CATERPILLAR®

SENR9703-05
July 2005

Systems Operation
Testing and Adjusting

C11 and C13 On-highway Engines

KCA1-Up (Engine)
KCB1-Up (Engine)
JAM1-Up (Engine)

i01658146

Important Safety Information

Most accidents that involve product operation, maintenance and repair are caused by failure to observe basic safety rules or precautions. An accident can often be avoided by recognizing potentially hazardous situations before an accident occurs. A person must be alert to potential hazards. This person should also have the necessary training, skills and tools to perform these functions properly.

Improper operation, lubrication, maintenance or repair of this product can be dangerous and could result in injury or death.

Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

Safety precautions and warnings are provided in this manual and on the product. If these hazard warnings are not heeded, bodily injury or death could occur to you or to other persons.

The hazards are identified by the “Safety Alert Symbol” and followed by a “Signal Word” such as “DANGER”, “WARNING” or “CAUTION”. The Safety Alert “WARNING” label is shown below.

⚠ WARNING

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

The message that appears under the warning explains the hazard and can be either written or pictorially presented.

Operations that may cause product damage are identified by “NOTICE” labels on the product and in this publication.

Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are, therefore, not all inclusive. If a tool, procedure, work method or operating technique that is not specifically recommended by Caterpillar is used, you must satisfy yourself that it is safe for you and for others. You should also ensure that the product will not be damaged or be made unsafe by the operation, lubrication, maintenance or repair procedures that you choose.

The information, specifications, and illustrations in this publication are on the basis of information that was available at the time that the publication was written. The specifications, torques, pressures, measurements, adjustments, illustrations, and other items can change at any time. These changes can affect the service that is given to the product. Obtain the complete and most current information before you start any job. Caterpillar dealers have the most current information available.

⚠ WARNING

When replacement parts are required for this product Caterpillar recommends using Caterpillar replacement parts or parts with equivalent specifications including, but not limited to, physical dimensions, type, strength and material.

Failure to heed this warning can lead to premature failures, product damage, personal injury or death.

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Systems Operation Section

i02310861

Engine Design

SMCS Code: 1000

S/N: KCA1-Up

C11

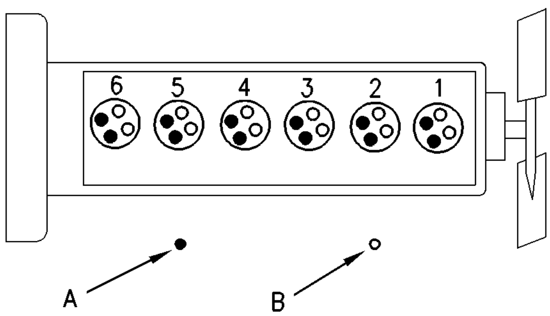

Illustration 1 g00935559

(A) Exhaust valves
(B) Inlet valves

Bore .... 130 mm (5.12 inch)

Stroke .... 140 mm (5.51 inch)

Displacement .... 11.1 L (680 cu in)

Cylinder arrangement .... In-line

Valves per cylinder 4

In order to check the engine valve lash setting, the engine must be cold and the engine must be stopped.

Engine valve lash

- Inlet .... 0.38 ± 0.08 mm (0.015 ± 0.003 inch)
- Exhaust .... 0.64 ± 0.08 mm (0.025 ± 0.003 inch)
- Variable valve actuator .... 0.610 ± 0.075 mm (0.0240 ± 0.0030 inch)
- Cat compression brake .... 0.864 ± 0.050 mm (0.034 ± 0.0020 inch)

Type of combustion .... Direct injection

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

The crankshaft rotation is viewed from the flywheel end of the engine. Crankshaft rotation .... Counterclockwise

Note: The front of the engine is opposite of the flywheel end of the engine. The left side of the engine and the right side of the engine are viewed from the flywheel end of the engine. The No. 1 cylinder is the front cylinder.

i02377343

Engine Design

SMCS Code: 1000

S/N: KCB1-Up

S/N: JAM1-Up

C13

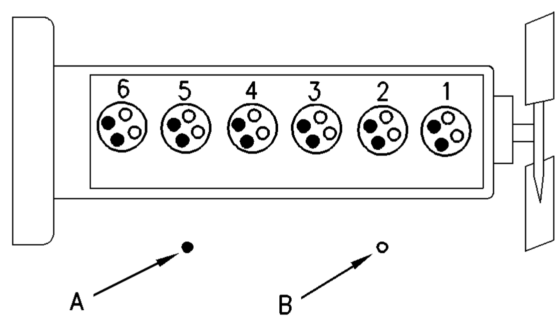

Illustration 2 g00935559

(A) Exhaust valves
(B) Inlet valves

Bore .... 130 mm (5.12 inch)

Stroke .... 157 mm (6.18 inch)

Displacement .... 12.5 L (763 cu in)

Cylinder arrangement .... In-line

Valves per cylinder 4

In order to check the engine valve lash setting, the engine must be cold and the engine must be stopped.

Engine valve lash

- Inlet .... 0.38 ± 0.08 mm (0.015 ± 0.003 inch)

Exhaust .... 0.64 ± 0.08 mm (0.025 ± 0.003 inch)
Variable valve actuator .... 0.610 ± 0.075 mm (0.024 ± 0.0030 inch)
Cat compression brake .... 0.864 ± 0.050 mm (0.034 ± 0.0020 inch)

Type of combustion .... Direct injection

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

The crankshaft rotation is viewed from the flywheel end of the engine. Crankshaft rotation .... Counterclockwise

Note: The front end of the engine is opposite of the flywheel end of the engine. The left side of the engine and the right side of the engine are viewed from the flywheel end of the engine. The No. 1 cylinder is the front cylinder.

i02205170

General Information

SMCS Code: 1000

The C11 engines are in-line six cylinder arrangements. The engine has a bore of 130 mm (5.12 inch) and a stroke of 140 mm (5.51 inch). The displacement of the engine is 11.1 L (680 cu in). Each cylinder has two inlet valves and two exhaust valves. The firing sequence of the engine is 1-5-3-6-2-4.

The C13 engines are in-line six cylinder arrangements. The engine has a bore of 130 mm (5.12 inch) and a stroke of 157 mm (6.18 inch). The displacement of the engine is 12.5 L (763 cu in). Each cylinder has two inlet valves and two exhaust valves. The firing sequence of the engine is 1-5-3-6-2-4.

The engines have two turbochargers. The engines arrange the two turbochargers in series. The two turbochargers allow the engine to have boost over the entire engine rpm range. The use of two turbochargers increases the maximum boost pressure to 410 kPa (60 psi). The engines also use a precooler before the air-to-air aftercooler (ATAAC).

The Electronic Unit Injector (EUI) provides increased control of the timing and increased control of the fuel air mixture. Engine rpm is controlled by adjusting the injection duration. Engine timing is controlled by the precise control of fuel injection timing.

The Engine Control Module (ECM) monitors the components of the engine during operation. In the event of a component failure, the operator will be alerted to the condition by the use of a check engine light and an event code will be logged in the ECM. Caterpillar Electronic Technician (ET) can be connected to the engine in order to read any logged faults. Also, the cruise control switches can be used to flash the code on the check engine light. Intermittent faults are logged and stored in memory.

Starting The Engine

The engine's ECM will automatically provide the correct amount of fuel in order to start the engine. Do not hold the throttle down while the engine is cranking. If the engine fails to start in 30 seconds, release the starting switch. Allow the starting motor to cool for two minutes before the starting motor is used again.

NOTICE

Excessive ether (starting fluid) can cause piston and ring damage. Use ether for cold weather starting purposes only.

Cold Mode Operation

The ECM will set the cold start strategy when the coolant temperature is below 18 °C (64 °F).

When the cold start strategy is activated, low idle rpm will be increased to 1000 rpm and the engine's power will be limited.

Cold mode operation will be deactivated when any of the following conditions have been met:

- Coolant temperature reaches 18 °C (64 °F).
- The engine has been running for fourteen minutes.

Cold mode operation varies the fuel injection amount and the timing for white smoke cleanup. The engine operating temperature is usually reached before the walk-around inspection is completed. The engine will idle at the programmed low idle rpm in order to be put in gear.

NOTICE

Do not move the vehicle with the engine in the cold mode condition. Engine power could be noticeably reduced. At a vehicle speed above 8 km/h (5 mph), low idle rpm will be reduced to the customer programmed low idle and the power will still be reduced.

After the cold mode is completed, the engine should be operated at low rpm until normal operating temperature is reached. The engine will reach normal operating temperature faster when the engine is operated at low rpm and low power demand.

Customer Specified Parameters

The engine is capable of being programmed for several customer specified parameters. For a brief explanation of each of the customer specified parameters, see the Operation and Maintenance Manual.

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Electronic Control System Components

SMCS Code: 1900

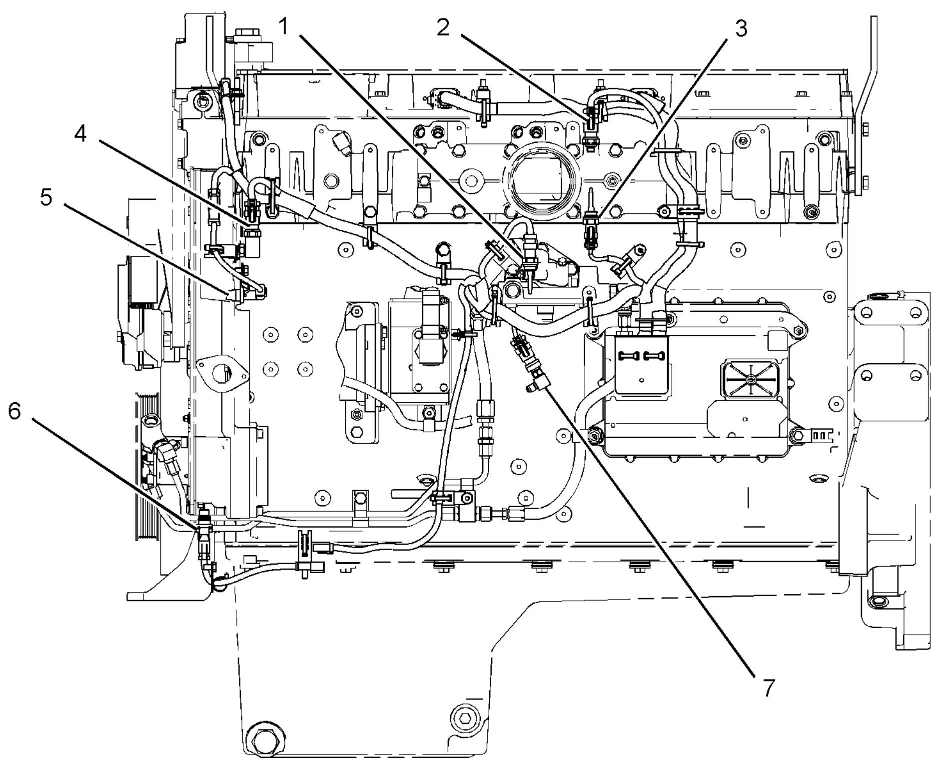

Illustration 3 g01191511

Left view of the engine

(1) Fuel temperature sensor
(2) Inlet manifold pressure sensor
(3) Inlet air temperature sensor
(4) Atmospheric pressure sensor
(5) Secondary speed/timing sensor
(6) Primary speed/timing sensor
(7) Engine oil pressure sensor

