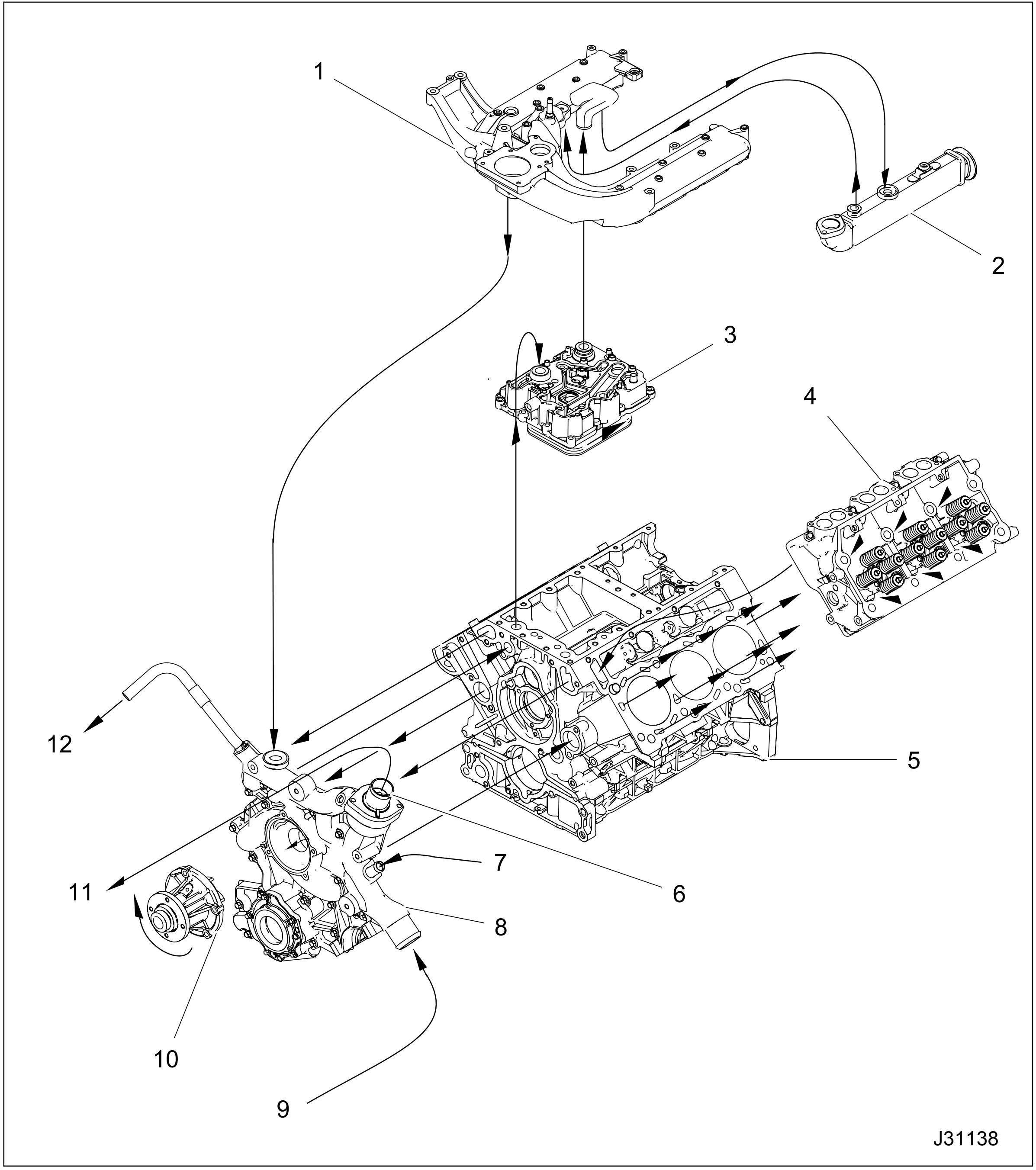

Figure 39 Cooling system

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

The cooling system keeps the engine within a designated temperature range.

The centrifugal water pump (hub and impeller) is mounted in the pump housing of the front cover. The water pump has a built in reservoir to catch small amounts of coolant that may seep past the seal.

Front Cover Housing Flow

The water pump draws coolant from the radiator through inlet of the front cover housing. Coolant flows from the water pump through three passages in the front cover.

- Two passages (left and right) direct coolant into the crankcase (front to rear) to cool the cylinder walls and the cylinder heads.
- The third passage directs coolant through a passage in the crankcase to the oil cooler cover.

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

Coolant returns through two front cover passages.

- A single return passage in top of the front cover.
  - Two opening (left and right) from the crankcase to this return passage.
  - A third opening directs coolant from the intake manifold to this return passage.
  - This return passage supplies coolant to the cab heater.
- A second passage directs coolant from the cab heater to the front cover

Return coolant is directed to the thermostat in the front cover.

- If the thermostat is open, coolant flows to the radiator and is blocked to the pump.
- If the thermostat is closed, coolant returns to the water pump and the radiator outlet is blocked.

As the engine reaches operating temperatures, the thermostat slowly opens and directs coolant to the radiator and blocks passage to the water pump. There is a small stop check valve through the thermostat disc that allows warming and equalizing flow across the thermostat.

Crankcase and Cylinder Head Flow

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

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

An optional coolant heater is installed in the crankcase for use in extremely cold weather. The coolant heater can be connected by a dealer.

