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.

Perkins 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 Perkins 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. Perkins dealers or Perkins distributors have the most current information available.

WARNING

When replacement parts are required for this product Perkins recommends using Perkins replacement parts.

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

Table of Contents

Systems Operation Section

General Information

i01845923

Introduction

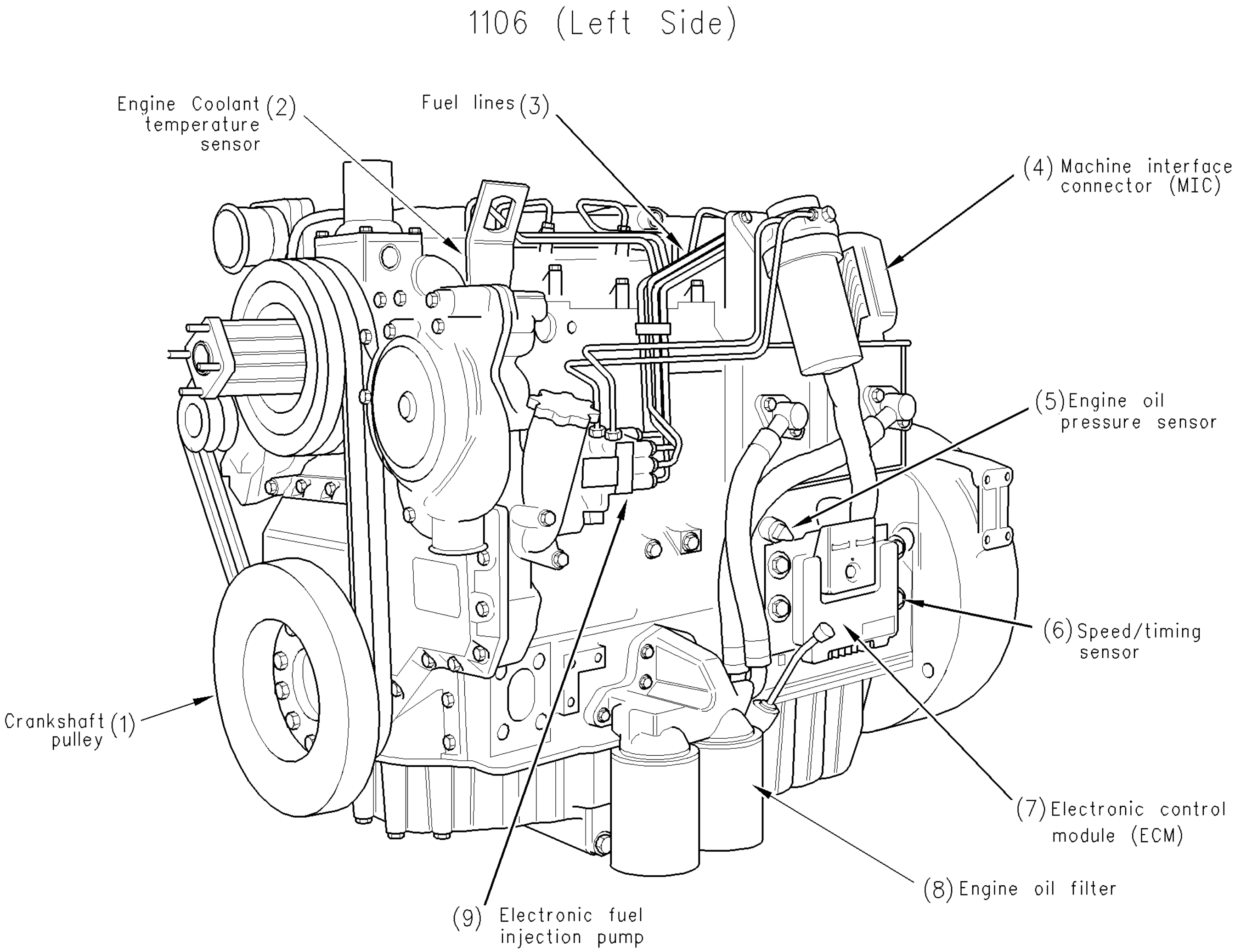

Illustration 1

g00940109

Left side view of the 1106 engine

Typical example of the 1106 engine

(1) Crankshaft pulley
(2) Engine coolant temperature sensor
(3) Fuel lines
(4) Machine interface connector (MIC)
(5) Engine oil pressure sensor
(6) Speed/timing sensor
(7) Electronic control module (ECM)
(8) Engine oil filter
(9) Electronic fuel injection pump