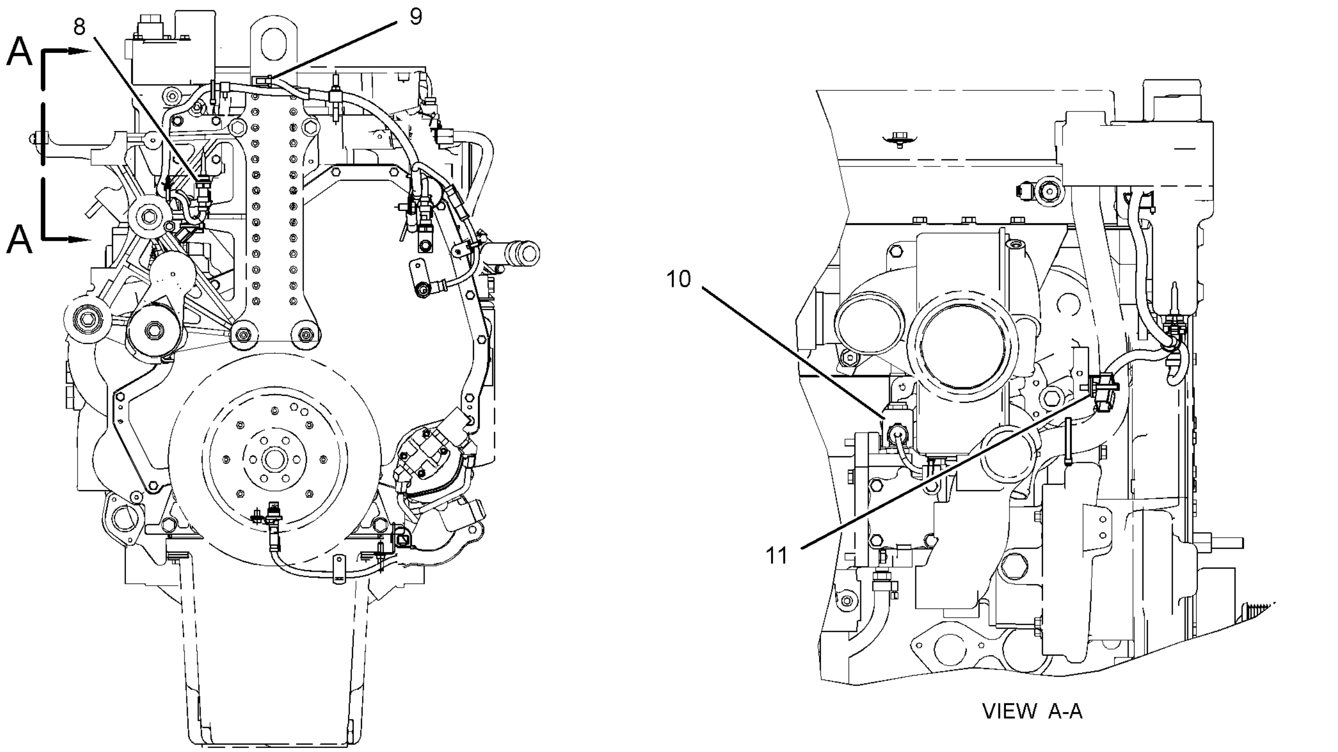

Illustration 4 g01191513

Front view of the engine

(8) Coolant temperature sensor
(9) Connector for the variable valve actuator
(10) Precooler valve
(11) Connector for the precooler valve

The electronic control system has the following components:

- Engine Control Module (ECM)
- Pressure sensors
- Temperature sensors
- Speed/Timing sensors
- Solenoids

The ECM functions as the governor for the engine. The ECM modulates the quantity of fuel and injection timing in order to govern the engine.

The ECM can activate the following starting aids:

- Air inlet heater
- Ether injection
- Cycling of injector solenoids

The ECM will provide the operator with an illuminated warning light if the engine senses an engine problem. The operator may also experience an engine derate. The warning light or the engine derate could turn off during engine operation. The diagnostic code will be logged in the ECM. The diagnostic code can then be diagnosed at a later time.

The ECM is password protected in order to secure calibration of the ECM and customer programmed information. The calibration can be adjusted with flash files by authorized dealers. The flash file is programmed into the personality module.

i02232302

Fuel System

SMCS Code: 1250

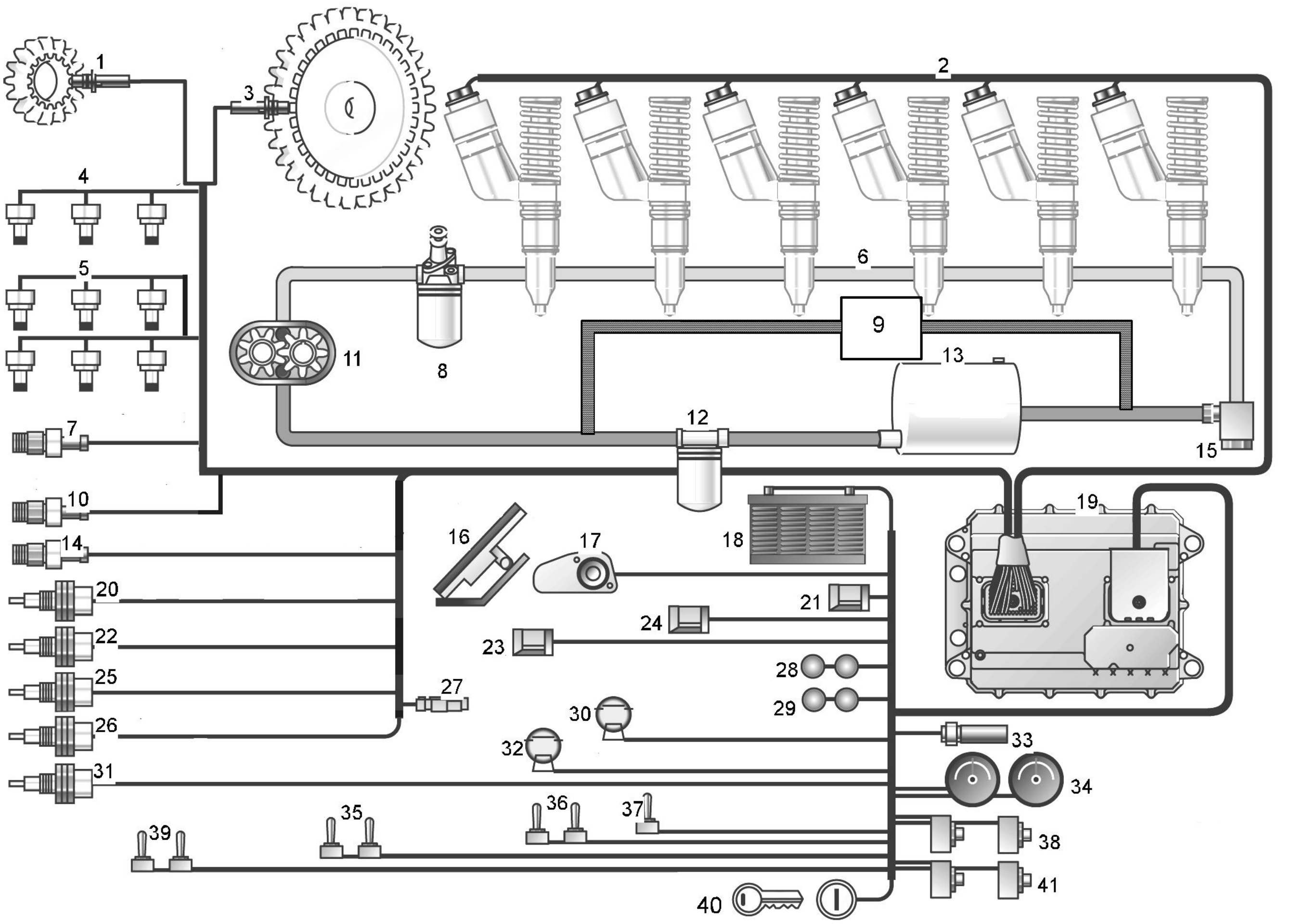

Illustration 5 g01099257

(1) Secondary speed/timing sensor
(2) Injectors
(3) Primary speed/timing sensor
(4) Retarder solenoid
(5) Solenoids for the Variable Valve Actuator
(6) Fuel supply rail
(7) Boost pressure sensor
(8) 2 Micron secondary fuel filter
(9) Fuel temperature regulator (If equipped)
(10) Atmospheric pressure sensor
(11) Fuel pump
(12) Primary fuel filter
(13) Fuel tank
(14) Engine oil pressure sensor
(15) Fuel pressure regulator
(16) Accelerator pedal
(17) Accelerator pedal position sensor
(18) Batteries
(19) Engine Control Module (ECM)
(20) Engine coolant temperature sensor
(21) SAE J1587/J1708 Data link
(22) Inlet air temperature sensor
(23) SAE J1939 Data link
(24) SAE J1922/J1708 Data link
(25) Fuel temperature sensor
(26) Ambient air temperature
(27) Timing calibration connector
(28) Warning and check engine lamps
(29) 2 Lamp outputs
(30) 6 Programmable outputs
(31) Engine coolant level sensor
(32) Cooling fan relay or solenoid
(33) Vehicle speed sensor
(34) Speedometer & tachometer
(35) PTO on/off switch and PTO set/resume switch
(36) Cruise on/off switch and cruise set/resume switch
(37) 7 Programmable inputs
(38) Service brake pedal position switches.
(39) Engine retarder switch
(40) Keyswitch
(41) Neutral & clutch pedal position switches

The electronic unit injector system consists of the following systems: the mechanical system and the electronic system. The mechanical system is made up of the low pressure fuel supply system and the electronic unit injectors. The electronic system provides complete electronic control of all engine functions. The electronic control system consists of the following three types of components: input, control, and output.

There are five major components of the electronic unit injector fuel system:

- Electronic unit injectors
- Fuel transfer pump
- ECM
- Sensors
- Solenoids

The electronic unit injectors produce fuel injection pressures up to 207000 kPa (30000 psi). The electronic unit injectors also fire up to 19 times per second at rated speed. The fuel transfer pump supplies the injectors by drawing fuel from the tank and by pressurizing the system between 60 and 125 PSI. The ECM is a powerful computer which controls all major engine functions. Sensors are electronic devices which monitor engine performance parameters. Engine performance parameters measure pressure, temperature and speed. This information is sent to the ECM via a signal. Solenoids are electronic devices which use electronic currents from the ECM to change engine performance. An example of an solenoid is the injector solenoid.

Low Pressure Fuel System

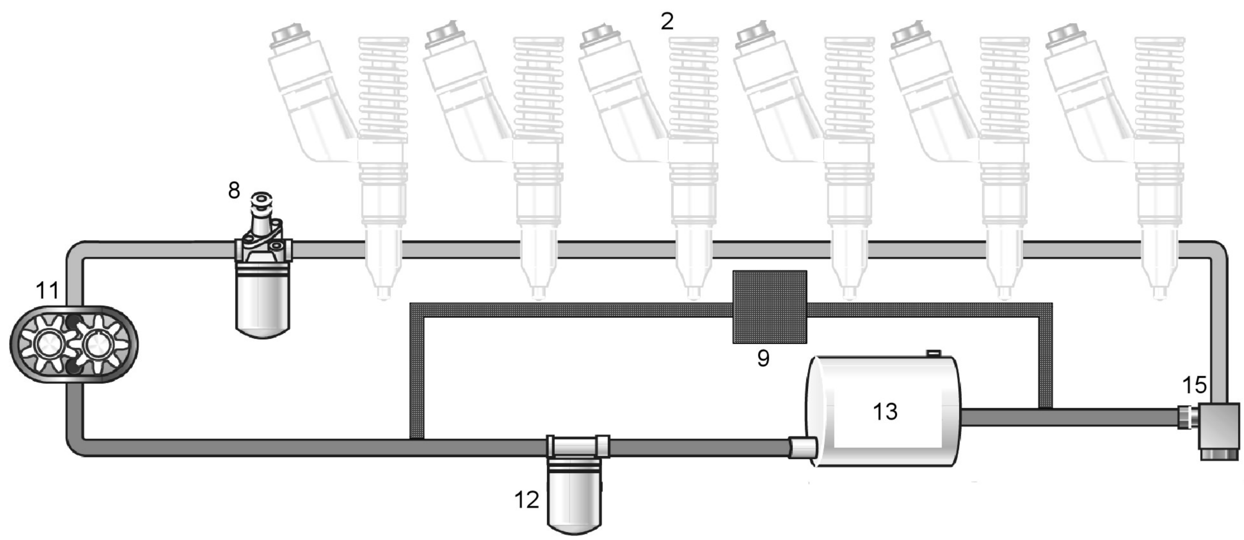

Illustration 6 g01125983

(2) Injectors
(6) Fuel supply rail
(8) 2 Micron secondary fuel filter
(9) Temperature regulator for the fuel (If equipped)
(11) Fuel pump
(12) Primary fuel filter
(13) Fuel tank
(15) Fuel pressure regulator

The low pressure fuel system supplies fuel from the fuel tank to the injectors. The low pressure fuel system has four basic functions:

- Supply fuel for combustion
- Supply fuel in order to cool the injectors.
- Remove air from the fuel.
- Warm the fuel in the fuel tank.

The major parts in a low pressure fuel system consist of the following components:

- Fuel tank
- Fuel transfer lines
- Primary fuel filter or water separator
- Fuel transfer pump
- Secondary fuel filter
- Fuel priming pump
- Fuel pressure regulator valve
- Fuel regulator valve

The electronic unit injectors, the fuel transfer pump, the ECM, sensors, and solenoids are part of the low pressure fuel system.

In the low pressure fuel system, the fuel is pulled from the fuel tank to the primary fuel filter or to the water separator. The primary fuel filter removes large debris from the fuel before the fuel flows into the transfer pump. The fuel transfer pump is a gear pump that contains a pressure relief valve. Fuel flows from the outlet port of the transfer pump to the secondary fuel filter. The secondary fuel filter has a rating of 2 microns. The secondary filter removes small abrasive contaminants from the fuel system, which can cause damage to the unit injectors.

The fuel filter base contains a hand operated fuel priming pump. The fuel priming pump removes air from the system when a fuel filter has been changed or a unit injector has been changed. The priming pump pulls fuel from the tank, around the transfer pump and into the filter. The transfer pump pushes fuel through the supply passage in the cylinder head and back to the tank.