Oil Cooler and EGR Cooler Flow

The front cover directs coolant to a passage in the crankcase. Coolant flows from the crankcase to the front of the oil cooler cover. The oil cooler and the oil filter base direct coolant to the front of the oil cooler.

Coolant flows through the oil cooler from the front to rear and exits through the EGR cooler supply port.

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

- The deaeration port is on top of the intake manifold.

Thermostat Operation

The thermostat has two outlets. One directs coolant to the radiator when the engine is at operating temperature. The other directs coolant to the water pump until the engine reaches operating temperature. The thermostat begins to open at 88 °C (190 °F) and is fully open at 96 °C (205 °F).

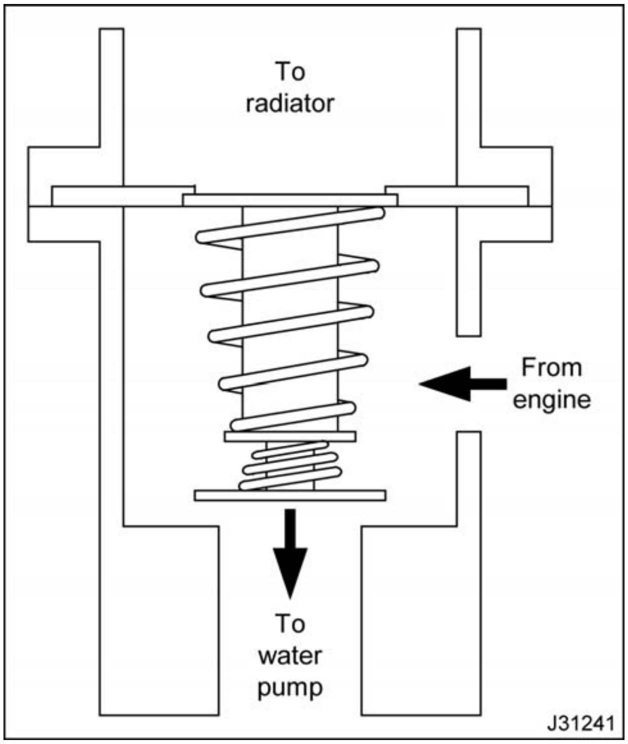

Figure 40 Coolant flow - thermostat closed

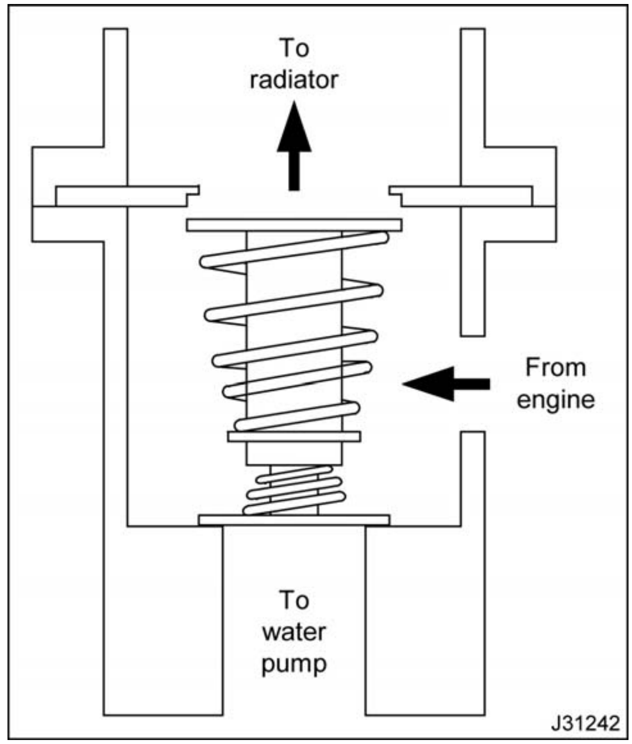

Figure 41 Coolant flow - thermostat open

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

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

Electronic Control System

Electronic Control System Components

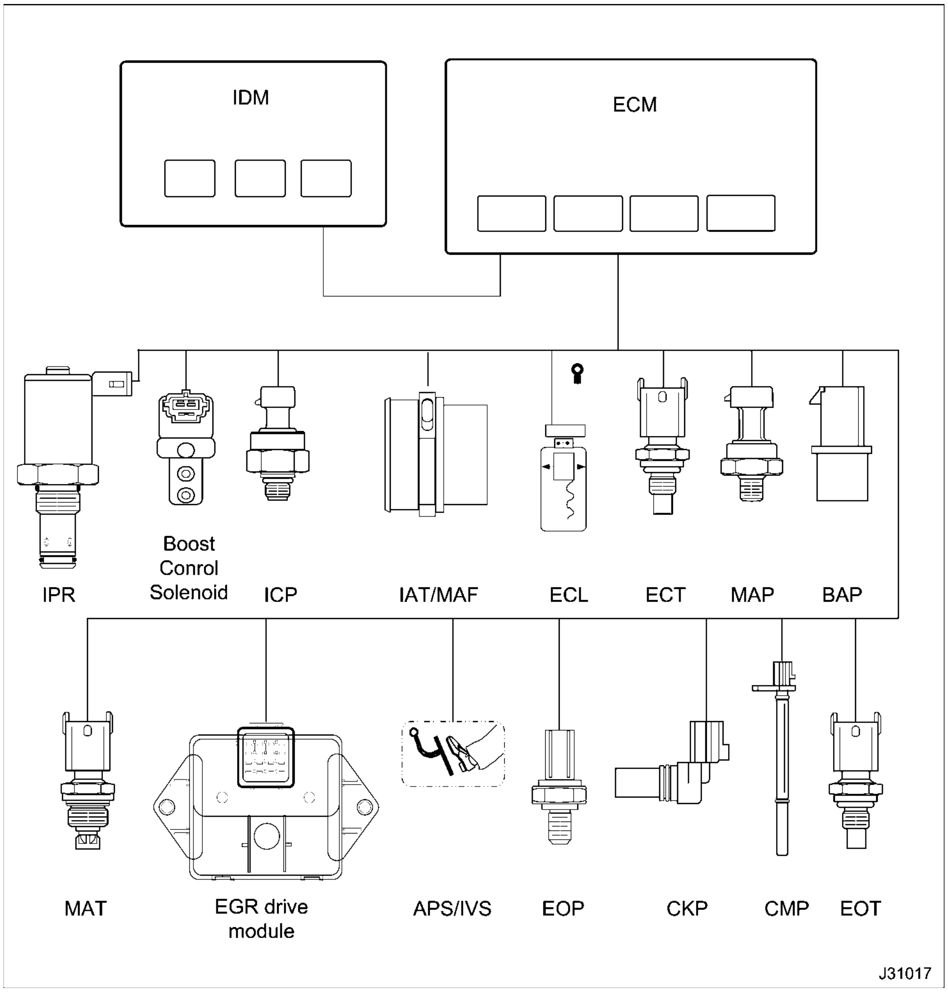

Figure 42 Electronic Control System

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

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

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.

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 set 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 for 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 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

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

Actuators

The ECM controls engine operation with the following:
EGR valve and drive module
Injection Pressure Regulator (IPR) valve
Intake air heater relay
Glow plug relay
Boost Control Solenoid (BCS)
HFCM control

Exhaust Gas Recirculation (EGR) Valve and Drive Module

The EGR valve controls the flow of exhaust gases to the intake manifold.

The EGR drive module controls the EGR actuator.