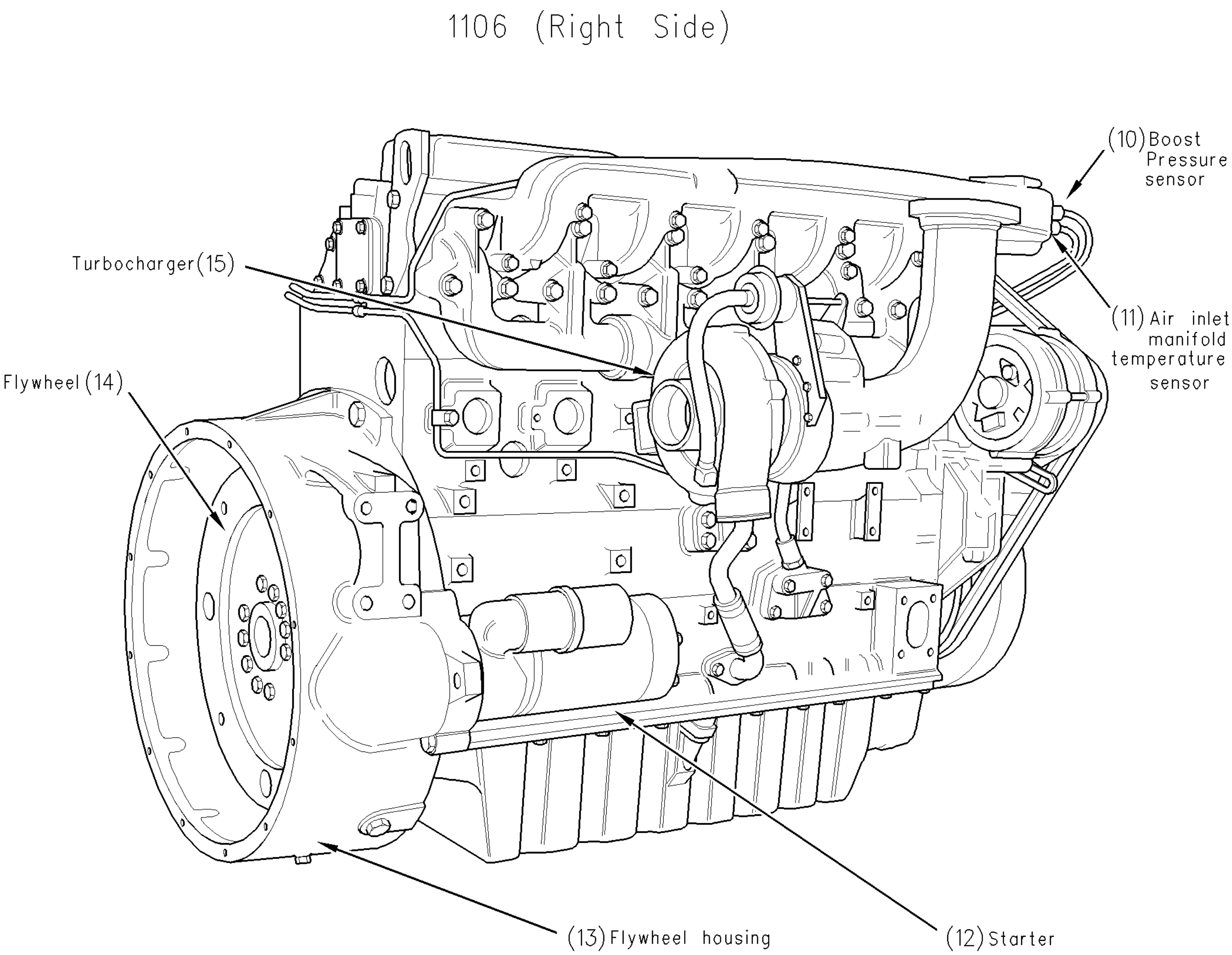

Illustration 2 g00940108

Right side view of the 1106 engine

Typical example of the 1106 engine

(10) Boost pressure sensor
(11) Air inlet temperature sensor
(12) Starter
(13) flywheel housing
(14) Flywheel
(15) Turbocharger

The 1106 diesel engine is electronically controlled. The 1106 engine uses an Electronic Control Module (ECM) to control a fuel injection pump. The pump supplies fuel to the fuel injection nozzles.

The six cylinders are arranged in-line. The cylinder head assembly has one inlet valve and one exhaust valve for each cylinder. The ports for the inlet and the exhaust valves are on the right side of the cylinder head. Each cylinder valve has a single valve spring.

Each cylinder has a piston cooling jet that is installed in the cylinder block. The piston cooling jet sprays engine oil onto the inner surface of the piston in order to cool the piston. The pistons have a Fastram combustion chamber in the top of the piston in order to provide an efficient mix of fuel and air. The piston pin is off-center in order to reduce the noise level.

The pistons have two compression rings and an oil control ring. The groove for the top ring has a hard metal insert in order to reduce wear of the groove. The skirt has a layer of graphite in order to reduce wear. The correct piston height is important in order to ensure that the piston does not contact the cylinder head. The correct piston height also ensures the efficient combustion of fuel which is necessary in order to conform to requirements for emissions.

A piston and connecting rod are matched to each cylinder. The piston height is controlled by the length of the connecting rod. Seven different lengths of connecting rods are available in order to attain the correct piston height. The different lengths of connecting rods are made by machining the small end bearing off-center in order to form an eccentric bearing. The amount of the eccentricity of the bearing creates the different lengths of the connecting rods. The crankshaft has seven main bearing journals. End play is controlled by thrust washers which are located on both sides of the center main bearing.

The timing case is made of aluminum. The timing gears are stamped with timing marks in order to ensure the correct assembly of the gears. When the number 1 piston is at the top center position on the compression stroke, the marked teeth of the following components will match the marks that are on the idler gear: crankshaft, camshaft, and fuel injection pump. There is no timing mark on the rear face of the timing case.

The crankshaft gear turns the idler gear which then turns the following gears:

- the camshaft gear
- the fuel injection pump
- a lower idler gear which turns the gear of the lubricating oil pump

The camshaft and the fuel injection pump run at half the rpm of the crankshaft. The cylinder block provides support for the full length of the dry cylinder liners. The cylinder liners are a press fit part. The cylinder liners are pressed into the cylinder block. The cylinder liners have a flame ring above the flange.

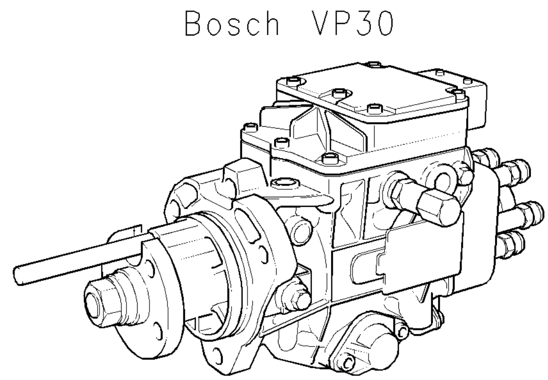

Illustration 3 g00910750

The Bosch VP30 fuel injection pump is installed on the engine. The pump conforms to current emissions. Both the pump timing and the high idle are preset at the factory. The pump is not serviceable. Adjustments to the pump timing and high idle should only be made by personnel which have had the correct training. The fuel injection pump uses the engine ECM to control the engine RPM.

The specifications for the 1106 refer to the Specifications, “Engine Design”.

Engine Operation

i01884420

Basic Engine

Introduction (Basic Engine)

The seven major components of the basic engine are the following parts:

- Cylinder block
- Cylinder head
- Pistons
- Connecting rods
- Crankshaft
- Vibration damper
- Timing gear case and gears
- Camshaft

Cylinder Block

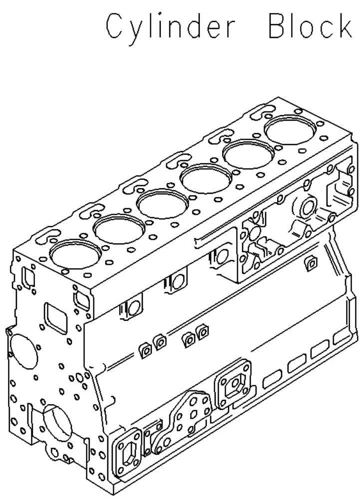

Illustration 4 g00896263

Cylinder block

The cylinder block is made of cast iron. The cylinder block provides support for the full length of the dry cylinder liners. Cylinder blocks have a flame ring above the cylinder liner flange.

The cylinder liners are made of cast iron. The production liners and the replacement liners are a press fit in the cylinder block. Both types of cylinder liners are honed to a specially controlled finish in order to ensure long life and low oil consumption.

The cylinder block has a bush that is installed for the front camshaft journal. The other camshaft journals run directly in the cylinder block.

D Plug

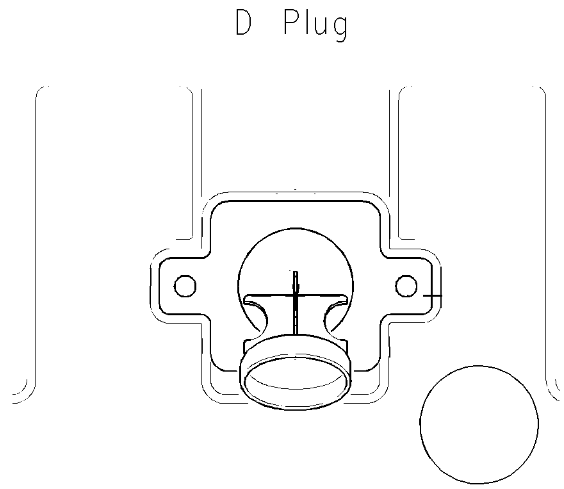

Illustration 5 g00901315

Pushrod side of the cylinder block that is showing the D plug

The D plugs are located on the pushrod side of the engine. The D plugs are in the engine block in order to block excessive amounts of oil. The D plug is intended to reduce the amount of oil through the breather hose. The pushrods fit in the cutout of the D plug.