The fuel pressure regulator consists of a check valve under spring pressure. The pressure relief valve opens at approximately 60 to 125 PSI. When the engine is in the off position and the fuel pressure drops below 60 PSI, the check valve closes. The check valve closes in order to prevent the fuel in the cylinder head from draining back into the fuel tank. Retaining the fuel in the head maintains a supply of fuel for the injectors during start-up.

The ECM controls major engine functions. Sensors are electronic devices that monitor engine performance parameters. The pressure sensor, the temperature sensor and the speed sensor provide information to the ECM by a signal voltage. Actuators are electronic devices which use electrical currents from the ECM to change engine performance. An example of an actuator is an injector solenoid.

Temperature Regulator for the fuel (If Equipped)

Later models will not have a temperature regulator for the fuel.

The fuel regulator valve is located in one of the return fuel lines. The fuel line runs from the fuel filter base to the fuel transfer pump. The fuel regulator valve is controlled by the temperature of the fuel. The valve is in the open position at temperatures below 21 °C (70 °F). The valve closes at temperatures above 27 °C (80 °F).

The temperature regulator for the fuel is used to supply the injectors with warm fuel during cold operation. Fuel is delivered to the injectors by a fuel passage in the cylinder head. The injectors are supplied with an excess of fuel. The excess fuel removes heat from the injectors. This heated fuel will mix with the cold fuel in the fuel tank. The fuel regulator valve in the return fuel line mixes fuel from the fuel tank with the excess fuel that is returning to the fuel tank. The warm fuel increases injector life.

Electronic Controls

The electronic control system provides complete electronic control of all engine functions. The electronic control system consists of the following three types of components: input, control, and output. Sensors monitor engine operating conditions. This information is sent to the ECM. The ECM has three main functions. The ECM provides power for the engine electronics and monitors input signals from the engine sensors. The ECM also acts as a governor to control engine rpm. The ECM stores active faults, logged faults, and logged events. The Personality Module is the software in the ECM which contains the specific maps that define power, torque, and rpm of the engine. The ECM sends electrical current to the output components in order to control engine operation. The ECM has the following connectors: two 70 pin harness connectors, one engine harness connector, and one vehicle harness connector. The vehicle harness connects the ECM to the engine control portion of the vehicle harness. The engine control portion includes the following components.

- Accelerator pedal position sensor
- Vehicle speed sensor
- Transmission
- Brake
- Clutch switches
- Cruise control
- PTO switch
- Data links
- Check engine light
- Warning light
- Engine retarder switch
- Speedometer
- Tachometer

- Cooling fan solenoid

The following list of features are part of the electronic control system:

- Cold start strategy
- Oil pressure
- Coolant temperature warning indicator
- Automatic altitude compensation
- Variable injection timing
- Electronic engine speed governing

These features result in the following items: precise engine speed control, very little smoke, faster cold starting, and built-in engine protection.

The ECM consists of the following two main components: the ECM and the personality module.

The ECM is a computer and the personality module is the software for the computer. The personality module contains the operating maps. The operating maps define the following characteristics of the engine:

- Horsepower
- Torque curves
- Rpm
- Other characteristics

The ECM, the personality module, the sensors, and the unit injectors work together in order to control the engine. The ECM, the personality module, the sensors, and the unit injectors can not control the engine alone.

The ECM determines a desired rpm that is based on the following criteria:

- Throttle signal
- Certain diagnostic codes
- Vehicle speed signal

The ECM maintains the desired engine rpm by sensing the actual engine rpm. The ECM calculates the fuel amount that needs to be injected in order to achieve the desired rpm.

Fuel Injection Timing and Delivery

The ECM controls the injected fuel amount by varying the signals to the unit injectors. The unit injectors will inject fuel only if the unit injector solenoid is energized. The ECM sends a 90 volt signal to the solenoid for energizing the solenoid. By controlling the timing of the 90 volt signal, the ECM controls injection timing. By controlling the duration of the 90 volt signal, the ECM controls the injected fuel amount.

Injection timing is determined by engine rpm, and other engine data. The ECM senses the top center position of cylinder number 1 from the signal that is provided by the engine speed sensor. The ECM decides when the injection should occur relative to the top center position. The ECM provides the signal to the unit injector at the desired time.

Unit Injector Mechanism

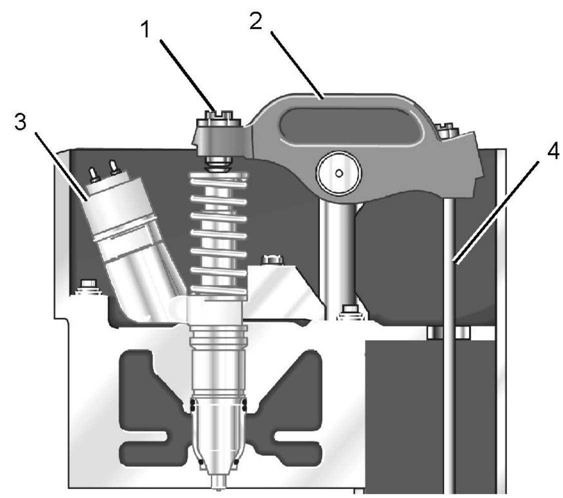

Illustration 7 g01099258

Typical examples of electronic unit injector fuel systems.

(1) Adjusting nut
(2) Rocker arm assembly
(3) Unit injector
(4) Pushrod

The unit injector pressurizes the fuel. The correct amount of fuel is then injected into the cylinder block at precise times. The ECM determines the injection timing and the amount of fuel that is delivered. The unit injector is operated by a camshaft lobe and a rocker arm. The camshaft has three camshaft lobes for each cylinder. Two lobes operate the inlet and exhaust valves, and the other lobe operates the unit injector mechanism. Force is transferred from the unit injector lobe on the camshaft through the lifter to the pushrod (4). The force of the pushrod is transferred through rocker arm assembly (2) and to the top of the unit injector. The adjusting nut (1) allows setting of the unit injector adjustment. Refer to Systems Operation/Testing and Adjusting, "Electronic Unit Injector - Adjust" for the proper setting of the unit injector adjustment.

Unit Injector

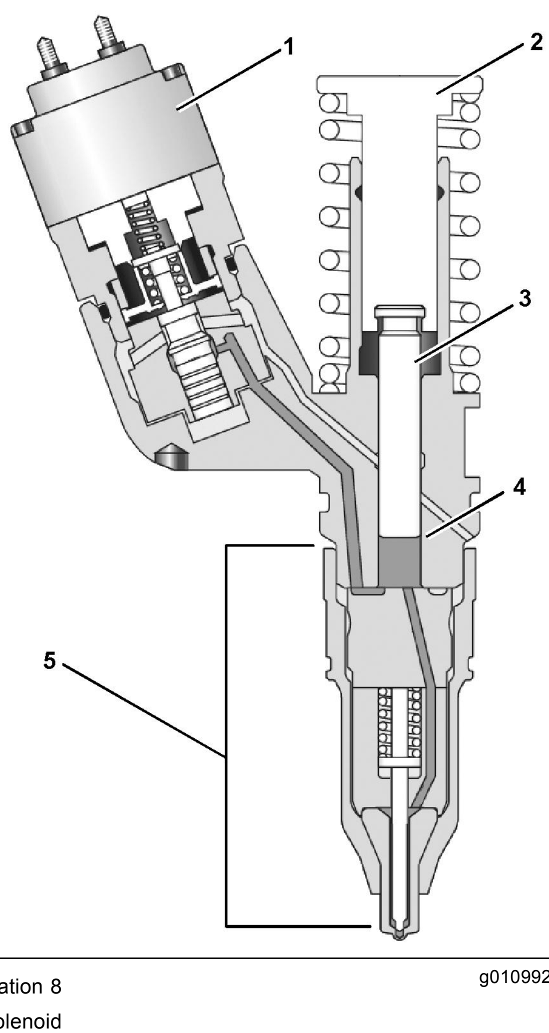

Illustration 8 g01099261

(1) Solenoid
(2) Tappet
(3) Plunger
(4) Barrel
(5) Nozzle assembly

Operation of the Electronic Unit Injector

The operation of the electronic unit injector consists of the following four stages: Pre-injection, Injection, End of injection, and Fill. Unit injectors use a plunger and barrel to pump high pressure fuel into the combustion chamber. Components of the injector include the tappet, the plunger, the barrel and nozzle assembly. Components of the nozzle assembly include the spring, the nozzle check, and a nozzle tip. The cartridge valve is made up of the following components: solenoid, armature, poppet valve, and poppet spring.

The injector is mounted in an injector bore in the cylinder head which has an integral fuel supply passage. The injector sleeve separates the injector from the engine coolant in the water jacket. Some engines use a stainless steel sleeve. The stainless steel sleeve fits into the cylinder head with a light press fit.

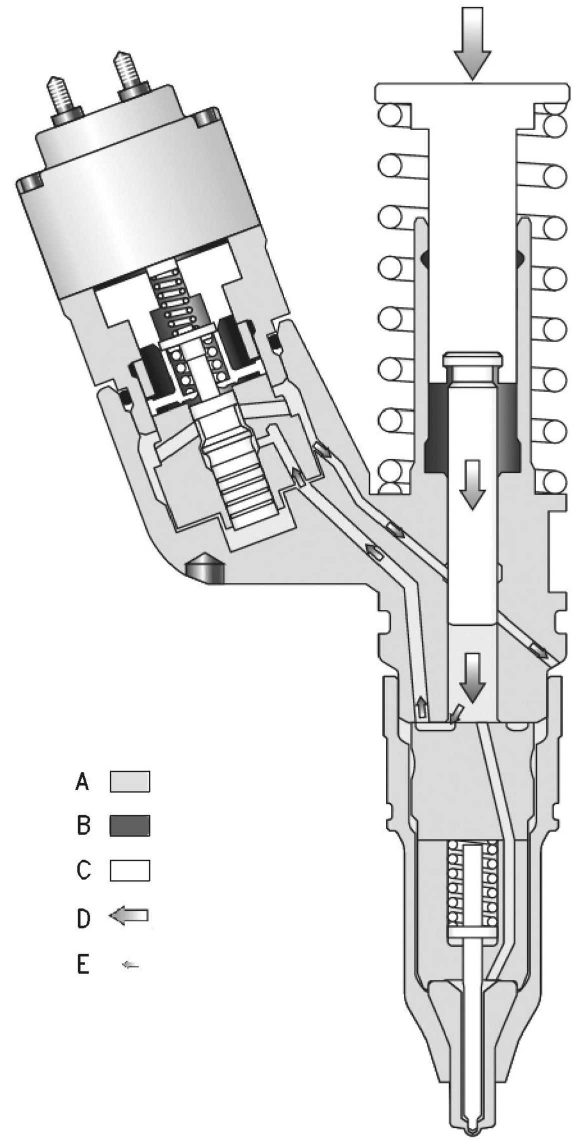

Illustration 9 g00942799

Pre-injection

(A) Fuel supply pressure
(B) Injection pressure
(C) Moving parts
(D) Mechanical movement
(E) Fuel movement.

Pre-injection metering starts with the injector plunger and the injector tappet at the top of the fuel injection stroke. When the plunger cavity is full of fuel, the poppet valve is in the open position and the nozzle check is in the open position. Fuel leaves the plunger cavity when the rocker arm pushes down on the tappet and the plunger. Fuel flow that is blocked by the closed nozzle check valve flows past the open poppet valve to the fuel supply passage in the cylinder head. If the solenoid is energized, the poppet valve remains open and the fuel from the plunger cavity continues flowing into the fuel supply passage.

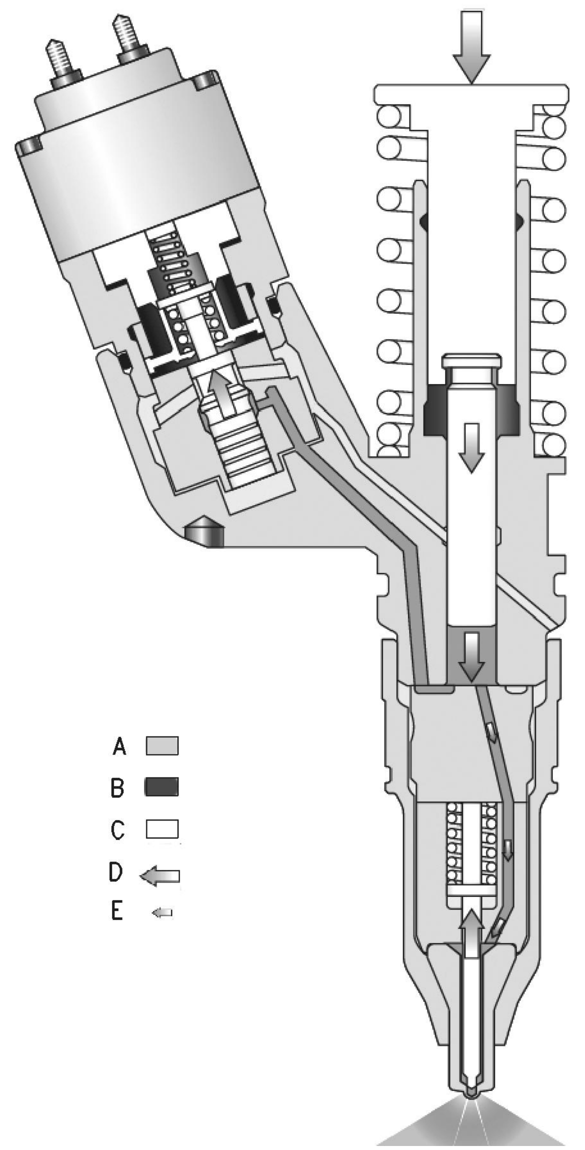

Illustration 10 g00942798

Injection

(A) Fuel supply pressure.
(B) Injection pressure
(C) Moving parts
(D) Mechanical movement
(E) Fuel movement.

