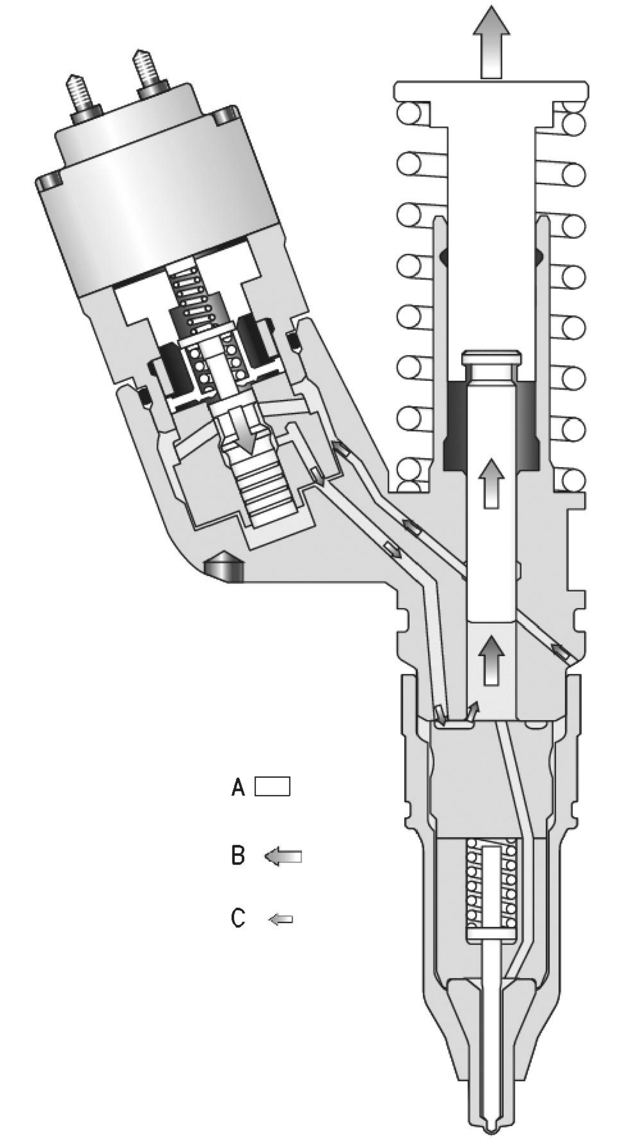

Illustration 12 g00942802

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

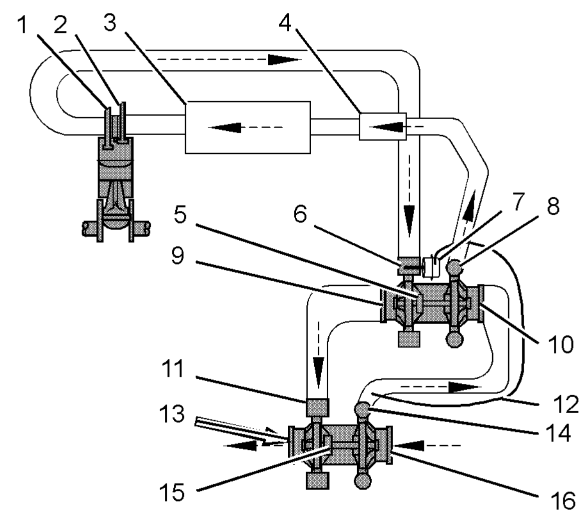

Illustration 13 g01180656

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

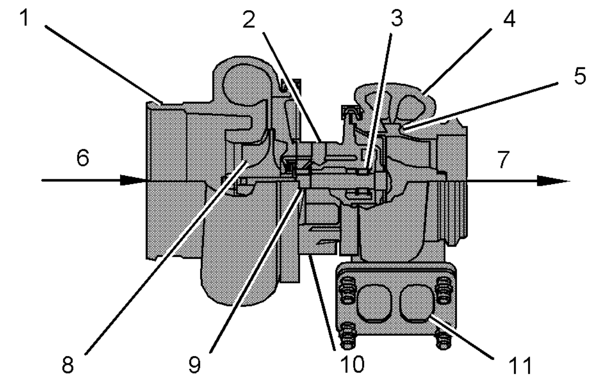

Illustration 14 g01114531

(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