Cylinder Head

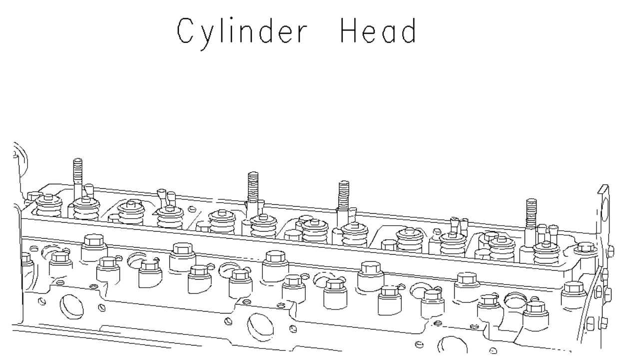

Illustration 6 g00901313

Cylinder head

The cylinder head assembly has one inlet valve and one exhaust valve for each cylinder. Each cylinder valve has a single valve spring. The valve and the valve spring are held in position by a valve spring cap and two collets.

The inlet valve and the exhaust valve move in phosphated guides. These valve guides can be replaced. There is an oil seal that fits over the top of valve guide.

The valve seats are replaceable. The ports for the inlet valve and the exhaust valves are on the right side of the cylinder head.

Pistons

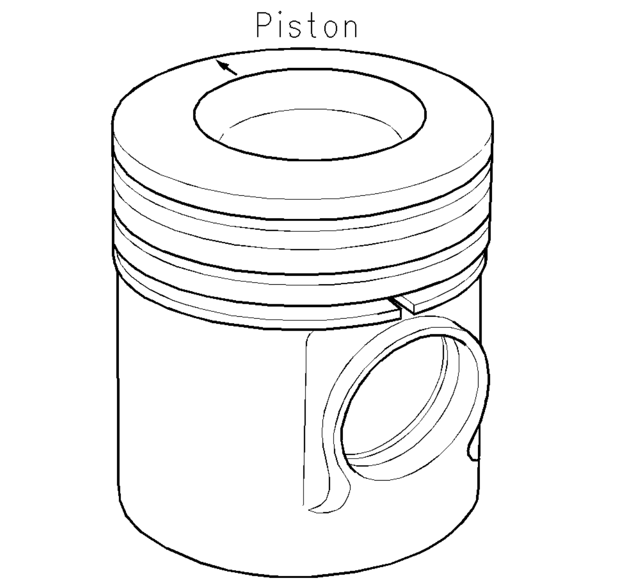

Illustration 7 g00907469

Piston

The pistons have a Fastram combustion chamber in the top of the piston. This chamber ensures an efficient mix of fuel and air.

The pistons have two compression rings and an oil control ring. The groove for the top ring has a hard metal insert that reduces wear of the groove. The skirt has a layer of graphite that reduces wear. The off-center piston pin reduces the noise level.

The engine has a piston cooling jet that is installed in the cylinder block for each cylinder. The piston cooling jet sprays lubricating oil onto the inner surface of the piston in order to cool the piston.

Connecting Rods

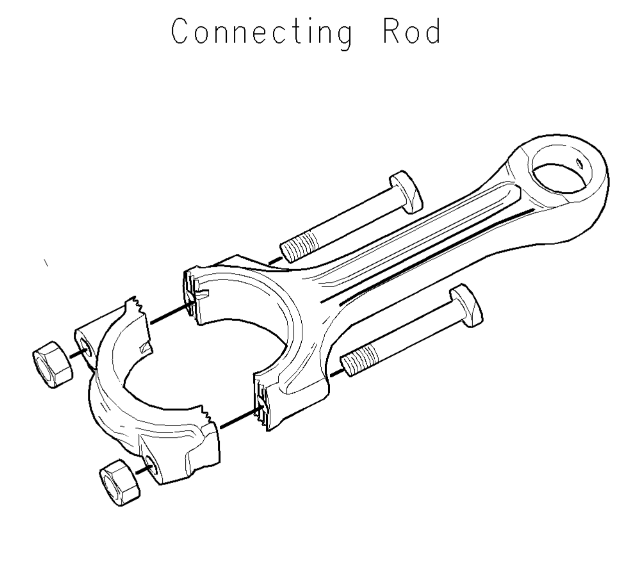

Illustration 8 g00898123

Connecting rod

The connecting rods are machined from forged molybdenum steel. The connecting rod has a small end that has the shape of a wedge.

The location of the bearing cap to the connecting rod is made by serrations in both the bearing cap and the connecting rod. The bearing cap is mounted to the connecting rod by two bolts and two nuts.

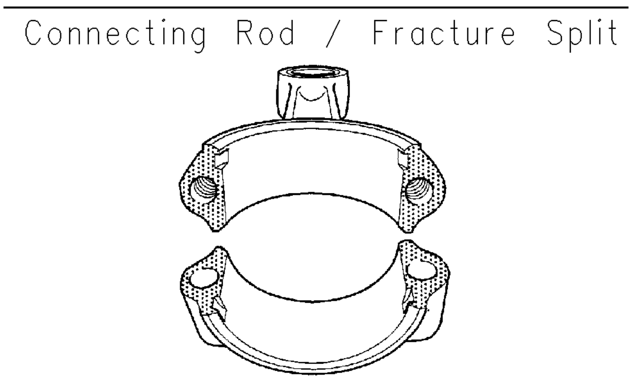

Illustration 9 g00919233

Fracture split of the connecting rod

Later engines are equipped with connecting rods that have a fracture split cap. The fracture split caps are retained with torx screws. Connecting rods that are fracture split have the following characteristics:

- Higher integrity for the rod

- The splitting produces an accurately matched surface on each side for improved strength.
- Modern design

Crankshaft

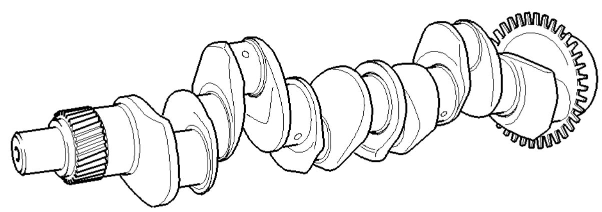

Illustration 10 g00976171

Crankshaft

The crankshaft is a chromium molybdenum forging. The crankshaft has seven main journals.

End play of the crankshaft is controlled by two half thrust washers that are located on both sides of the center main bearing.

The main bearings are made with a steel back and a bearing material. The bearing material is an alloy. The alloy is constructed of aluminum and of tin. The exception is the center main bearing, which is lead bronze with a lead finish. The main bearing caps are made of cast iron or spheroidal graphite (SG) iron.