The EGR drive module receives the desired EGR valve position from the ECM across the CAN2 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 valve position. When an EGR control error is detected, the EGR drive module sends a message to the ECM and a DTC is set.

Injection Pressure Regulator (IPR) Valve

The IPR valve controls pressure in the Injection Control Pressure (ICP) system to actuate the fuel injectors. The IPR valve is a variable position valve controlled by switching the ground circuit in the ECM.

Intake Air Heater Relay

The ECM activates the intake air heater relay. The relay delivers V_{bat} to the intake air heater for up to 30 seconds, depending on engine oil temperature and altitude. The ground circuit is supplied directly from the battery ground at all times. Relay is controlled by switching on a voltage source from the ECM.

Glow Plug Relay

The ECM activates the glow plug relay. The relay delivers V_{bat} to the glow plugs for up to 120 seconds, depending on engine coolant temperature and altitude. The ground circuit is supplied directly from the battery ground at all times. Relay is controlled by switching on a voltage source from the ECM.

Boost Control Solenoid (BCS) Assembly

The BCS controls boost pressure to the turbocharger pneumatic actuator. The BCS is a variable position valve controlled by switching the power circuit from the ECM. The pneumatic actuator control the turbocharger bypass valve.

Horizontal Fuel Conditioning Module (HFCM)

The ECM sends a signal to the fuel pump relay that controls power to the HFCM fuel pump.

Injection Drive Module (IDM)

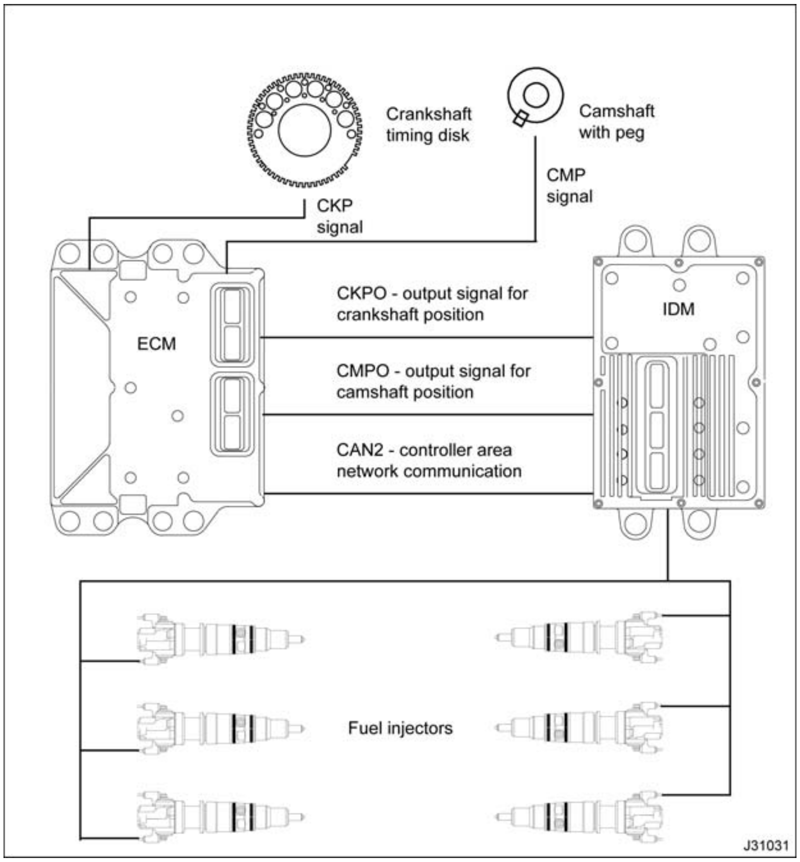

Figure 43 Injection Drive Module (IDM)

Injector Drive Module (IDM) Functions

The three functions of the IDM are:

- 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 CAN2 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 sets a DTC. The IDM also does self-diagnostic checks and will send a fault to the ECM. The ECM will set a DTC to indicate a fault from 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 set a DTC when a problem exists. Other tests require the technician to evaluate parameters, if a problem exists.