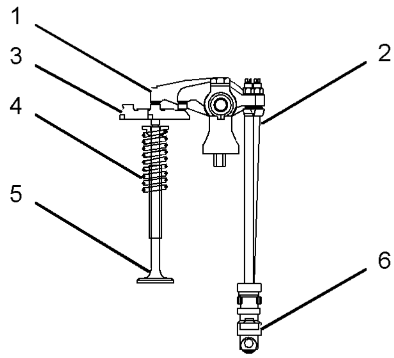

Illustration 15 g01114533

(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

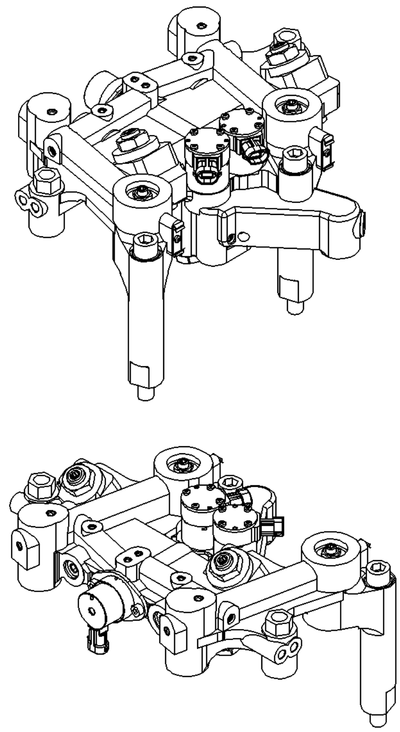

Illustration 16 g01114534

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

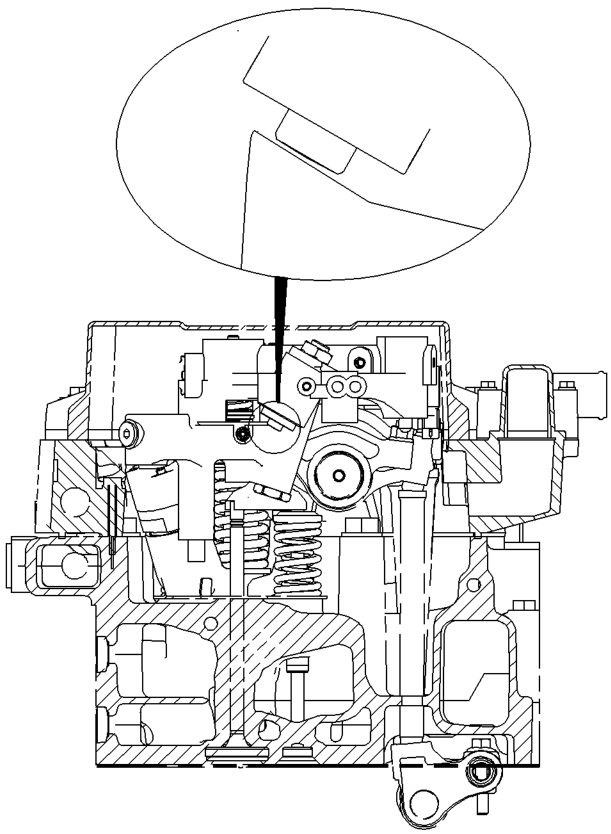

Illustration 17 g00948824

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