Vibration Damper

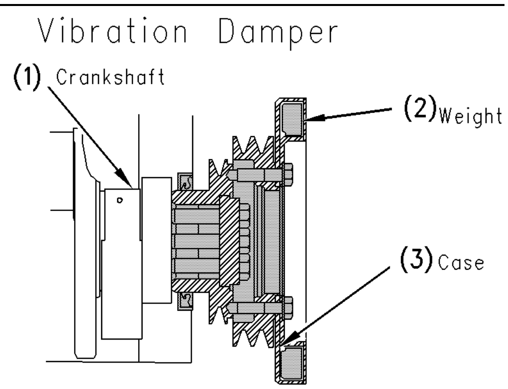

Illustration 11 g00904848

Vibration damper

(1) Crankshaft
(2) Weight
(3) Case

The force from combustion in the cylinders will cause the crankshaft to twist. This is called torsional vibration. If the vibration is too great, the crankshaft will be damaged. The vibration damper limits the torsional vibration. The vibration damper is designed as a viscous damper. The space between the weight and the case is filled with a viscous fluid.

Gears and Timing Gear Case

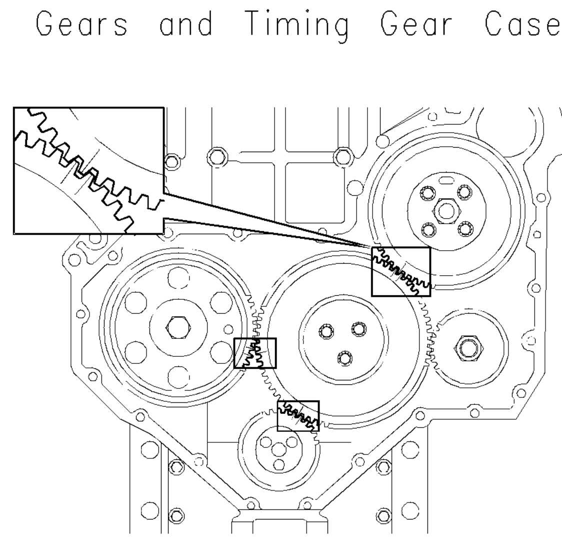

Illustration 12 g00901328

Timing gears

The timing case is constructed of either aluminum or cast iron. The aluminum cover of the timing case contains the front oil seal.

The timing gears are made of steel or cast iron.

The crankshaft gear drives an upper idler gear and a lower idler gear. The upper idler gear drives the camshaft and the fuel injection pump. The lower idler gear drives the oil pump. The water pump drive gear is driven by the fuel injection pump gear.

The camshaft and the fuel injection pump rotate at half the engine speed.

Camshaft

The engine has a single camshaft. The camshaft is made of cast iron. The camshaft lobes and the eccentric lobe for the priming pump are chill hardened.

The camshaft is driven at the front end. As the camshaft turns, the camshaft lobes move the valve system components. The valve system components move the cylinder valves.

The camshaft gear must be timed to the crankshaft gear. The relationship between the lobes and the camshaft gear causes the valves in each cylinder to open at the correct time. The relationship between the lobes and the camshaft gear also causes the valves in each cylinder to close at the correct time.

i01852849

Air Inlet and Exhaust System

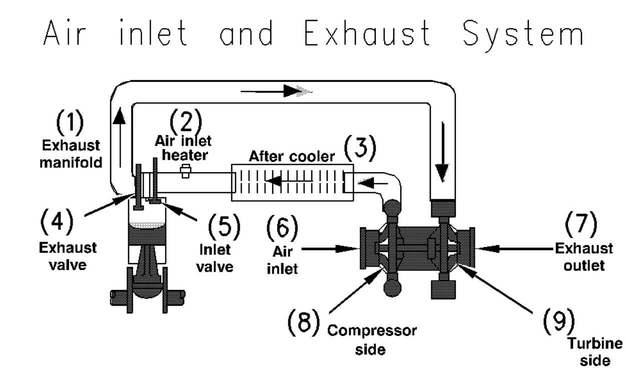

Illustration 13 g00904874

Air inlet and exhaust system

(1) Exhaust manifold
(2) Air inlet heater
(3) Aftercooler core
(4) Exhaust valve
(5) Inlet valve
(6) Air inlet
(7) Exhaust outlet
(8) Compressor side of turbocharger
(9) Turbine side of turbocharger

The components of the air inlet and exhaust system control the quality of air and the amount of air that is available for combustion. The components of the air inlet and exhaust system are the following components:

- Air cleaner
- Turbocharger
- Aftercooler
- Cylinder head
- Valves and valve system components
- Piston and cylinder
- Exhaust manifold

Air is drawn in through the air cleaner into air inlet (6) by turbocharger compressor wheel (8). The air is compressed and heated to about 150 °C (300 °F) before the air is forced to the aftercooler (3). As the air flows through the aftercooler the temperature of the compressed air lowers to about 50 °C (120 °F). Cooling of the inlet air increases combustion efficiency. Increased combustion efficiency helps achieve the following benefits:

- Lower fuel consumption
- Increased horsepower output
- Reduced particulate emission

From the aftercooler, air is forced into the inlet manifold. Air flow from the inlet chambers into the cylinders is controlled by inlet valves (5). There is one inlet valve and one exhaust valve for each cylinder. The inlet valves open when the piston moves down on the intake stroke. When the inlet valves open, cooled compressed air from the inlet port is pulled into the cylinder. The complete cycle consists of four strokes:

- Inlet
- Compression
- Power
- Exhaust

Exhaust gases from exhaust manifold (1) enter the turbine side of the turbocharger in order to turn turbocharger turbine wheel (9). The turbine wheel is connected to the shaft that drives the compressor wheel. Exhaust gases from the turbocharger pass through exhaust outlet (7), a muffler and an exhaust stack.

The air inlet heater aids in engine start-up and reducing white smoke during engine start-up.

Turbocharger

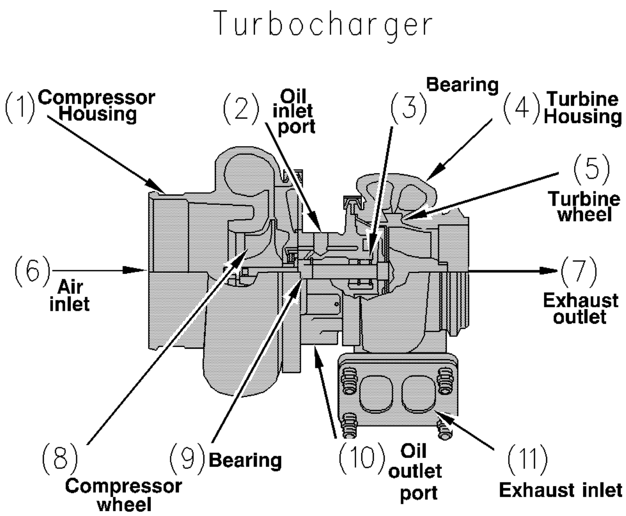

Illustration 14 g00904915

Turbocharger

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

The turbocharger is installed on the center section or on the top of the exhaust manifold. All the exhaust gases from the engine go through the turbocharger. The exhaust gases enter turbine housing (4) through exhaust inlet (11). The exhaust gases then push the blades of turbine wheel (5). The turbine wheel is connected by a shaft to compressor wheel (8).