Engine and Vehicle Sensors

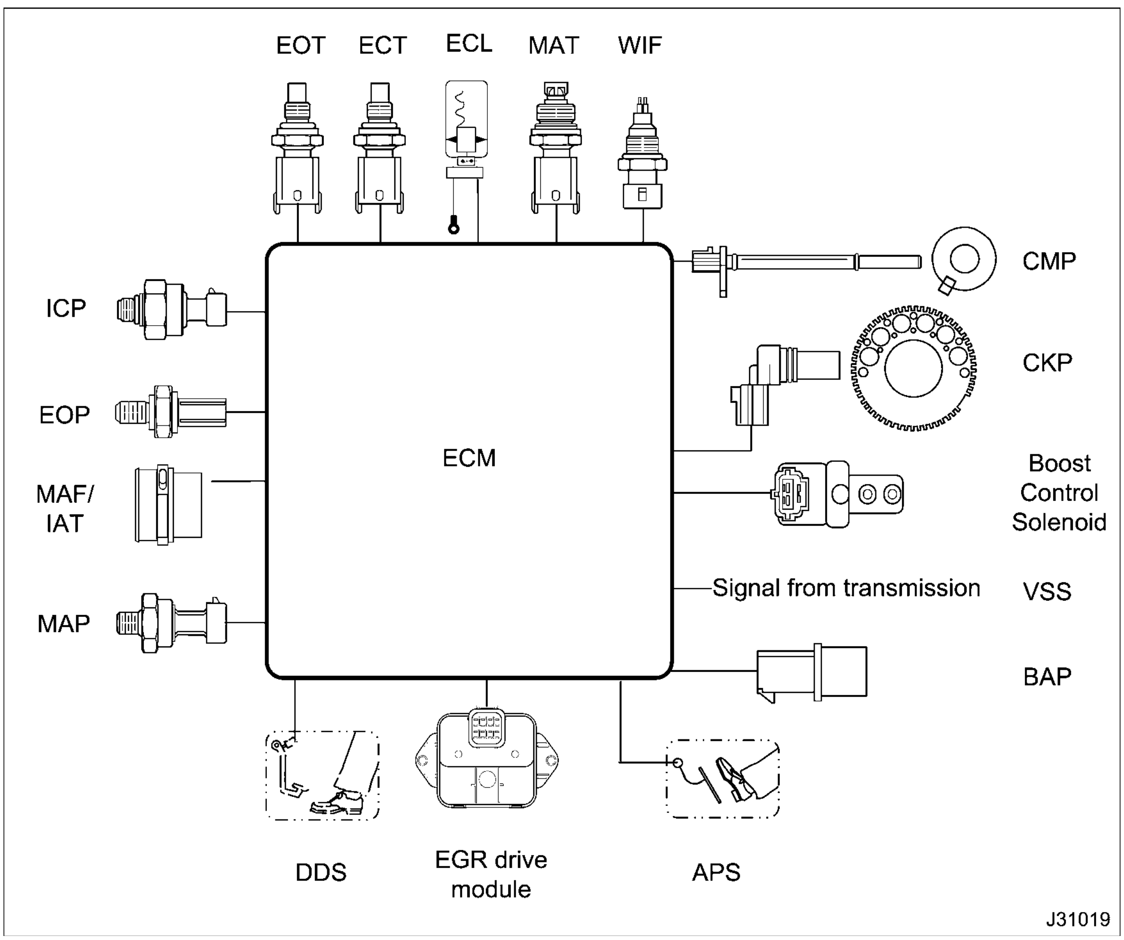

Figure 44 Engine and vehicle sensors

Thermistor Sensor

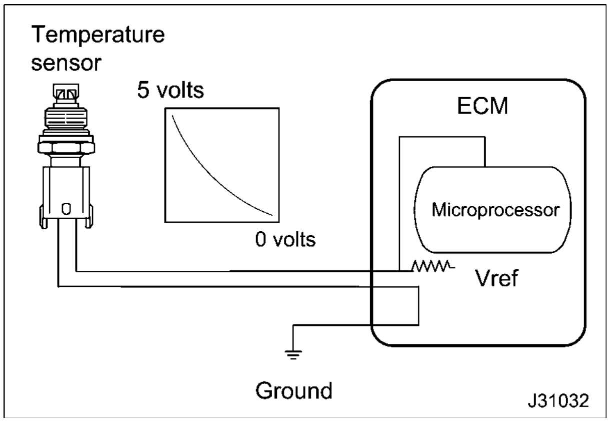

Figure 45 Thermistor

Four thermistor type sensors used

- ECT
- EOT
- MAT
- IAT

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 glow plug operation. The ECT is a backup, if the EOT is out of range. The ECT sensor is installed in the left side of the front cover assembly.

Engine Oil Temperature (EOT)

The ECM monitors the EOT signal to control fuel quantity, inlet air heater operation, and timing during operation of 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 oil filter base.

Manifold Air Temperature (MAT)

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

Intake Air Temperature (IAT)

The ECM monitors the IAT signal to control timing and fuel rate during cold starts. The IAT sensor is mounted with the MAF sensor in the air flow between the inlet of the turbocharger and the air filter.