To start injection, the ECM sends a current to the solenoid on the cartridge valve. The solenoid creates a magnetic field which attracts the armature. When the solenoid is energized, the armature assembly will lift the poppet valve so the poppet valve contacts the poppet seat. This is the closed position. Once the poppet valve closes, the flow path for the fuel that is leaving the plunger cavity is blocked. The plunger continues to push fuel from the plunger cavity and the fuel pressure builds up. When the fuel pressure reaches approximately 34500 kPa (5000 psi), the force of the high pressure fuel overcomes the spring force. This holds the nozzle check in the closed position. The nozzle check moves off the nozzle seat and the fuel flows out of the injector tip. This is the start of injection.

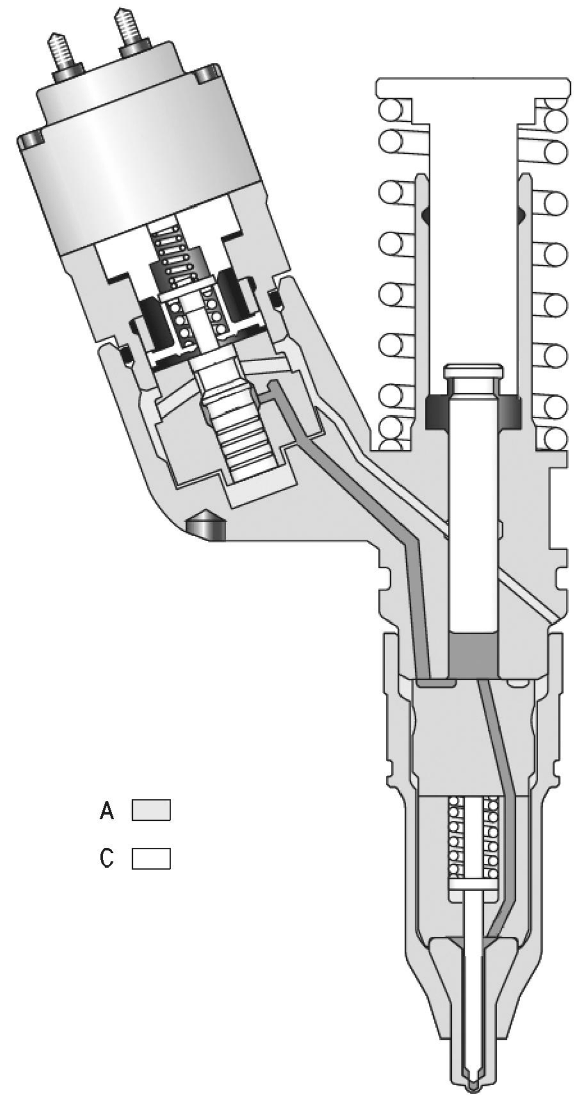

Illustration 11 g00942801

End of injection

(A) Fuel supply pressure
(C) Moving parts

Injection is continuous while the injector plunger moves in a downward motion and the energized solenoid holds the poppet valve closed. When injection pressure is no longer required, the ECM stops current flow to the solenoid. When the current flow to the solenoid stops, the poppet valve opens. The poppet valve is opened by the fuel injector spring and the fuel pressure. High pressure fuel can now flow around the open poppet valve and into the fuel supply passage. This results in a rapid drop in injection pressure. When the injection pressure drops to approximately 24000 kPa (3500 psi), the nozzle check closes and injection stops. This is the end of injection.

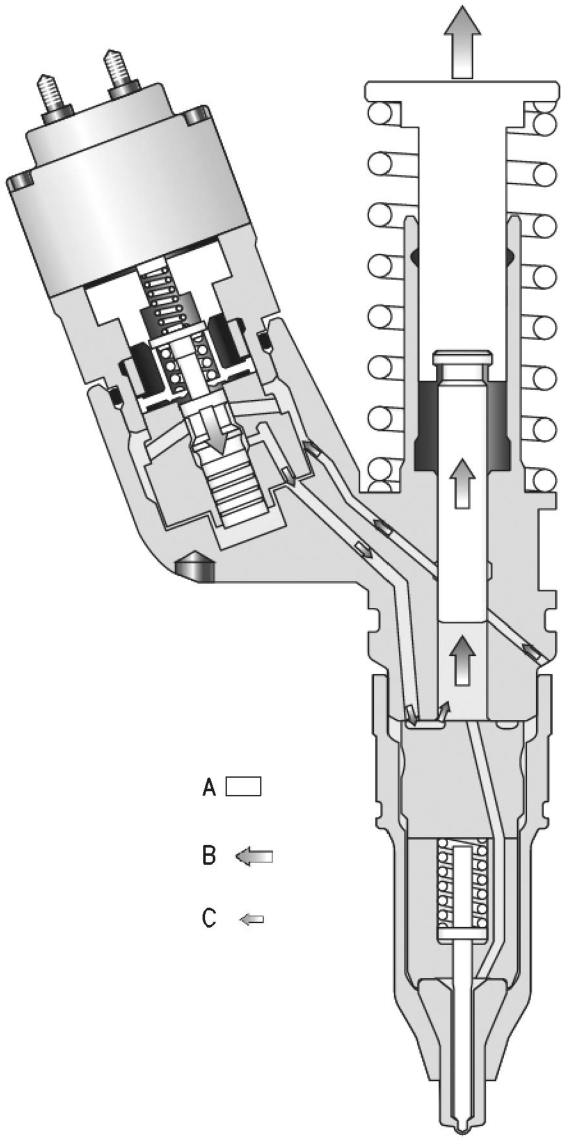

Illustration 12 g00942802

Fill

(A) Moving parts
(B) Mechanical movement
(C) Fuel movement.

When the plunger reaches the bottom of the barrel, fuel is no longer forced from the plunger cavity. The plunger is pulled up by the tappet and the tappet spring. The upward movement of the plunger causes the pressure in the plunger cavity to drop below fuel supply pressure. Fuel flows from the fuel supply passage around the open poppet and into the plunger cavity as the plunger travels upward. When the plunger reaches the top of the stroke, the plunger cavity is full of fuel and fuel flow into the plunger cavity stops. This is the beginning of pre-injection.

i02363770

Air Inlet and Exhaust System

SMCS Code: 1050

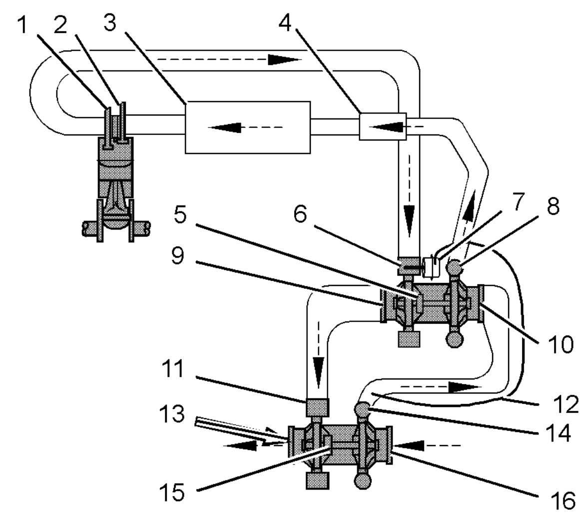

Illustration 13 g01180656

Turbocharger in series

(1) Exhaust valve
(2) Inlet valve
(3) Air-To-Air Aftercooler
(4) Precooler
(5) High pressure turbocharger
(6) Turbine inlet
(7) Wastegate
(8) Compressor outlet
(9) Turbine outlet
(10) Compressor inlet
(11) Turbine inlet
(12) Hose for the wastegate
(13) Turbine outlet
(14) Compressor outlet
(15) Low pressure turbocharger
(16) Compressor inlet

Basic Operation

The following components make up the air inlet and exhaust system:

- Low pressure turbocharger
- High pressure turbocharger
- Precooler
- Aftercooler
- Cylinder head
- Valves and valve train components
- Piston and cylinder
- Exhaust manifold

The engines are equipped with two turbochargers in series. Turbocharged engines are more responsive and turbocharged engines have increased horsepower.

Air is drawn through the air cleaner and flows to the compressor side of the low pressure turbocharger. The low pressure turbocharger compresses the air in order to create boost. The compressed air is sent to the air inlet of the high pressure turbocharger. The high pressure turbocharger compresses the air in order to create higher boost pressures. After the air exits from the high pressure turbocharger the compressed air is cooled by the precooler.

The precooler is a heat exchanger. The precooler uses coolant to extract the heat from the compressed air. The air then flows through the Air-to-Air Aftercooler (ATAAC). The air will then enter the cylinder head. The water supply for the precooler is regulated. The water supply is shut off below 1200 RPM. Cooling the compressed air increases combustion efficiency.

The inlet valves control the air flow into the combustion chamber. Each cylinder contains two inlet valves and two exhaust valves. The inlet valves open when the piston moves down on the inlet stroke. When the inlet valves open, cooled compressed air is pulled into the cylinder. The inlet valves close and the piston begins to move up on the compression stroke. The air in the cylinder is compressed. When the piston is near the top of the compression stroke, fuel is injected into the cylinder. The fuel mixes with the air and combustion occurs. During the power stroke, the combustion force pushes the piston downward. The exhaust valves open and the exhaust gases are pushed through the exhaust port into the exhaust manifold as the piston rises on the exhaust stroke. After the exhaust stroke, the exhaust valves close and the cycle starts again. The complete cycle consists of four strokes:

- Intake
- Compression
- Power
- Exhaust

Turbocharger

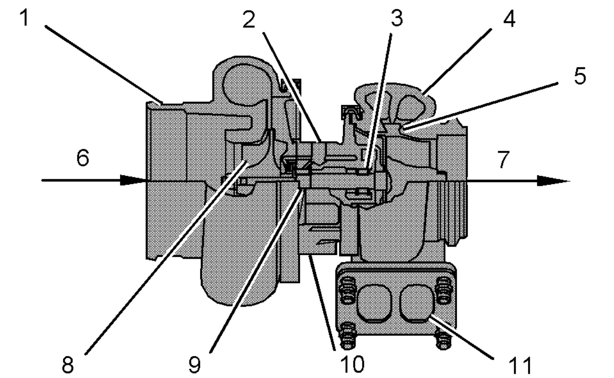

Illustration 14 g01114531

(1) Compressor housing
(2) Oil inlet port
(3) Bearing
(4) Turbine housing
(5) Turbine wheel
(6) Air inlet
(7) Exhaust outlet
(8) Compressor wheel
(9) Bearing
(10) Oil outlet port
(11) Exhaust inlet

The two turbochargers work together in order to produce boost across the entire engine RPM range. The increased boost at low RPM fills the combustion chamber with dense air. The dense air mixes with the fuel in order to promote a complete combustion.

The turbochargers have a compressor wheel (8) and a turbine wheel (5). The compressor wheel and the turbine wheel are connected to a common shaft. The shaft is supported by bearings (3 & 9). The bearings are lubricated by pressurized engine oil. The oil enters through oil inlet port (2). The engine oil lubricates the bearings and the oil removes heat. The oil returns to the oil pan through oil outlet port (10).

The high pressure turbocharger is equipped with a wastegate which is actuated by the boost from the low pressure turbocharger. The wastegate controls boost pressure. The wastegate is controlled by the pressure against the diaphragm in the canister for the wastegate. The canister consists of a spring and a diaphragm. The boost pressure creates a force against the diaphragm. The pressure against the diaphragm causes the diaphragm to move. The actuating lever is connected to the diaphragm. The movement of the actuating lever controls the position of the wastegate. The movement of the wastegate allows exhaust gases to bypass the turbine wheel. When the exhaust bypasses the turbine wheel the rotation of the compressor wheel slows down. Boost level is determined by the RPM of the compressor wheel.