When the load on the engine increases, more fuel is injected into the cylinders. The combustion of this additional fuel produces more exhaust gases. The additional exhaust gases cause the turbine and the compressor wheels of the turbocharger to turn faster. As the compressor wheel turns faster, more air is forced into the cylinders. The increased flow of air gives the engine more power by allowing the engine to burn the additional fuel with greater efficiency.

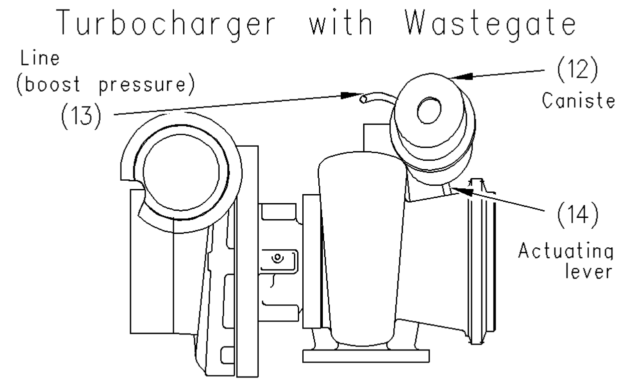

Illustration 15 g00907531

Turbocharger with the wastegate

(12) Canister
(13) Line (boost pressure)
(14) Actuating lever

The turbocharger has a wastegate. The wastegate helps improve the emissions of the engine. The operation of the wastegate is controlled by the boost pressure. At high boost pressures, the wastegate opens in order to decrease boost pressure. At low boost pressure, the wastegate closes in order to increase boost pressure.

When the engine is operating under conditions of low boost, a spring pushes on a diaphragm in canister (12). This action moves actuating lever (14) in order to close the valve of the wastegate. Closing the valve of the wastegate allows the turbocharger to operate at maximum performance.

As the boost pressure through line (13) increases against the diaphragm in canister (12), the valve of the wastegate is opened. When the valve of the wastegate is opened, the rpm of the turbocharger is limited by bypassing a portion of the exhaust gases. The exhaust gases are routed through the wastegate which bypasses the turbine wheel of the turbocharger.

Bearings (3) and (9) for the turbocharger use engine oil under pressure for lubrication and cooling. The oil comes in through oil inlet port (2). The oil then goes through passages in the center section in order to lubricate the bearings. This oil also cools the bearings. Oil from the turbocharger passes through oil outlet port (10) in the bottom of the center section. The oil then returns to the engine oil pan.

Valve System Components

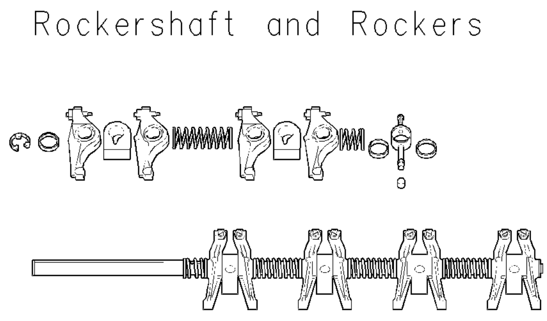

Illustration 16 g00907525

Rocker shaft and rockers

The valve system components control the flow of inlet air into the cylinders during engine operation. The valve system components also control the flow of exhaust gases out of the cylinders during engine operation.

The crankshaft gear drives the camshaft gear through an idler gear. The camshaft must be timed to the crankshaft in order to get the correct relation between the piston movement and the valve movement.

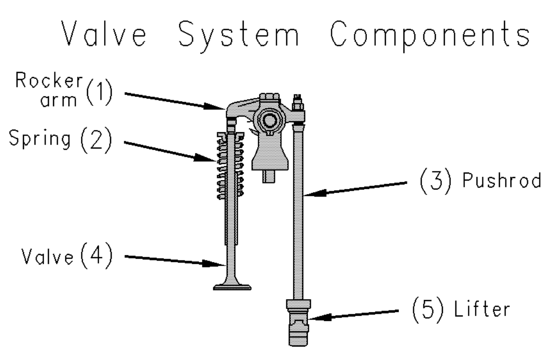

Illustration 17 g00904080

Valve system components

(1) Rocker
(2) Spring
(3) Pushrod
(4) Valve
(5) Lifter

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 lifter (5) to move pushrod (3) up and down. Upward movement of the pushrod against rocker arm (1) results in downward movement (opening) of valve (4).

Each cylinder has one inlet valve and one exhaust valve. The valve spring (2) closes the valve when the lifter moves down.

i01853824

Cooling System

Introduction (Cooling System)

The engine has a basic cooling System. The cooling system has the following components:

- Radiator
- Water pump
- Oil cooler
- Water temperature regulator (thermostat)