Hot Wire Sensor

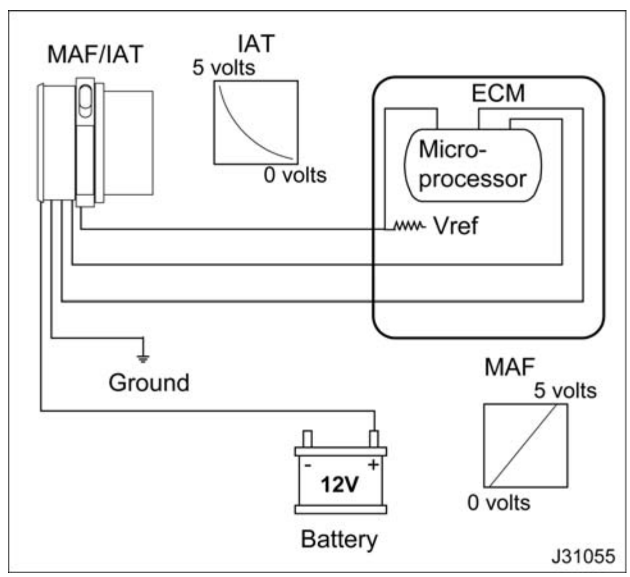

Figure 46 Hot wire sensor

One hot wire type sensor used

- MAF

Mass Air Flow (MAF)

The MAF sensor is mounted in the air flow between the inlet of the turbocharger and the air filter.

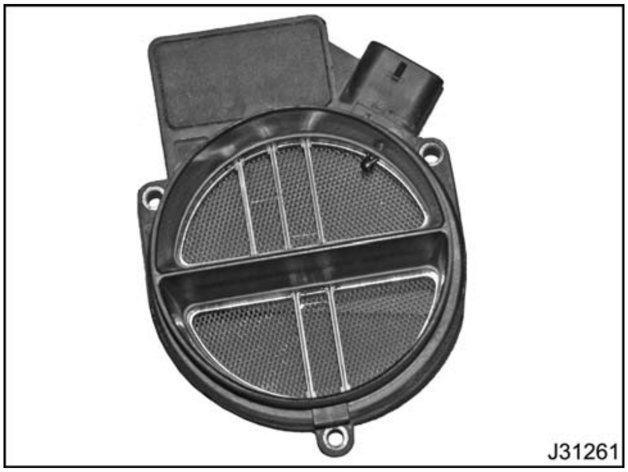

Figure 47 MAF/IAT sensor unit

The MAF sensor is an flow meter that operates on the principle of hot-film anemometry. A heated element is placed within the airflow stream, and maintained at a constant temperature differential above the air temperature. The amount of electrical power required to maintain the heated element at the proper temperature is a direct function of the mass flow rate of the air past the element.

As the flow rate increases, more heat is transferred to the air, and the electrical power required to maintain the desired operating temperature increases. Conversely, a decrease in airflow results in a decrease in the power required to maintain the proper operating temperature.

The power required to maintain constant temperature is converted to a digital signal.

The ECM monitors the MAF signal to control EGR operation. The ECM also uses the MAF signal to control timing and fuel rate during cold starts and limits smoke emissions during normal operations.

Variable Capacitance Sensor

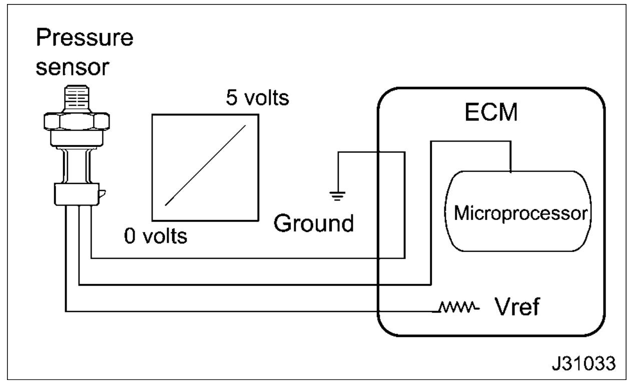

Figure 48 Variable capacitance sensor

Two variable capacitance sensors used

- BAP
- 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
- 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, glow plug, and air heater operation. The BAP sensor is 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 the Boost Control Solenoid (BCS). The MAP sensor is installed to the right of the intake air elbow in the intake manifold.

Micro Strain Gauge (MSG) Sensor

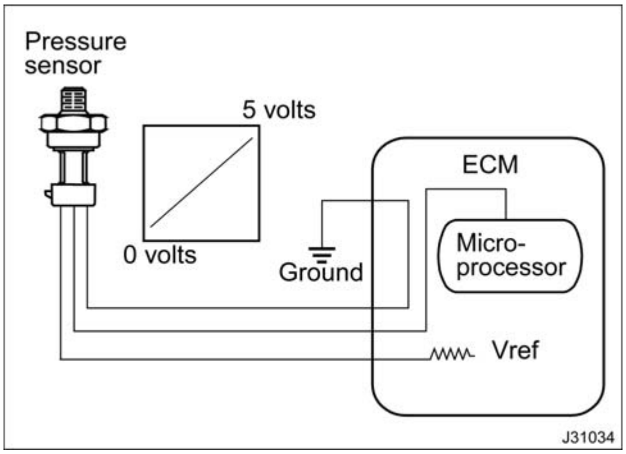

Figure 49 MSG sensor

One micro strain gauge type sensor used

- 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
- Signal ground

The sensor is powered by V_{REF} received from the ECM and is grounded through the ECM to a common sensor ground.