Valve System Components

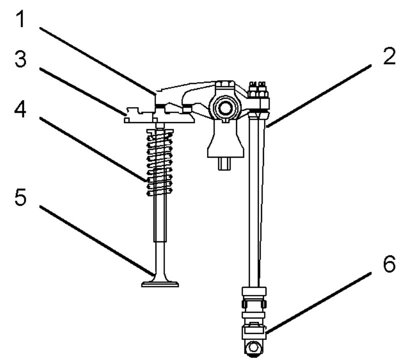

Illustration 15 g01114533

(1) Rocker arm
(2) Pushrod
(3) Valve bridge
(4) Valve spring
(5) Valve
(6) Lifter

The valve system components control the flow of inlet air into the cylinders and out of the cylinders during engine operation. The valve mechanism also operates the fuel injector.

The camshaft must be timed to the crankshaft in order to get the correct relation between the piston movement and the valve movement.

The camshaft has two camshaft lobes for each cylinder. The lobes operate the inlet and exhaust valves. As the camshaft turns, lobes on the camshaft cause lifters (6) to move pushrods (2) up and down. Upward movement of the pushrods against rocker arms (1) results in downward movement (opening) of valves (5).

Each cylinder has two inlet valves and two exhaust valves. The valves are actuated at the same time by a valve bridge (3). Valve springs (4) close the valves when the lifters move down.

Variable Valve Actuator

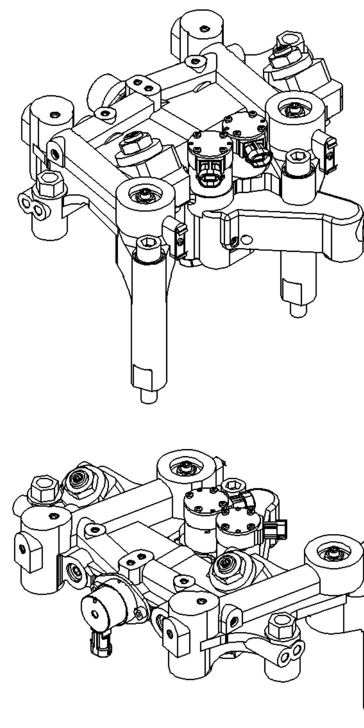

Illustration 16 g01114534

NOTICE

Do not disassemble the Variable Valve Actuator. There are no components of the Variable Valve Actuator that are serviceable. If the Variable Valve Actuator is disassembled, the warranty will be void.

The variable valve actuator and the Cat compression brake use engine oil for operation.

Variable Valve Actuator

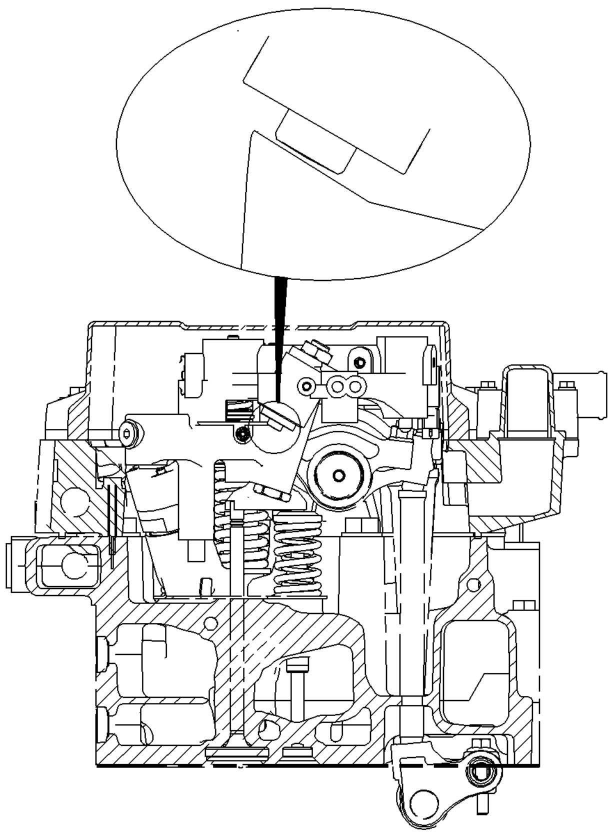

Illustration 17 g00948824

The variable valve actuator is used to control the closing of the inlet valves. The variable valve actuator does not operate until the engine has reached a desired temperature. The oil for the variable valve actuator flows from the oil filter base to the valve cover base. The oil bypass valve is located in the valve cover base. The bypass valve is open when the engine is below normal operating temperatures. The oil drains into the valve cover. The ECM is programmed to close the oil bypass valve at a preset temperature. When the valve closes the oil will flow into the housing of the variable valve actuator. The oil will fill the passageways for operation. The variable valve actuator exhausts a small quantity of oil at the base of the solenoids. The majority of the oil in the variable valve actuator is evacuated back into the oil supply rail.

The variable valve actuator holds the inlet valves open. The valves would normally close with the profile of the camshaft lobe. The solenoid is energized when the inlet valves are open. As the camshaft rotates the valves begin to close. The solenoid traps engine oil in the passageways. The trapped oil holds the plunger in the down position. The camshaft continues to rotate allowing the valves to close. The valves stop closing when the rocker arm makes contact with the plunger. This causes the inlet valve to remain slightly open.

Cat Compression Brake

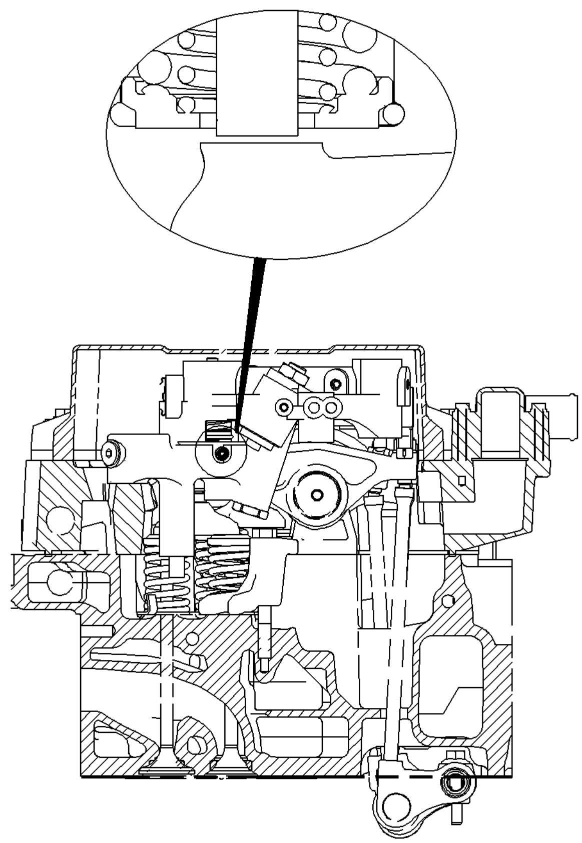

Illustration 18 g00948608

The Cat compression brake is used to slow the rotation of the engine. Pressure increases in the cylinder when the crankshaft is on the compression stroke. As the piston approaches top center the exhaust valves open and the pressure is released. The ECM controls the actuation of the Cat compression brake. The Cat compression brake can only be activated when the fuel delivery is shut off.

The engine oil for the Cat compression brake enters the variable valve actuator through the rocker shaft. The oil fills a passageway in the variable valve actuator. The Cat compression brake utilizes a master piston in order to actuate the slave piston. The master piston operates from the mechanical movement of the fuel injector rocker arm. The solenoid controls the outlet port. Oil pressure is not created when the port is open. When the port is closed the master piston creates pressure inside the housing. The oil pressure forces the slave piston downward. The downward movement causes the exhaust valves to open.

i02387310

Lubrication System

SMCS Code: 1300

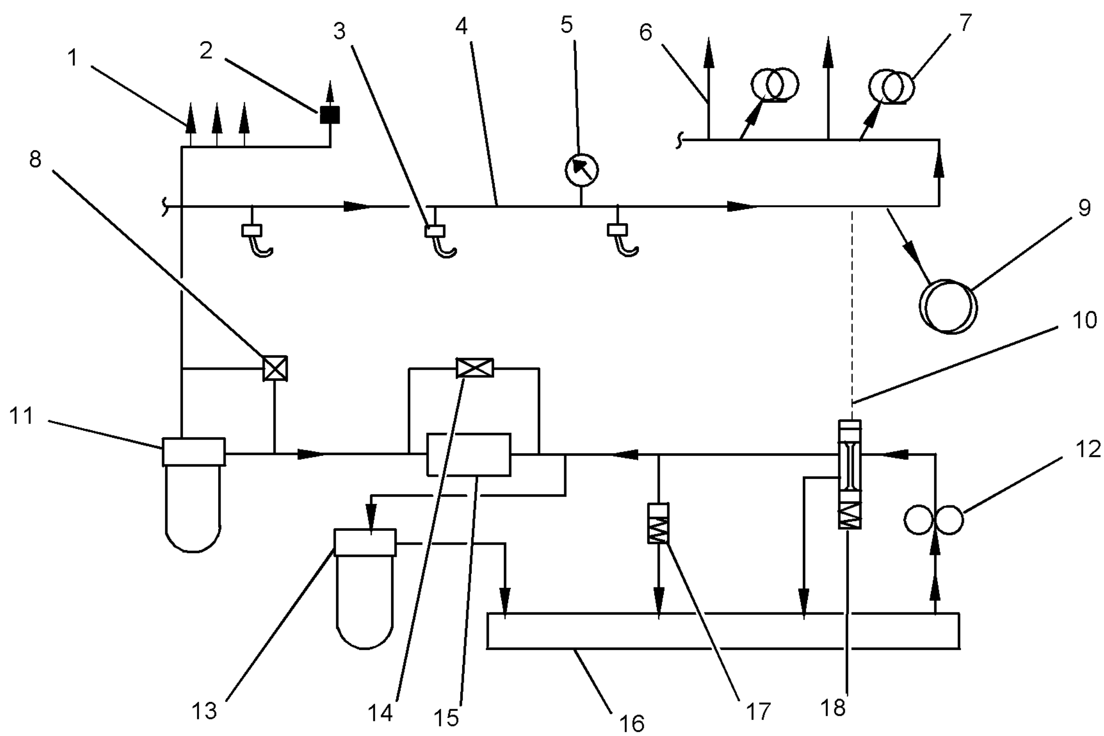

Illustration 19

g01113661

Lubrication system schematic

(1) Oil flow to Variable valve actuators
(2) Warm up valve
(3) Piston cooling jets
(4) Main oil gallery in cylinder block
(5) Engine oil pressure sensor
(6) Oil flow to valve mechanism and Cat compression brake (if equipped)
(7) Camshaft journals
(8) Oil filter bypass valve
(9) Main bearings
(10) Signal line
(11) Primary engine oil filter
(12) Engine oil pump
(13) Secondary oil filter
(14) Oil cooler bypass valve
(15) Engine oil cooler
(16) Oil pan sump
(17) High pressure relief valve
(18) Oil pump bypass valve

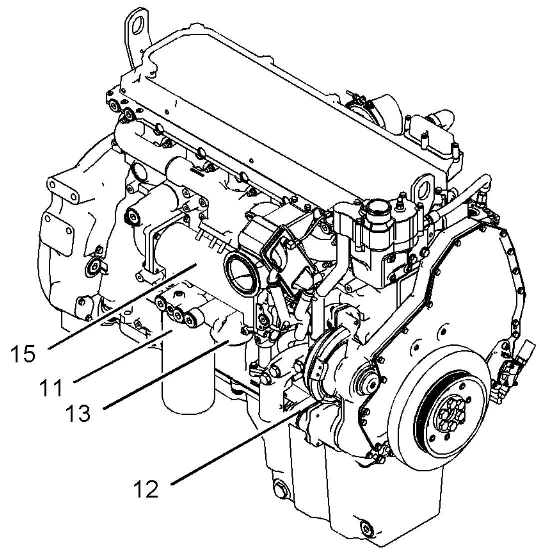

Illustration 20 g01113698

Typical example

Right side of engine

(11) Primary engine oil filter
(12) Engine oil pump
(13) Secondary oil filter (not shown)
(15) Engine oil cooler

The lubrication system supplies 110 °C (230 °F) filtered oil at approximately 275 kPa (40 psi) at rated engine operating conditions. Oil pump bypass valve (18) is controlled by the engine oil manifold pressure, rather than the oil pump pressure. The engine oil manifold pressure is independent of the pressure drop that is caused by the engine oil filter and the engine oil cooler.

Oil cooler bypass valve (14) maintains the engine oil temperature to 110 °C (230 °F). High pressure relief valve (17), which is located in the filter base, protects the filters and other components during cold starts. The opening pressure of the high pressure relief valve is 680 kPa (98 psi). Secondary oil filter (13) is a five micron filter which filters five percent of the oil flow before returning the oil to the sump. The opening pressure of the oil filter bypass valve is a pressure differential of 170 kPa (25 psi). Engine oil pressure sensor (5) is part of the engine protection system.