Coolant Flow

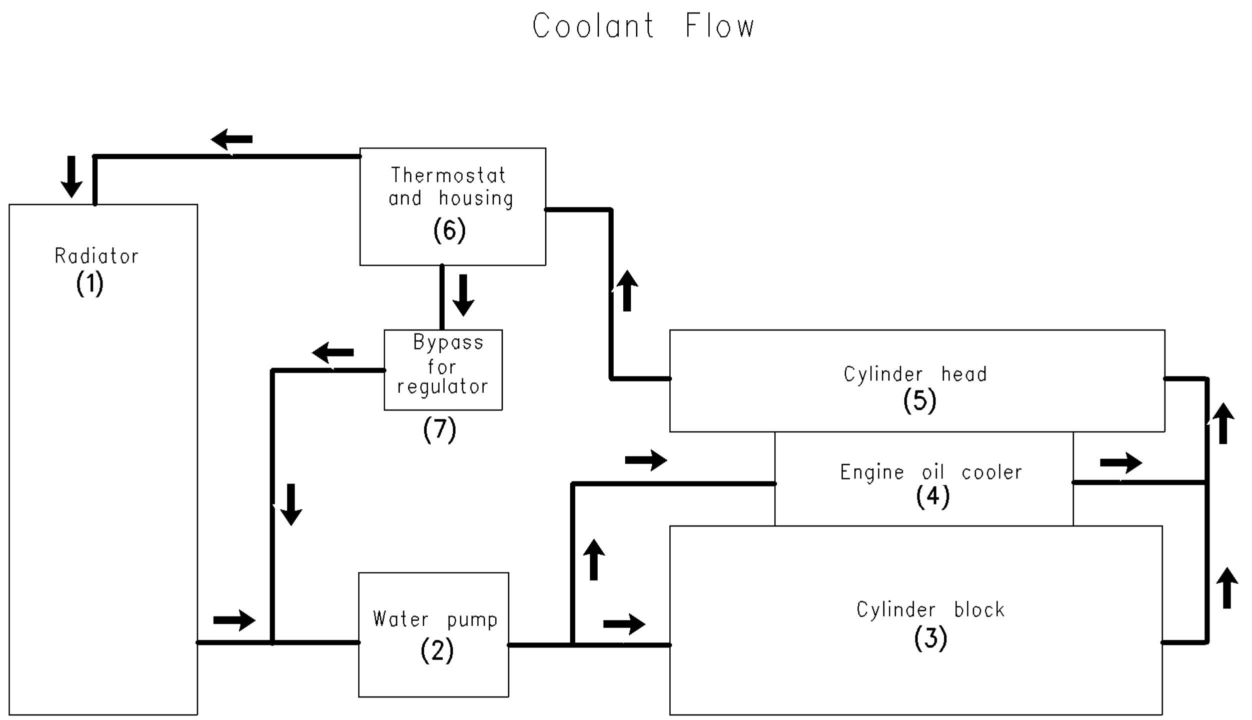

Illustration 18 g00896204

Coolant flow

(1) Radiator
(2) Water pump
(3) Cylinder block
(4) Engine oil cooler
(5) Cylinder head
(6) Water temperature regulator (thermostat) and housing
(7) Bypass for the water temperature regulator (thermostat)

The coolant flows from the bottom of the radiator to the centrifugal water pump. The water pump is installed on the front of the timing case. The water pump is driven by a gear. The gear of the fuel injection pump drives the water pump gear. The water pump forces the coolant through a passage in the timing case to the front of the cylinder block.

The coolant divides as the coolant enters the cylinder block. Most of the coolant flows along the right hand side of the cylinder block. The coolant then flows around the outside of the cylinders to the rear of the cylinder block.

The remainder of the coolant flows along a passage in the left side of the cylinder block to the oil cooler. The coolant flows around the element of the oil cooler to the rear of the cylinder block. The coolant then flows to the rear of the cylinder head.

The coolant flows forward through the cylinder head. The coolant then flows into the housing of the water temperature regulator. If the thermostat is closed, the coolant goes directly through a bypass to the inlet side of the water pump. If the thermostat is open, the bypass is closed and the coolant flows to the top of the radiator.

i01753649

Lubrication System

Pressure for the lubrication system is supplied by the engine oil pump which uses rotors. The engine oil pump is driven by an idler gear. The crankshaft gear drives the idler gear. The engine oil pump has an inner rotor and an outer rotor. The axis of rotation of the rotors are off-center relative to each other. There is a key between the inner rotor and the drive shaft.

The inner rotor has four lobes which mesh with the five lobes of the outer rotor. When the inner lobe rotates, the distance increases between the lobes of the outer rotor and the lobes of the inner rotor in order to create suction. When the distance decreases between the lobes, pressure is created.

Lubricating oil from the oil pan flows through a strainer and a pipe to the suction side of the engine oil pump. The lubricating oil flows from the outlet side of the pump through a pipe and a passage to the filter head. The oil then flows from the filter head through a pipe to a plate type oil cooler . The oil cooler is located on the left side of the engine. The oil cooler is a plate type oil cooler.

From the oil cooler, the oil returns through a pipe to the filter head. The oil then flows from the filter head to the bypass valve and from the bypass valve to the oil filter.

The oil flows from the oil filter through a passage that is drilled across the cylinder block to the oil gallery. The oil gallery is drilled through the total length of the left side of the cylinder block. If the oil filter is on the right side of the engine, the oil flows through a passage that is drilled across the cylinder block to the pressure gallery.

Lubricating oil from the oil gallery flows through high pressure passages to the main bearings of the crankshaft. Then, the oil flows through the passages in the crankshaft to the connecting rod bearing journals. The pistons and the cylinder bores are lubricated by the splash of oil and the oil mist.

Lubricating oil from the main bearings flows through passages in the cylinder block to the journals of the camshaft. Then, the oil flows from the second journal of the camshaft at a reduced pressure to the cylinder head. The oil then flows into the rocker arm bushing of the rocker arm levers. The valve stems, the valve springs and the valve lifters are lubricated by the splash and the mist of the oil.

The hub of the idler gear is lubricated by oil from the oil gallery. The timing gears are lubricated by the splash of the oil.

The turbocharger is lubricated by oil from the oil filter through the engine block. An external line from the engine block supplies oil to the turbocharger. The oil then flows through a line to the oil pan.

Piston cooling jets are installed in turbocharged engines. The piston cooling jets are supplied with the oil from the oil gallery. The piston cooling jets spray lubricating oil on the underside of the pistons in order to cool the pistons.

i01878711

Electrical System

The electrical system is a negative ground system.

The charging circuit operates when the engine is running. The alternator in the charging circuit produces direct current for the electrical system.

Starting Motor

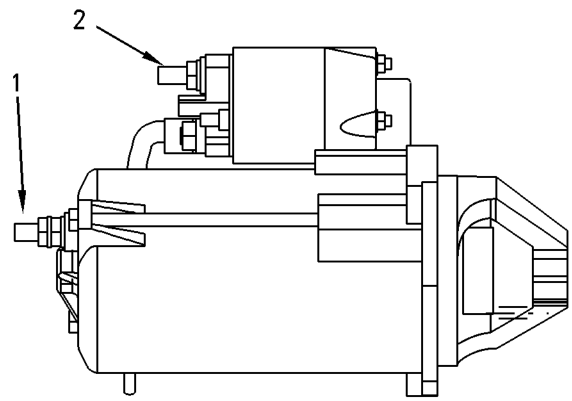

Illustration 19 g00954820

12 Volt Starting Motor

(1) Terminal for connection of the battery cable
(2) Terminal for connection of the ignition switch