Injection Control Pressure (ICP) sensor

The ECM monitors the ICP signal to determine the injection control pressure for engine operation. 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 through the right side valve cover in the oil rail.

Magnetic Pickup Sensor

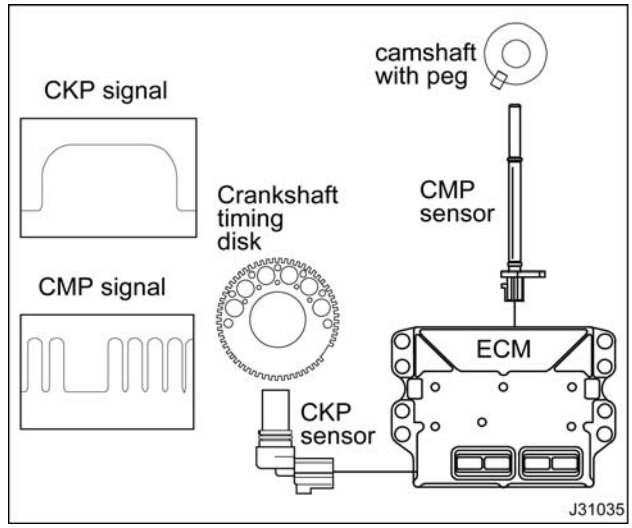

Figure 50 Magnetic pickup

Two magnetic pickup type sensors used

- CKP
- CMP

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 front right side of the lower crankcase.

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 left side of the lower crankcase.

Potentiometer

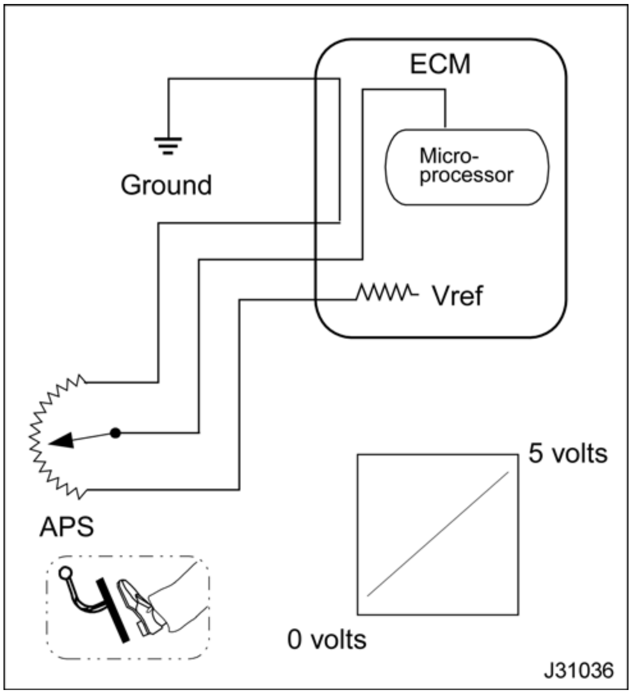

Figure 51 Potentiometer

One potentiometer used

- 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.

Switches

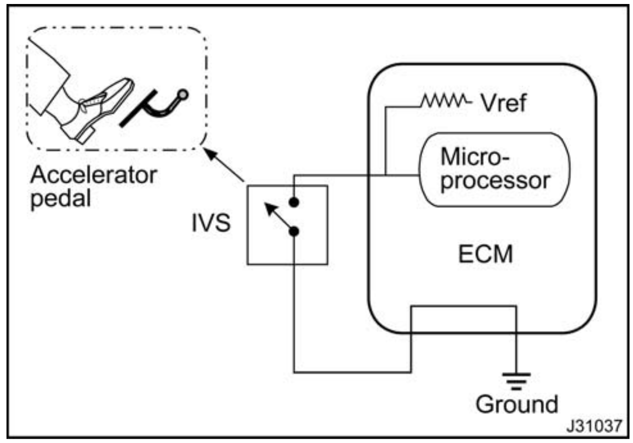

Figure 52 Switch

Five switches used

- DDS (transmission select)
- IVS
- WIF
- EOP
- ECL

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

Driveline Disengagement Switch (DDS)

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

Idle Validation Switch (IVS)

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

Water In Fuel (WIF)

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

Engine Oil Pressure (EOP) Switch

The ECM monitors the EOP signal for reference only. The ECM uses the EOP signal to control the instrument panel oil pressure gauge and for EWPS warning, lights the Warn Engine Lamp (WEL) for low oil pressure. The EOP switch closes a circuit to ground after the engine oil pressure reaches 34 to 48 kPa (5 to 7 psi). When the pressure is above 48 kPa (7 psi) the gauge reads normal. If the oil pressure drops below 41 kPa (6 psi) the gauge reads 0 kPa (0 psi). The EOP switch is in the oil filter base assembly.

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 Oil/Water Lamp (OWL) on the instrument panel is illuminated.