The turbocharger cartridge bearings are lubricated by the oil supply line from the main oil gallery, and the oil drain line returns the oil flow to the sump.

Oil Flow Through The Lubrication System

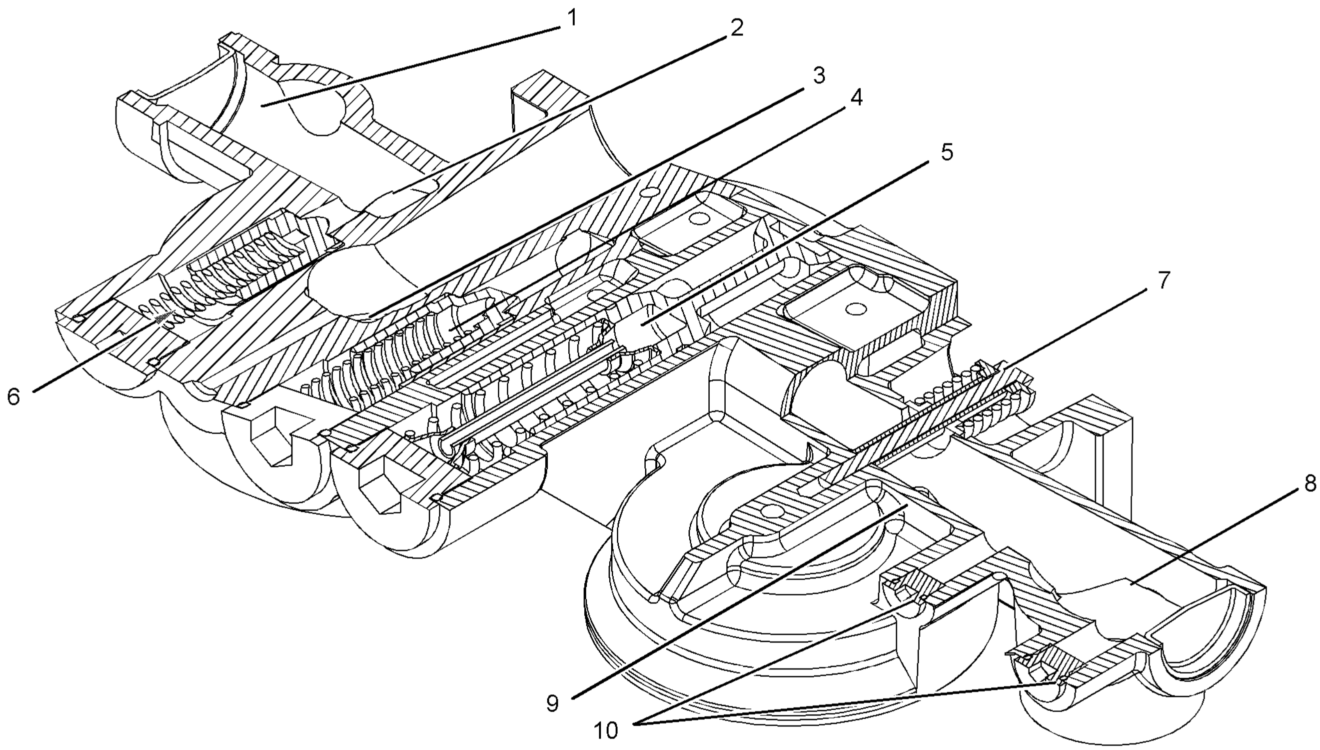

Illustration 21 g01114104

Oil filter base

(1) Oil from engine oil cooler
(2) Passage to engine oil filter
(3) Filtered oil
(4) Cooler bypass valve
(5) Bypass valve for the engine oil pump
(6) Engine oil filter bypass valve
(7) High pressure relief valve
(8) Oil from engine oil pump
(9) Passages to secondary oil filter
(10) S·O·S ports

The engine oil pump is mounted to the back of the front gear train on the lower right hand side of the engine. The engine oil pump is driven by an idler gear from the crankshaft gear. Oil is pulled from the sump through oil pump bypass valve (5) on the way to the engine oil cooler. The bypass valve controls the oil pressure from the engine oil pump. The engine oil pump can supply excess oil for the lubricating system. When this situation is present, the oil pressure increases and the bypass valve opens. The open bypass valve allows the excess oil to return to the sump.

High pressure relief valve (7) regulates high pressure in the system. The high pressure relief valve will allow the oil to return to the sump when the oil pressure reaches 680 kPa (98 psi). The fully open pressure for the high pressure relief valve is 695 kPa (100 psi). The oil then flows through the engine oil cooler. The engine oil cooler uses engine coolant in order to cool the oil. The oil cooler bypass valve (4) directs the oil flow through the engine oil cooler by two different methods.

Oil cooler bypass valve (4) will open when the oil pressure exceeds a pressure differential of 196 kPa (28 psi). Opening of the bypass valve will bypass the oil through the engine oil cooler. The bypass valve is fully open when the engine oil pressure reaches a pressure differential of 202 kPa (29 psi). This will allow engine oil to completely bypass the engine oil cooler.

Approximately five percent of the oil flow is directed through an orificed passage that leads to the secondary oil filter (if equipped). The oil flows through the bypass filter and to the engine oil sump. The main oil flow now flows toward the primary engine oil filter. The valve is fully open when the oil pressure differential across oil filter bypass valve (6) reaches 196 kPa (28 psi). This will allow the oil flow to bypass the primary engine oil filter. Then, the engine oil will lubricate the engine parts. The bypass valve provides immediate lubrication to the engine components when there is a restriction in the primary engine oil filter due to the following conditions:

- Cold oil with high viscosity
- Plugged primary engine oil filter

Note: Refer to Specifications, "Engine Oil Filter Base" for a cross section of the valves in the engine oil filter base.

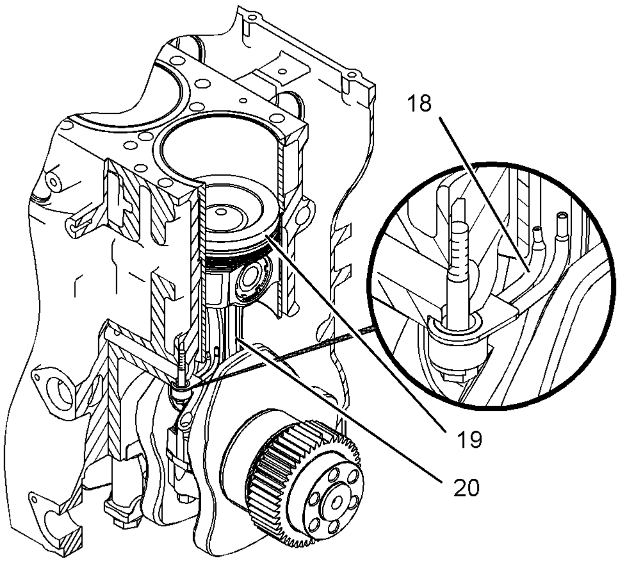

Illustration 22 g01113667

Interior of cylinder block

(18) Piston cooling jet
(19) Piston
(20) Connecting rod

Filtered oil flows through main oil gallery (2) in the cylinder block to the following components:

- Piston cooling jets (18)
- Valve mechanism
- Camshaft bearings
- Crankshaft main bearings
- Turbocharger

The piston cooling jets provide the underside of the piston with liberal amounts of oil. The oil is used to remove heat from the piston. The oil is also used as a lubricant.

The breather allows engine blowby to escape from the crankcase. The engine blowby is discharged into the atmosphere through a hose. This prevents pressure from building up that could cause seals or gaskets to leak.

i02392181

Cooling System

SMCS Code: 1350

Coolant Flow

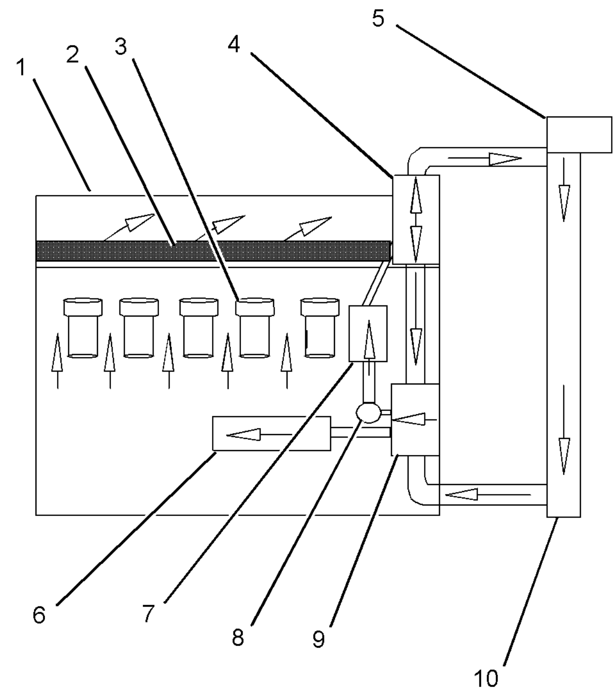

Illustration 23 g01024586

Cooling system schematic

(1) Cylinder head
(2) Return manifold
(3) Cylinder liners
(4) Temperature regulator housing
(5) Expansion tank
(6) Engine oil cooler
(7) Precooler
(8) Diverter valve
(9) Water pump
(10) Radiator

The water pump is gear-driven. The water pump is located on the right hand side of the engine. The water pump supplies the coolant for the engine cooling system. The coolant is supplied to the following components:

- Cylinder head (1)
- Cylinder liners (3)
- Precooler (7)
- Diverter valve (8)

- Engine oil cooler (6)
- Air compressor (not shown)
- Coolant conditioner element (not shown)

Note: In air-to-air aftercooled systems, a coolant mixture with a minimum of 30 percent ethylene glycol base antifreeze must be used for efficient water pump performance. This mixture keeps the cavitation temperature range of the coolant high enough for efficient performance.

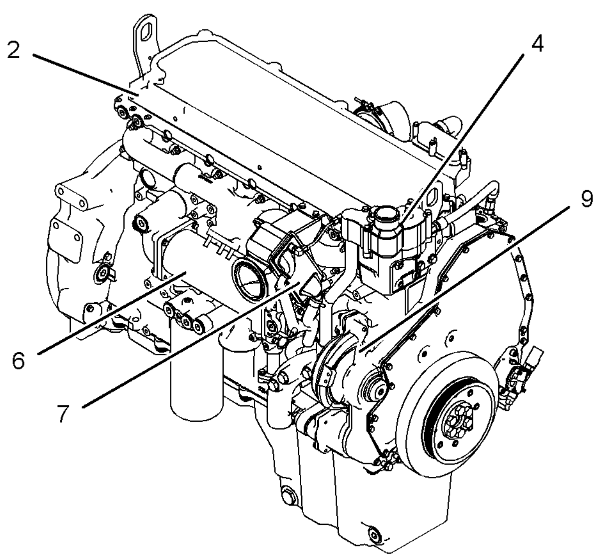

Illustration 24 g01113719

Typical right side of engine

(2) Return manifold
(4) Temperature regulator housing
(7) Precooler
(9) Water pump
(6) Engine oil cooler

Water pump (9) pulls the coolant from the bottom of radiator (10). The water pump is located on the right hand side of the front timing gear housing.

The water pump impeller rotates at 1.37 times the engine speed. The water pump is driven by an idler gear. The idler gear is turned by the crankshaft gear. The water pump shaft is supported by two ball bearings. One ball bearing is located in the water pump housing. The other ball bearing is located in the front timing gear housing. The water pump impeller face is open. The impeller and the rear cover is made out of cast iron. The water pump seal is a cartridge seal that is located on the inlet side of the water pump in order to provide good water flow around the seal for cooling.

The coolant is pumped through engine oil cooler (6). Some of the coolant from the water pump (9) is directed toward the precooler (7). If the coolant temperature is below 80 °C (176 °F), the solenoid is energized, and coolant is blocked from the precooler. If the coolant temperature is above 80 °C (176 °F), the diverter valve (8) is open. Coolant flows through precooler (7) when the diverter valve opens in order to cool the compressed intake air. The precooler is a heat exchanger that removes heat from the compressed air from the turbocharger. The remaining coolant flows to the supply manifold. The supply manifold, which is located in the cylinder block, distributes coolant around the upper portion of the cylinder liners. At each cylinder, the coolant flows from the cylinder liner to the cylinder head. The cylinder head is divided into single cylinder cooling sections. In the cylinder head, the coolant flows across the center of the cylinder and across the injector seat boss. At the center of the cylinder, the coolant flows around the injector sleeve over the exhaust port. The coolant then exits into return manifold (2). The return manifold collects the coolant from each cylinder and the return manifold directs the flow to temperature regulator housing (4). When the coolant temperature regulator is in the closed position, the coolant flows through the coolant temperature regulator. This allows the coolant to flow directly back to the water pump for recirculation by bypassing the radiator. When the coolant temperature regulator is in the open position, the coolant is directed through the radiator and back to the water pump inlet.