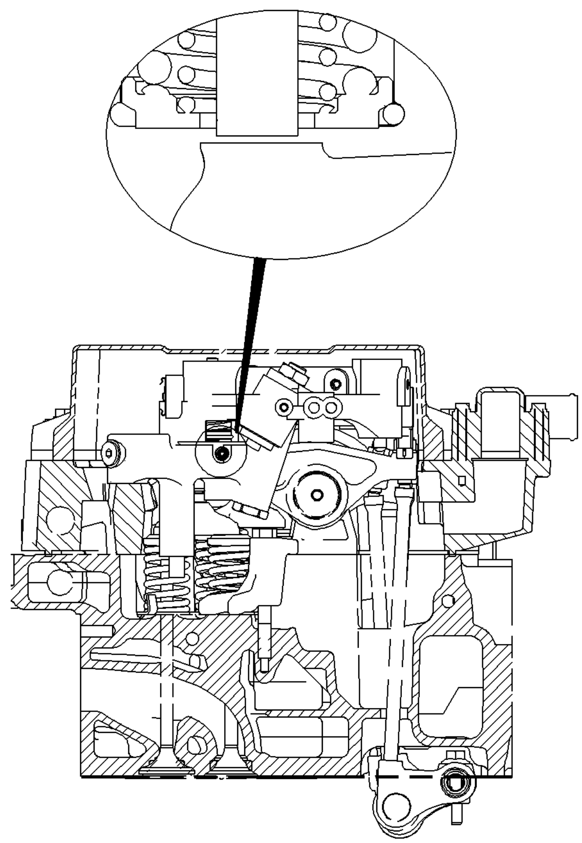

Illustration 18 g00948608

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

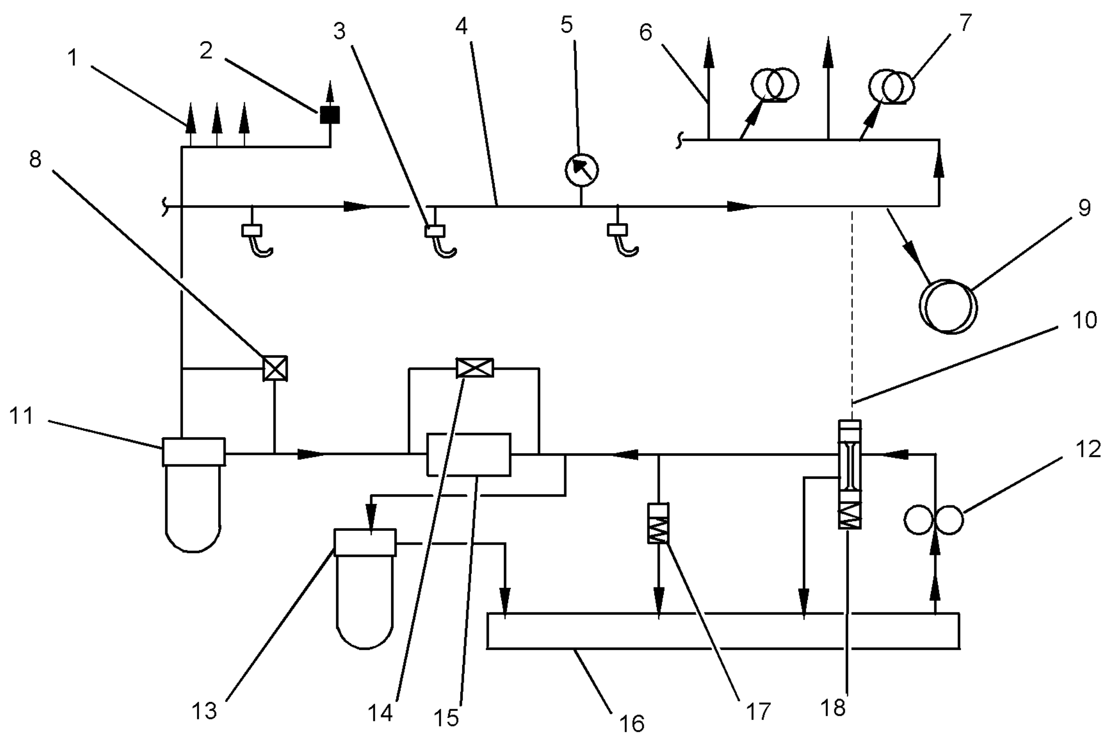

Illustration 19

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

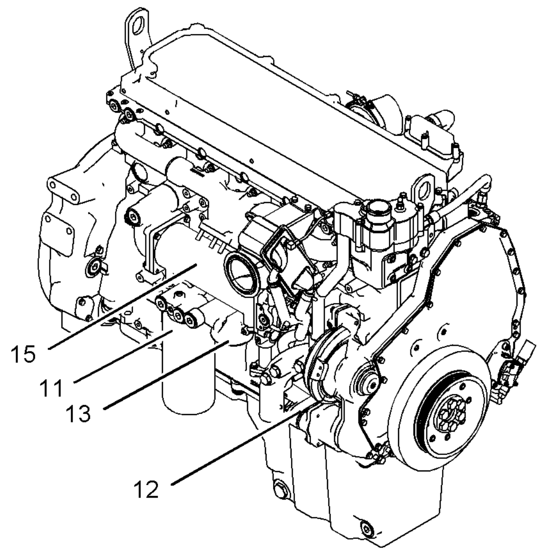

Illustration 20 g01113698

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