Glow Plug Control System

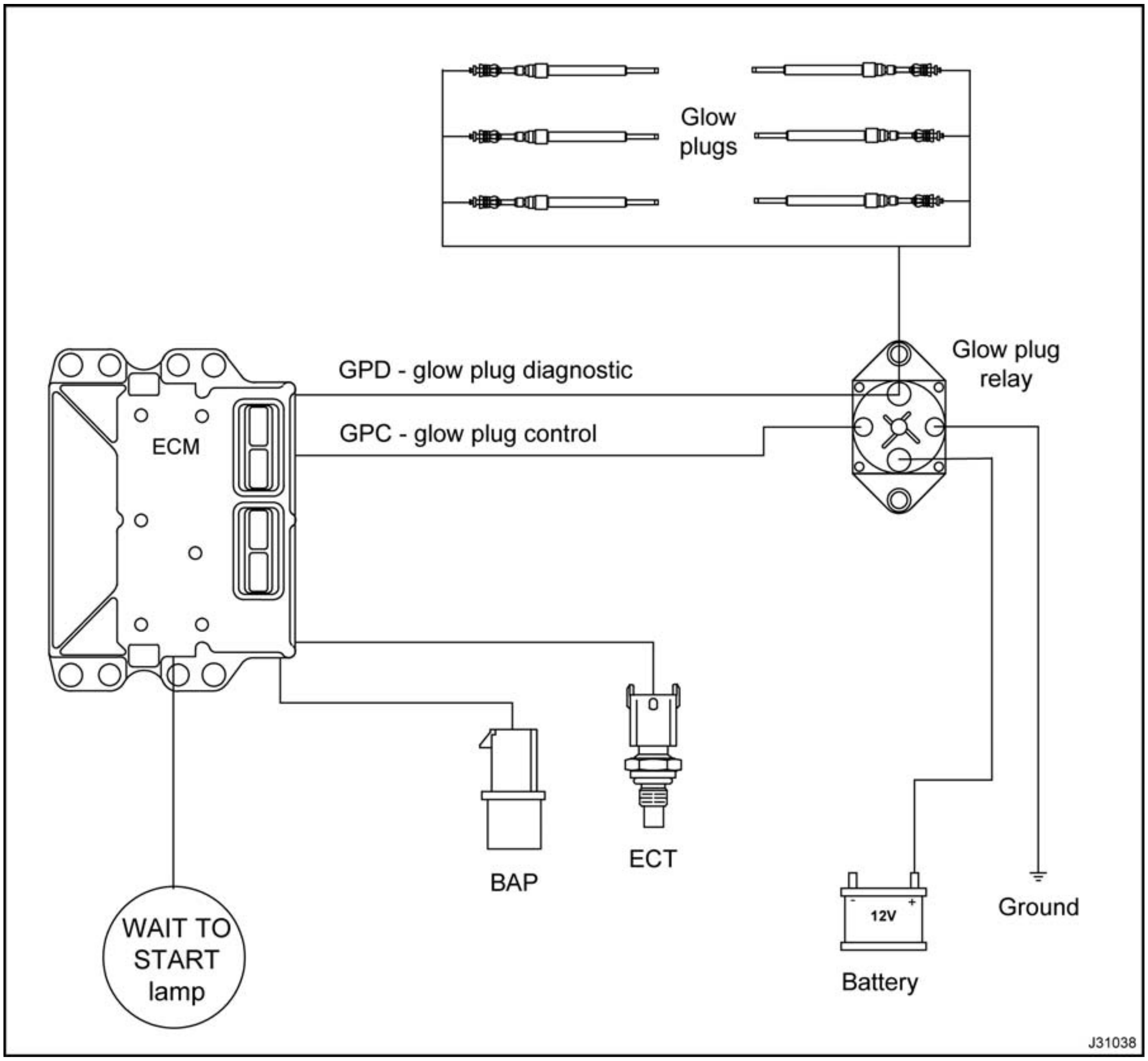

Figure 53 Glow plug control system

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

The ECM energizes the glow plugs, by energizing glow plug relay while monitoring programmed conditions for engine coolant temperature and atmospheric pressure.

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

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

Glow plug activation time is increased, if the engine is cold and the barometric pressure is low (high altitude).