Supply Manifold

Cooling is provided for only the portion of the cylinder liner above the seal in the cylinder block. The coolant enters the cylinder block at each cylinder through slits in the supply manifold. The supply manifold is an integral casting in the cylinder block. The coolant flows around the circumference of the cylinder liner and into the cylinder head through a single drilled passage for each liner. The coolant flow is split at each cylinder liner so that 60 percent flows around the cylinder liner and the remainder flows directly to the cylinder head.

Temperature Regulator Housing

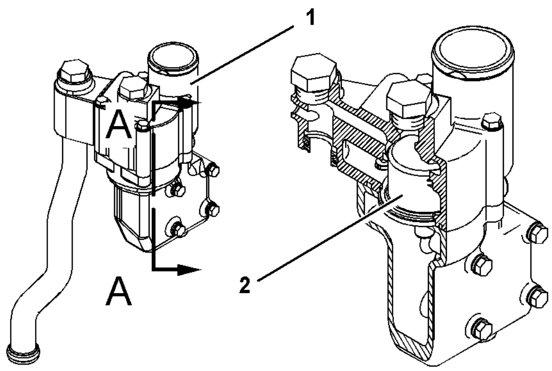

Illustration 25 g01113720

Typical right front side of engine

(1) Temperature regulator housing
(2) Coolant temperature regulator

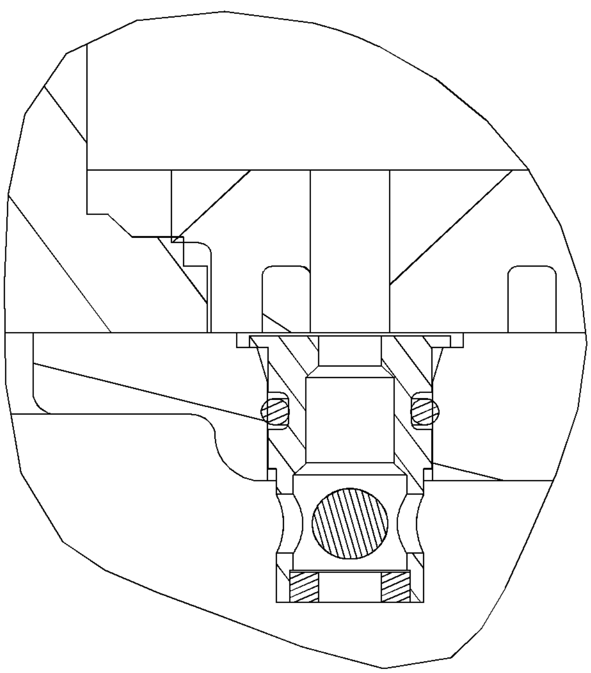

Illustration 26 g01194969

Proper orientation of the vent valve

The coolant temperature regulator is a full flow bypass type that is used to control the outlet temperature of the coolant. When the engine is cold, the coolant temperature regulator is in the closed position. This allows the coolant to flow through the coolant temperature regulator from the return manifold. This allows the coolant to bypass the radiator. The coolant goes directly to the water pump for recirculation. As the coolant temperature increases, the coolant temperature regulator begins to open directing some of the coolant to the radiator and bypassing the remainder to the water pump inlet. At the full operating temperature of the engine, the coolant temperature regulator moves to the open position. This allows all the coolant flow to be directed to the radiator. The coolant then goes to the water pump. This route provides the maximum heat release from the coolant. A vent line is recommended from the manifold to the radiator overflow tank in order to provide venting for the cooling system. The recommended vent line is a #4 Aeroquip.

Coolant Conditioner (If Equipped)

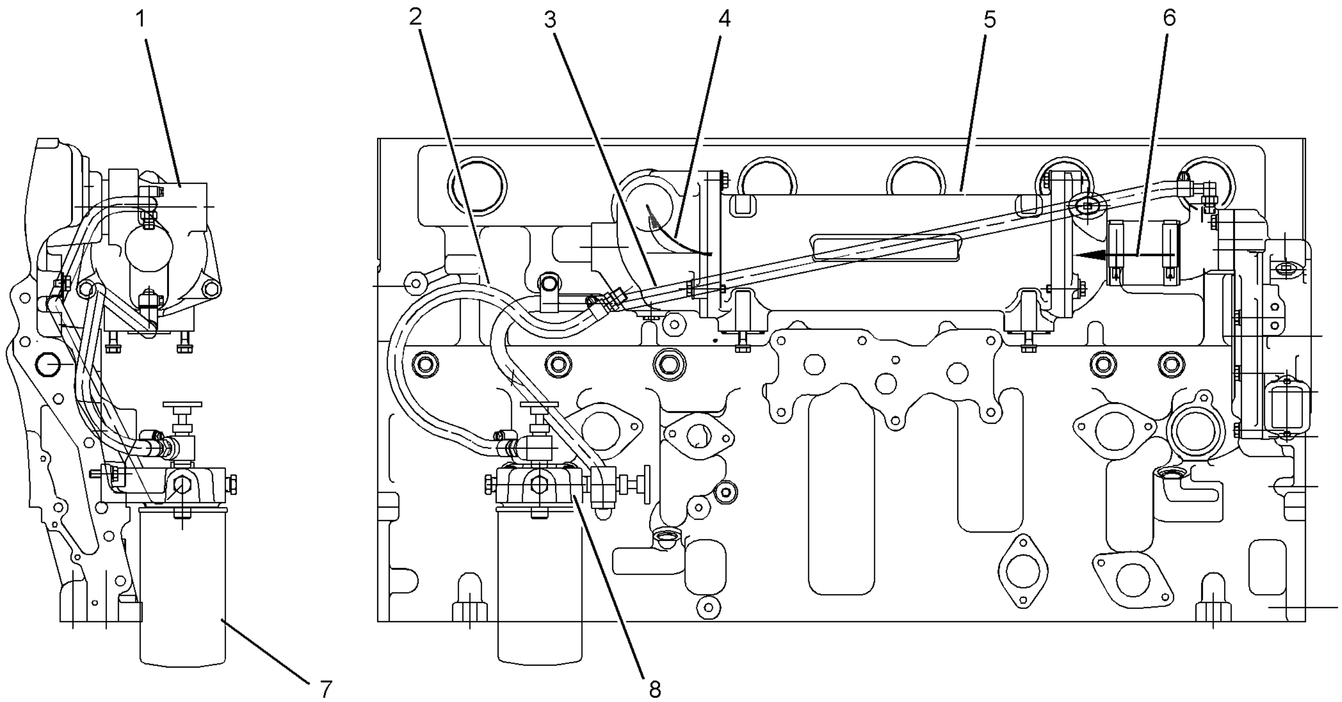

Illustration 27

g01113722

(1) Engine oil cooler elbow
(2) Outlet hose
(3) Inlet hose
(4) Coolant flow to cylinder head
(5) Engine oil cooler
(6) Coolant flow from water pump
(7) Coolant conditioner element
(8) Coolant conditioner base

Some conditions of operation can cause pitting on critical engine components. This pitting is caused by corrosion or by cavitation erosion. The addition of a corrosion inhibitor can keep this type of damage to a minimum.

Coolant conditioner element (7) is a spin-on element that is similar to the fuel filter and to the engine oil filter elements. The coolant conditioner element attaches to coolant conditioner base (8) that is mounted on the engine. Coolant flows from the water pump through inlet hose (3) and into the coolant conditioner base. The coolant that is conditioned then flows through outlet hose (2) into engine oil cooler elbow (1). There is a constant flow through the coolant conditioner element.

The element has a specific amount of inhibitor for acceptable cooling system protection. As the coolant flows through the element, the corrosion inhibitor, which is a dry material, disperses into the coolant. The coolant and the inhibitor are mixed to the correct concentration. Two basic types of elements are used for the cooling system, the precharge and the maintenance elements. Each type of element has a specific use. Each type of element must be used correctly to get the necessary concentration for cooling system protection. The elements also contain a filter. Even after the conditioner material is dispersed, the elements should be left in the system so the coolant flows through the filter.

The precharge coolant conditioner element has more than the normal amount of corrosion inhibitor. The precharge coolant conditioner element is used when a system is first filled with new coolant. This element must add enough corrosion inhibitor in order to bring the complete cooling system up to the correct concentration.

The maintenance elements have a normal amount of inhibitor and the maintenance elements are installed at each change interval. The maintenance elements provide enough inhibitor in order to keep the corrosion protection at an acceptable level. In order to provide the cooling system with protection, maintenance elements are installed at specific intervals.

Coolant for Air Compressor

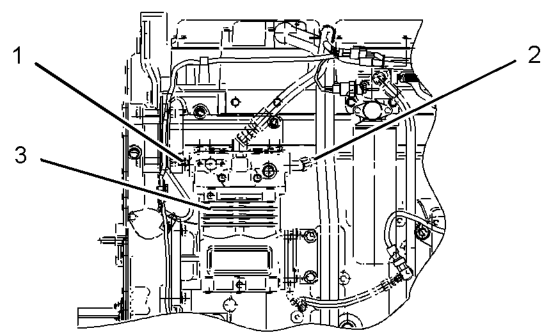

Illustration 28 g01113724

Typical air compressor

(1) Outlet hose
(2) Inlet hose
(3) Air compressor

The coolant that is used for air compressor (3) comes from the cylinder head through inlet hose (2). The coolant exits the air compressor through outlet hose (1) and flows back to the cylinder head.

i02169374

Basic Engine

SMCS Code: 1200

Cylinder Block

The cylinder block is a unique design with a deep counterbore that supports the cylinder liner. The cylinder block also forms the coolant jacket. Two oil manifolds are provided in the cylinder block for engine lubrication. The manifold on the lower right side of the cylinder block provides oil to the following components:

- Piston cooling jets
- Crankshaft bearings
- Oil filter base

The manifold on the upper left side of the cylinder block provides oil to the following components:

- Camshaft bearings
- Valve mechanism

The manifold on the right supplies oil to the manifold on the left. The oil travels through the cut above the number one main bearing and the cut above the number four main bearing.

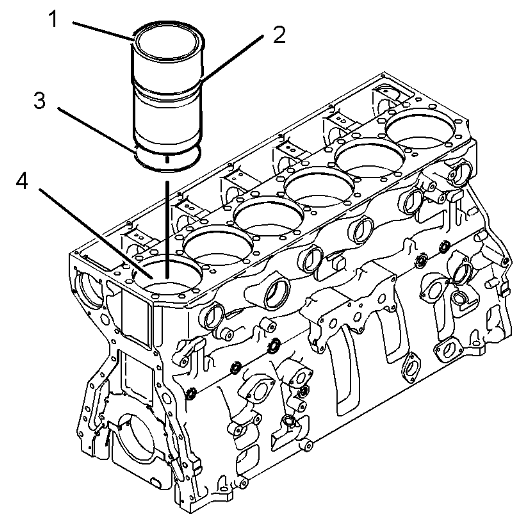

Illustration 29 g01099436

Cylinder liners (1) are seated on a ridge (4) in the middle of the cylinder wall between the crankcase and the coolant jacket. The ridge is created by a counterbore in the cylinder block. The cylinder liners have a lip (2) which rests on the ridge. The seals of the coolant jacket are located in the upper regions and middle regions of the cylinder liners. The lower barrier uses a D-ring seal (3) that is located above the seating surface of the cylinder liner. The upper barrier is the head gasket which is above the coolant jacket.

The cylinder block has seven main bearings in order to support the crankshaft. Each main bearing cap is fastened to the cylinder block with two bolts.

Pistons, Rings, and Connecting Rods

The high compression ratio of the engine requires the use of a piston that is made of steel.

The pistons have three rings:

- Compression ring
- Intermediate ring
- Oil ring

The rings are located in grooves in the piston. The rings seal the crankcase from the combustion gases and the rings also provide control of the engine oil. The design of the compression ring is a barrel face with a plasma face coating. The design of the intermediate ring is a tapered shape and a chrome finish. The oil ring is double railed with a coil spring expander. The oil ring has a ground profile and a chrome finish.

The connecting rod is a conventional design. The cap is fastened to the shank by two bolts that are threaded into the shank. Each side of the small end of the connecting rod is machined at an angle of 12 degrees in order to fit within the piston cavity. This allows a larger surface area on the piston, and connecting rod in order to minimize bearing load.

Crankshaft

The crankshaft converts the linear motion of the pistons into rotational motion. The crankshaft drives a group of gears (front gear train) on the front of the engine. The front gear train provides power for the following components:

- Camshaft
- Water pump
- Engine oil pump
- Air compressor
- Fuel transfer pump
- Accessory drive

The crankshaft is held in place by seven main bearings. The oil holes and the oil grooves in the shell of the upper bearing supply oil to the connecting rod bearings. The oil holes for the connecting rod bearings are located at the following main bearing journals: 2, 3, 5, and 6.