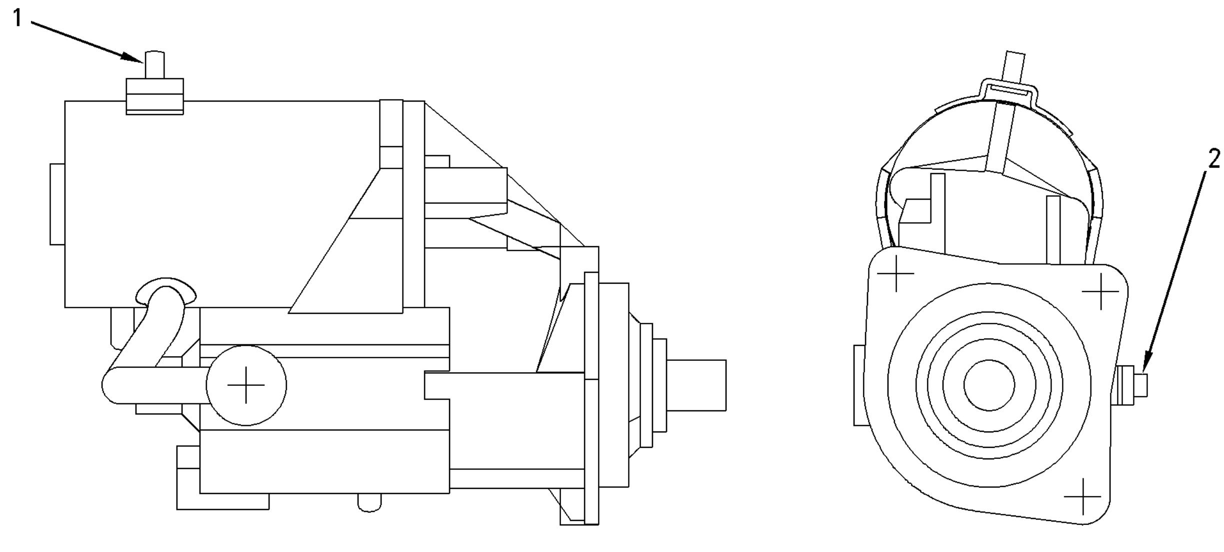

Illustration 20 g00956095

24 Volt Starting Motor

(1) Terminal for connection of the ignition switch

(2) Terminal for connection of the battery cable

The starting motor turns the engine flywheel. The rpm must be high enough in order to initiate a sustained operation of the fuel ignition in the cylinders.

The starting motor has a solenoid. When the ignition switch is activated, voltage from the electrical system will cause the solenoid to move the pinion toward the flywheel ring gear of the engine. The electrical contacts in the solenoid close the circuit between the battery and the starting motor barely before the pinion engages the ring gear. This causes the starting motor to rotate. This type of activation is called a positive shift.

When the engine begins to run, the overrunning clutch of the pinion drive prevents damage to the armature. Damage to the armature is caused by excessive speeds. The clutch prevents damage by stopping the mechanical connection. However, the pinion will stay meshed with the ring gear until the ignition switch is released. A spring in the overrunning clutch returns the clutch to the rest position.

Alternator

The alternator produces the following electrical output:

- Three-phase
- Full-wave
- Rectified

The alternator is an electro-mechanical component. The alternator is driven by a belt from the fan drive pulley. The alternator charges the storage battery during the engine operation.

The alternator is cooled by an external fan which is mounted behind the pulley. The fan forces air through the holes in the front of the alternator. The air exits through the holes in the back of the alternator.

The alternator converts the mechanical energy and the magnetic energy into alternating current and voltage. This conversion is done by rotating a direct current electromagnetic field on the inside of a three-phase stator. The electromagnetic field is generated by electrical current flowing through a rotor. The stator generates alternating current and voltage.

The alternating current is changed to direct current by a three-phase, full-wave rectifier. Direct current flows to the output terminal of the alternator. The rectifier has three exciter diodes. The direct current is used for the charging process.

A regulator is installed on the rear end of the alternator. Two brushes conduct current through two slip rings. The current then flows to the rotor field. A capacitor protects the rectifier from high voltages.

The alternator is connected to the battery through the ignition switch. Therefore, alternator excitation occurs when the switch is in the ON position.

i01853831

Fuel Injection

Introduction (Fuel Injection)

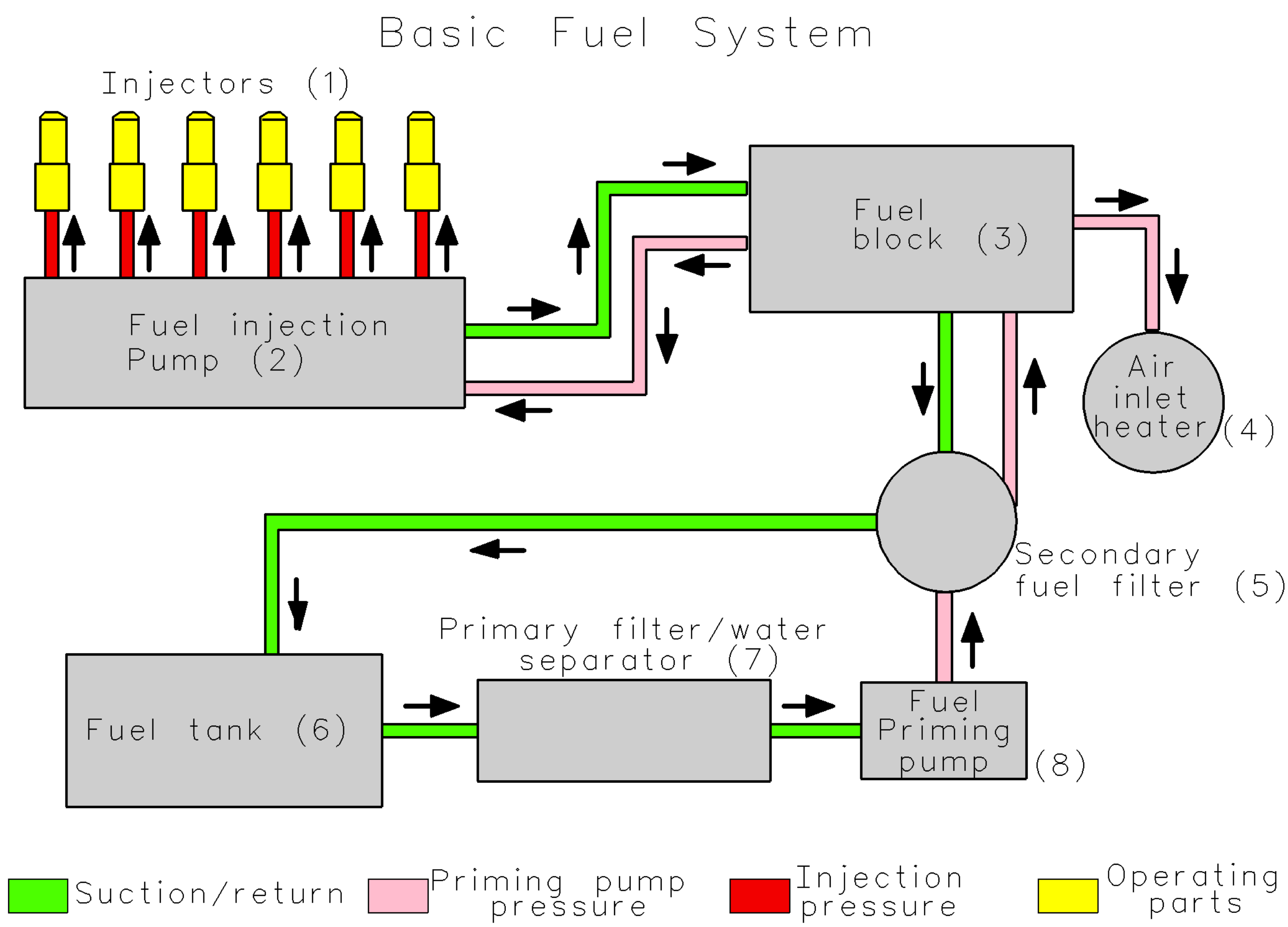

Illustration 21 g00911634

Diagram of the basic fuel system (typical example)

(1) Injectors
(2) Fuel injection pump
(3) Fuel block
(4) Air inlet heater
(5) Secondary fuel filter
(6) Fuel tank
(7) Primary filter/water separator
(8) Fuel priming pump

The engine has a Bosch VP30 Fuel Injection pump. The Bosch VP30 is an axial piston distributor injection pump that is electronically controlled.