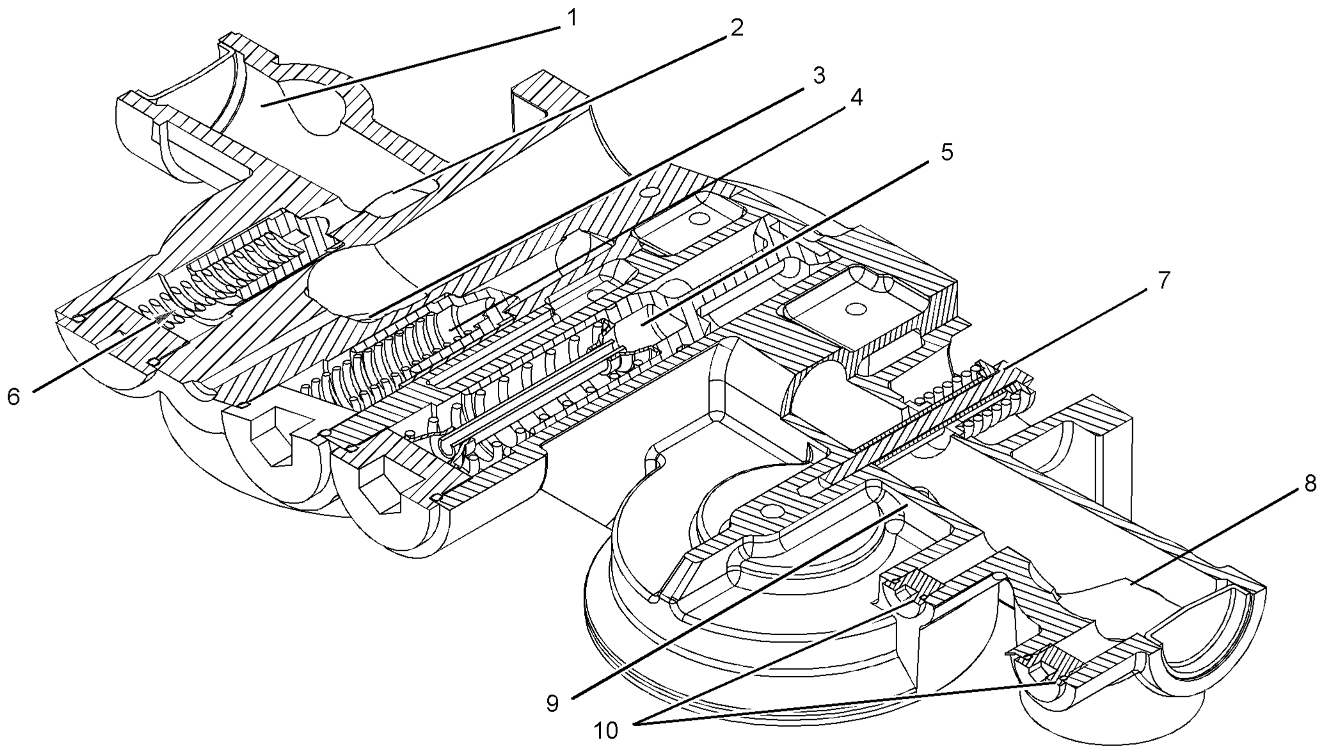

Illustration 21 g01114104

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.

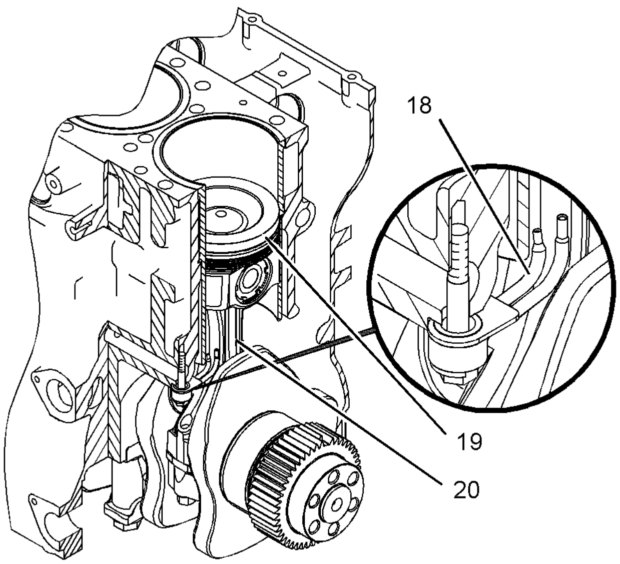

Illustration 22 g01113667

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

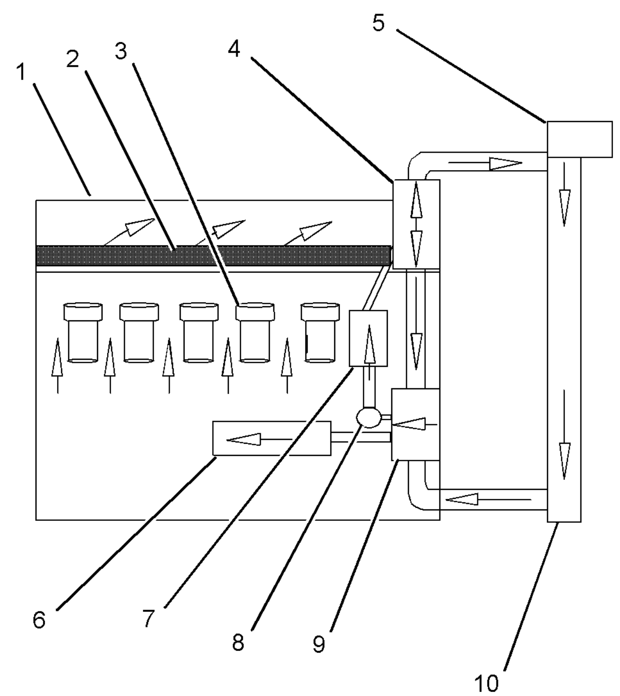

Illustration 23 g01024586

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)