Hydrodynamic seals are used at both ends of the crankshaft to control oil leakage. The hydrodynamic grooves in the seal lip move lubrication oil back into the crankcase as the crankshaft turns. The front seal is located in the front housing. The rear seal is installed in the flywheel housing.

Camshaft

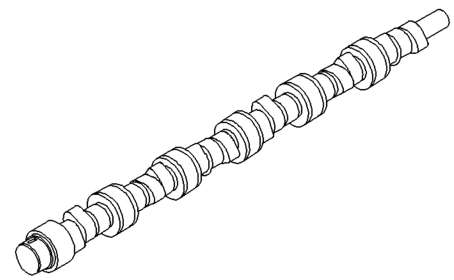

Illustration 30 g00762808

The camshaft has three lobes at each cylinder in order to operate the unit injector, the exhaust valves, and the inlet valves. Seven bearings support the camshaft. The camshaft is driven by an idler gear that is turned by the crankshaft in the front gear train. Each bearing journal is lubricated from the oil manifold in the cylinder block. A thrust pin that is located at the rear of the block positions the camshaft through a circumferential groove. The groove is machined at the rear of the camshaft. Timing of the camshaft is accomplished by aligning marks on the crankshaft gear, idler gear, and camshaft gear with each other.

The injector lobe on the camshaft has a modified profile. The modified profile produces multiple injections.

Vibration Damper

The force from combustion in the cylinders and from driveline components will cause the crankshaft to twist. This is called torsional vibration. If the vibration is too great, the crankshaft will be damaged. Driveline components can excite torsional stress. This stress will cause damage to components. The vibration damper limits the torsional vibrations to an acceptable amount in order to prevent damage to the crankshaft.

The viscous vibration damper is installed on the front of the crankshaft. The viscous vibration damper has a weight in a case. The space between the weight and the case is filled with a viscous fluid. The weight moves in the case in order to limit the torsional vibration.

Rear Power Take-Off (If Equipped)

The Rear Power Take-Off (RPTO) is an integral part of the flywheel housing. The RPTO provides continuous live power through a series of direct drive gears. The direct drive has the following gears: crankshaft gear, idler gear, and output shaft gear. The gears are driven off the rear of the crankshaft. The camshaft will increase the length of the engine by 89 mm (3.5 inch). Approximately, 73 Kg (160 lb) is added to the weight of the engine.

The gear train is capable of handling up to 1108 N·m (815 lb ft) of torque throughout the full engine speed range (idle to rated rpm). The RPTO has a ratio of 1.3:1. The output shaft end play is controlled with a rotating thrust plate and two stationary hydrodynamic thrust washers.

Oil is fed by pressure through drilled passages in the flywheel housing and shafts. This will lubricate all bearings and thrust surfaces. The gears are lubricated by splashing oil. No additional preventive maintenance or adjustment is necessary with the RPTO.

The design of the RPTO allows the use of the 9S-9082 Engine Turning Tool from the right side of the flywheel housing. However, the timing bolt location is on the left side of the flywheel housing.

i02377617

CAT Compression Brake

SMCS Code: 1119; 1129

The Cat compression brake is controlled by the Engine Control Module (ECM). The Cat compression brake helps the operator to slow the vehicle on grades, in curves, or for a necessary speed reduction. The service brakes should not be used continuously on long descending grades. The service brakes are assisted by the Cat compression brake. The engine crankshaft is turned by the rear wheels during downhill operation or during any slow down condition.

The crankshaft of the engine is rotated by the following components: Clutch, Transmission, Drive shaft, and Differential. A braking torque can be applied to the drive train of the vehicle in order to reduce the speed of the vehicle.

When the Cat compression brake is activated, braking power is accomplished by opening the engine's exhaust valves. The exhaust valves are opened near the top of the compression stroke in order to release the highly compressed air into the exhaust system. The Cat compression brake can only be activated when the engine is in the no-fuel position. Thus, combustion does not occur and no positive force is produced on the piston. The compressed air pressure that is released to the atmosphere prevents the energy from returning to the engine piston on the power stroke. The result is a loss of energy since the work that is done by the compression of the cylinder charge is not returned by the expansion process. This loss of energy is taken from the rear wheels. The rear wheels provide the braking action for the vehicle.

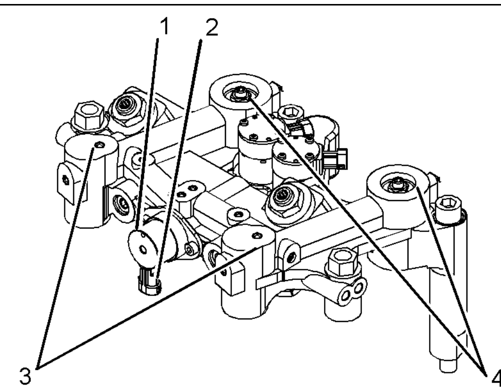

Illustration 31 g01113757

(1) Solenoid valve
(2) Valve connector
(3) Master cylinder
(4) Slave cylinder

The Cat compression brake consists of three identical housing assemblies. Each housing assembly is positioned over two cylinders. The housing assembly is mounted to the supports for the rocker arm shaft with studs and nuts. The rocker arm and the exhaust bridge assembly is used to transfer force from slave piston (3) to the exhaust valves. The brake logic signal for the Cat compression brake is carried to solenoid valve (1) by the lead wire. This is done in order to activate the Cat compression brake on the two cylinders of the engine.

The control circuit for the Cat compression brake permits the operation of either one, two, or all three of the compression brake housing assemblies. This provides progressive braking capabilities with the retarding effect of two cylinders, of four cylinders, or of all six cylinders in the engine.

Operation of the Cat Compression Brake

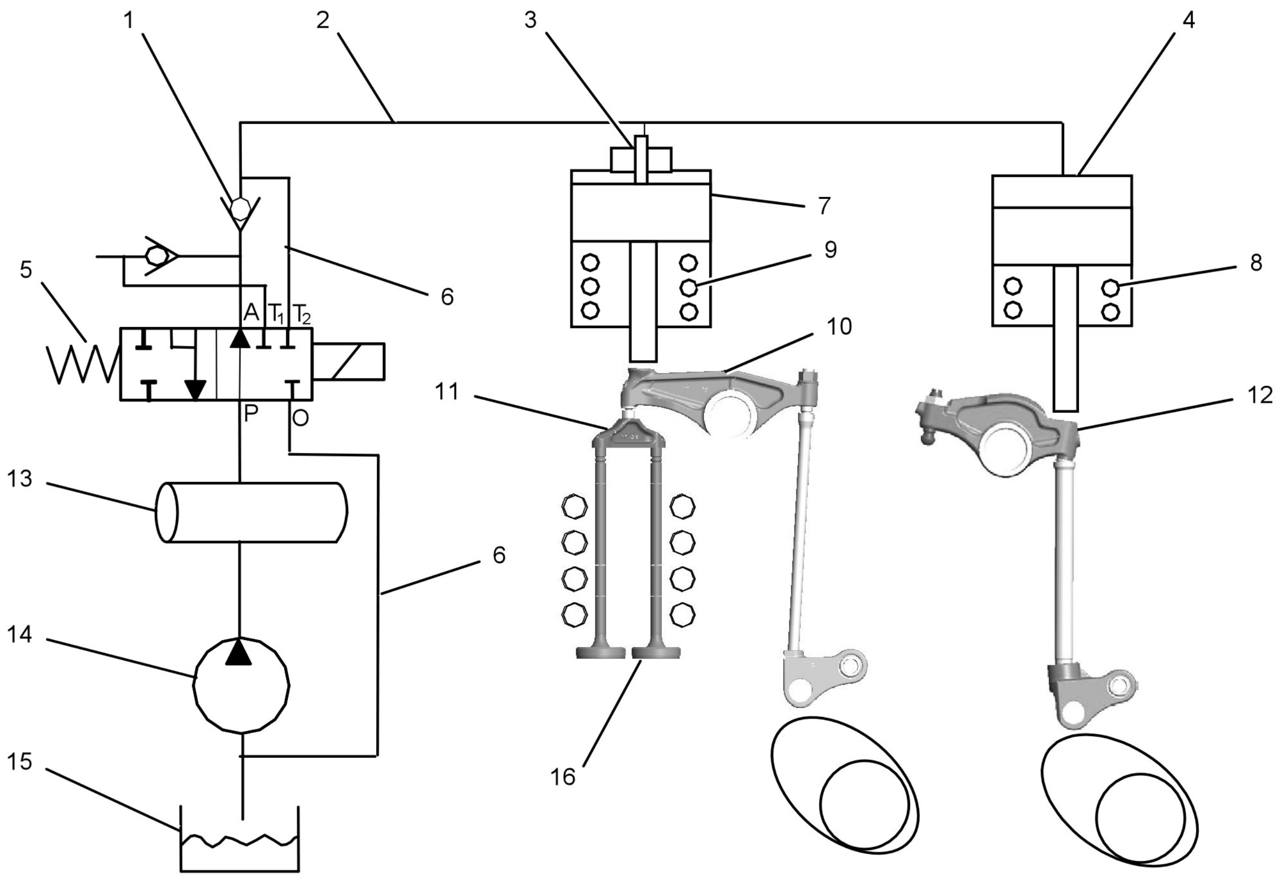

Illustration 32 g01126530

Schematic for master-slave circuit

(1) Check valve
(2) High pressure oil passage
(3) Slave piston adjustment screw
(4) Master piston
(5) Actuator valve
(6) Oil drain passage
(7) Slave piston
(8) Master piston spring
(9) Spring for the slave piston
(10) Exhaust rocker arm
(11) Exhaust bridge
(12) Fuel injector rocker arm
(13) Rocker arm shaft oil passage
(14) Engine oil pump
(15) Engine oil pan
(16) Exhaust valve
(A) Actuation port
(T1) Drain port
(T2) Drain port
(P) Actuator spool for supply port

The Cat compression brake is operated by engine oil that is distributed around the studs of the rocker shaft. This oil is supplied through the supports for the rocker shaft (13). Actuator valve (5) controls the oil flow in the compression brake housing.

When the actuator valve is activated by a signal from the ECM, low pressure oil passes from the actuator spool supply port (P) to the actuation port (A). The oil flow opens the check valve (1) and flows into the high pressure oil passage (2). Oil is supplied to the slave piston (7) and the master piston (4).

The oil pressure overcomes the spring (8) and the master piston moves toward the fuel injector rocker arm. Oil fills the passageway between the master piston and the slave piston. The master piston will follow the movement of the fuel injector rocker arm. The master piston moves upward with the fuel injector rocker arm. The movement of the master piston causes oil to close the check valve. The closed check valve causes pressure to increase in the hydraulic circuit of the master and slave piston.

The slave piston is forced downward. The slave piston makes contact with the exhaust valve rocker arm. The slave piston continues to apply a force to the exhaust valve rocker arm. This force causes the exhaust valves to open. As the exhaust valves open the cylinder pressure is relieved through the open exhaust valves. This creates a net braking force at the flywheel.

The fuel injector rocker arm continues to rotate and the master piston follows the motion. As the master piston moves downward the hydraulic pressure is decreased. The exhaust rocker arm completes the opening of the exhaust valves. The exhaust valves are returned to the closed position by the exhaust rocker arm. The slave piston is picked up by the exhaust rocker arm (10). The open check valve relieves the oil pressure. De-energizing the actuator valve allows the oil to drain from port (T1) and (T2). The exhaust valves close and the slave piston returns to the starting position.

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Electrical System

SMCS Code: 1400; 1550; 1900

Grounding Practices

Proper grounding for the engine electrical systems is necessary for proper engine performance and reliability. Improper grounding will result in uncontrolled electrical circuit paths and unreliable electrical circuit paths.

Uncontrolled engine electrical circuit paths can result in damage to main bearings, crankshaft bearing journal surfaces, and aluminum components.

To ensure proper functioning of the engine electrical systems, an engine-to-frame ground strap with a direct path to the negative battery post must be used. This may be provided by way of a starting motor ground, a frame to starting motor ground, or a direct frame to engine ground.

An engine-to-frame ground strap must be used in order to connect the grounding stud of the engine to the frame of the vehicle and to the negative battery post.

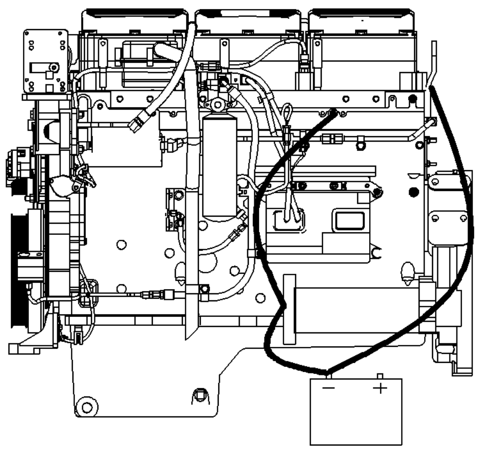

Illustration 33 g00766579

Typical example

Grounding Stud To Battery Ground (“-”)