Inlet Air Heater Control System

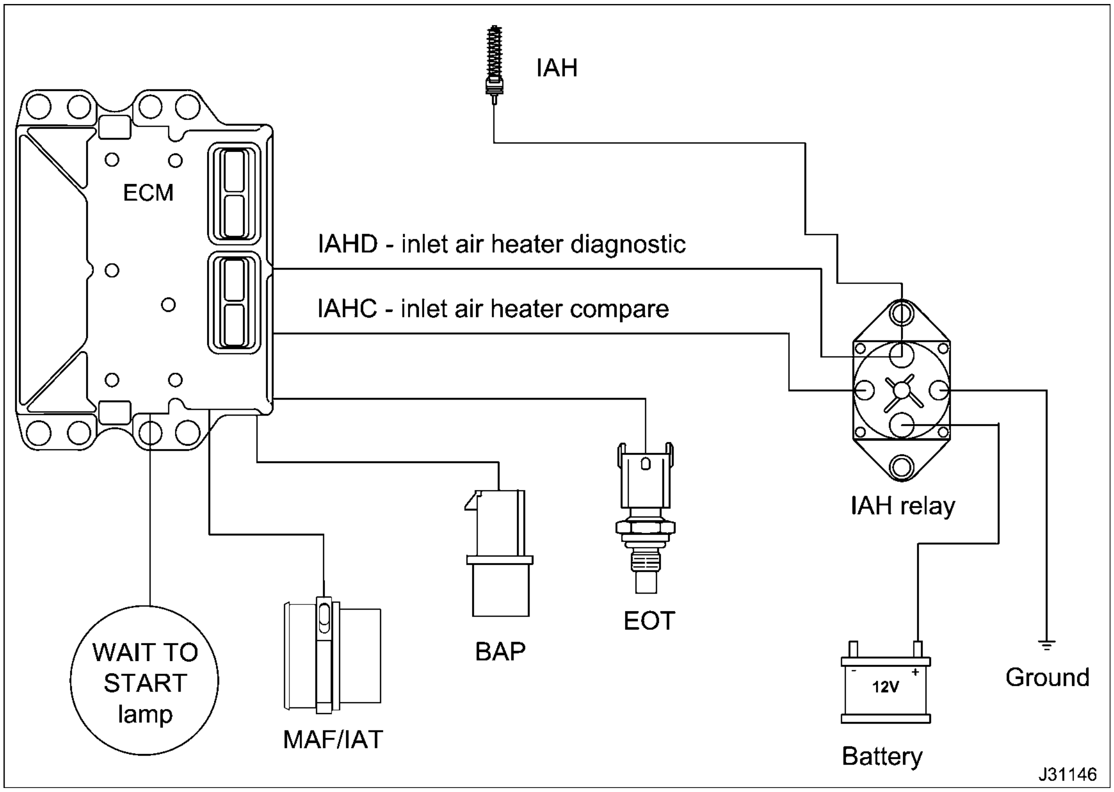

Figure 54 Inlet air heater control system

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

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

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

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

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

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

Table of Contents

Standard Features

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)

Service Diagnostics

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

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

Fast Idle

Fast Idle increases engine idle speed up to 875 rpm for faster warm-up to operating temperature. This occurs by the ECM monitoring the ECT sensor input and adjusting the fuel injector operation accordingly.

Low idle speed is increased proportionally when the engine coolant temperature is below 70 °C (158 °F) at 700 rpm to below -10 °C (14 °F) at 875 rpm maximum.

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 75 °C (167 °F) while the engine has been idling with no load for more than 5 minutes.

CAP is standard on trucks with a neutral safety switch. CAP is also standard on trucks without an Idle Shutdown Timer (IST).

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 a red warning lamp and sound an audible alarm when the ECM detects:

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

The EWPS warns the operator that the engine coolant temperature or oil pressure is not to specification. The ECM will illuminate an amber caution lamp when the ECM detects:

- High coolant temperature
- Low oil pressure

When the EWPS is enabled and a critical engine condition occurs, the on-board electronics will send the warning to the instrument panel.

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.

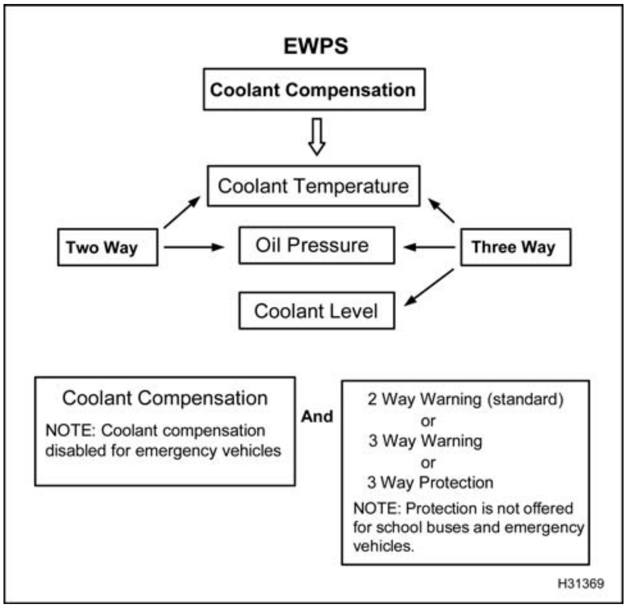

Figure 55 EWPS flowchart

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 110 °C (230 °F), a red warning 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), a red warning lamp will be illuminated and DTC 321 will be set.
- When the coolant temperature is above 112 °C (234 °F), a red warning 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.

Coolant Temperature Compensation (Engine Over Temperature Protection System)

Coolant temperature compensation reduces fuel delivery when the engine coolant temperature is above cooling system specifications. Standard engine warning systems engage after reduced fuel delivery.

Reduced fuel delivery begins when the engine coolant temperature reaches approximately 111 °C (232 °F). A rapid reduction of 15% is achieved when engine coolant temperature reaches approximately 113 °C (235 °F).

A red warning lamp will come on and an audible alarm will sound when ECT reaches approximately 113 °C (235 °F). A coolant temperature event logging function will occur when ECT reaches approximately 116 °C (240 °F) and will record the event in engine hours and odometer readings.

Inlet Air Heater (IAH)

The Inlet Air Heater (IAH) control system warms the incoming air to aid cold engine starting and reduce exhaust emissions during warm-up.

Glow Plugs

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

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.

Cruise Control Switches

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.

Optional Features

Road Speed Limiting

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

Reset Service Interval (Optional)

Reset service interval warns the operator of the need to change the oil and oil filter.

To reset the service interval message using the cruise control switches see "Reset Service Interval Message (page 93)" in the "Diagnostic Software Operation (page 70)" section of this manual.

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.

A red warning 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.

Resets for Idle Shutdown Timer

The IST will reset when:

Power Take Off (PTO) is active.
Engine speed is not at idle speed (700 rpm).
Vehicle movement is detected.
Engine coolant operating temperature is below 60 °C (140 °F).
Ambient air temperature is below 16 °C (61 °F) or above 35 °C (95 °F).
Brake pedal movement, Brake On/Off (BOO), or a Brake Pressure Switch (BPS) switch fault is detected.
Shift selector is moved from neutral or park.