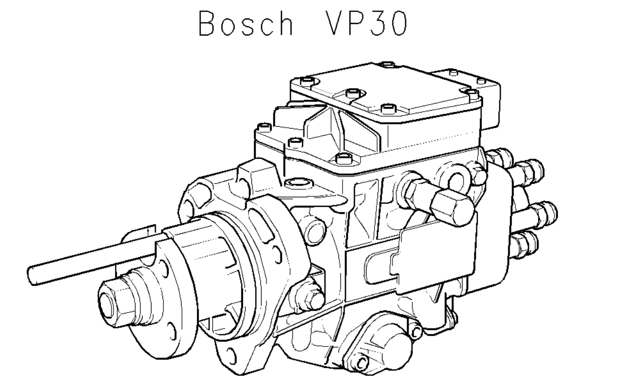

Illustration 22 g00901301

Bosch VP30 fuel injection pump

The axial piston distributor injection pump that is electronically controlled generates injection pressure for all cylinders in a single pump. The injection pump is responsible for the distribution of fuel to the fuel injectors. The injection pressure is generated by a piston. The piston is moving axially. The movement of the piston is parallel to the fuel injection pump shaft.

When the engine is cranking, the fuel is pulled from fuel tank (6) through fuel filter/water separator (7) by the fuel priming pump (8). When the fuel passes through the water separator, any water in the fuel will go to the bottom of the bowl. Fuel priming pump (8) sends the fuel at a low pressure to the secondary fuel filter (5). From the secondary fuel filter (5), the fuel passes through the fuel supply line to the fuel injection pump (2). The fuel injection pump (2) sends fuel through the high pressure fuel lines to each of the fuel injectors (1). The injectors (1) spray atomized fuel into the cylinder.

The fuel injection pump needs fuel for lubrication. The precision parts of the pump are easily damaged. The engine must not be started until the fuel injection pump (2) is full of fuel. The system must be primed when any part of the system is drained of fuel.

The following list contains examples of both service and repairs when you must prime the system:

- A fuel filter is changed.
- A fuel line is removed.
- The fuel injection pump is replaced.

Components of the Fuel injection System

The fuel injection system has the following mechanical components:

- Primary filter/water separator
- Fuel priming pump
- Secondary fuel filter
- Air inlet heater
- Fuel injection pump
- Fuel injectors

Primary Filter/water Separator

The primary filter/water separator is located between the fuel tank and the priming pump. The primary filter/water separator has a rating of 10 microns.

Fuel Priming Pump

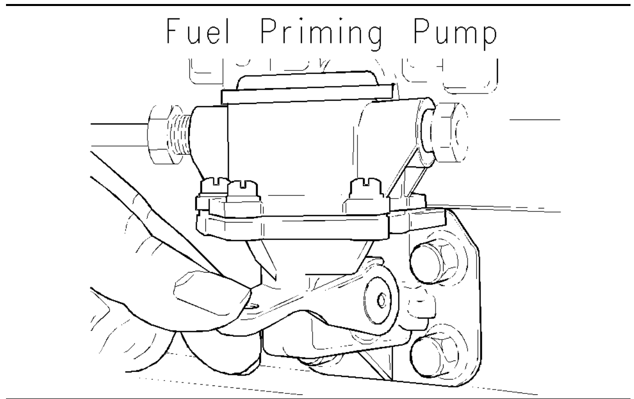

Illustration 23 g00907689

Fuel priming pump

The pump has a lever which is manually operated in order to prime the fuel system. In order to release air from the system, the orifice in the cover of the fuel filter is in the inlet side of the filter. The orifice is connected to the fuel tank by the fuel return line from the fuel filter. The priming pump gives a head of pressure for the fuel transfer pump. The fuel transfer pump is located in the fuel injection pump. The priming pump operates on an eccentric lobe on the camshaft.

Secondary Fuel Filter

The secondary fuel filter is located after the priming pump. The filter is always before the fuel injection pump. The filter has a rating of 2 microns.

Air Inlet Heater

NOTICE

An air inlet heater that is damaged will allow the fuel to drain into the inlet manifold when the engine is running. This condition could cause exhaust smoke. Excessive fuel could also cause an overspeed condition. An overspeed condition may result in severe engine damage.

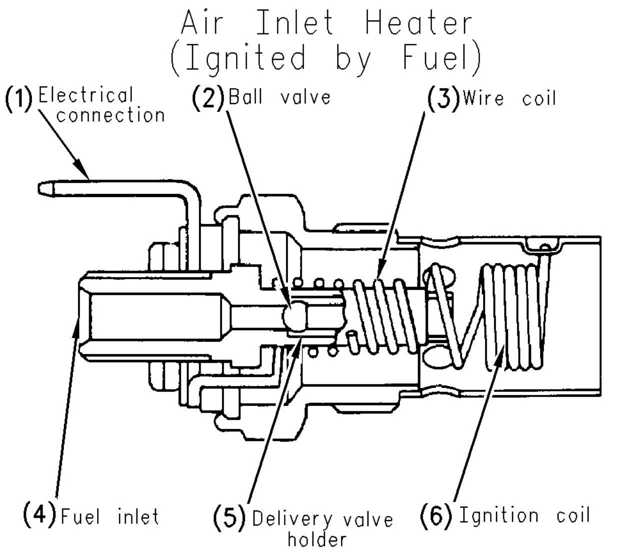

Illustration 24 g00891473

Air inlet heater

(1) Electrical connection
(2) Ball valve
(3) Wire coil
(4) Fuel inlet
(5) Delivery valve holder
(6) Ignition coil

The air inlet heater is installed in the inlet manifold in order to heat the intake air in cold weather. The air inlet heater is ignited by fuel.

When the ignition switch is turned to the HEAT position or when the control switch is pushed and the fuel shutoff control is in the ON position, the electrical current is supplied to the electrical connection (1). The electrical current flows to the wire coil (3) which causes the wire coil to become very hot. A small amount of fuel will flow through the fuel line when the engine is cranking.

The air inlet heater ignites a controlled amount of diesel fuel in the intake manifold in order to heat the intake air to the engine. The air inlet heater uses electric current to cause a heater coil in the body to create heat. The heat causes the expansion of the delivery valve holder (5) which opens the ball valve (2) in order to allow the fuel to flow into the air inlet heater.

The fuel is vaporized by the heat of the valve body. When the engine is cranked, the air is forced into the inlet manifold. The vapor is ignited by the ignition coil (6). The heat from the combustion of the fuel heats the intake air.

When the ignition switch is turned to the RUN position or the control switch is released, electric current stops to the air inlet heater. When the engine begins to run, the flow of air in the inlet manifold makes the air inlet heater cool quickly. The valve closes. This stops the fuel flow in the fuel supply line.

Fuel Injection Pump

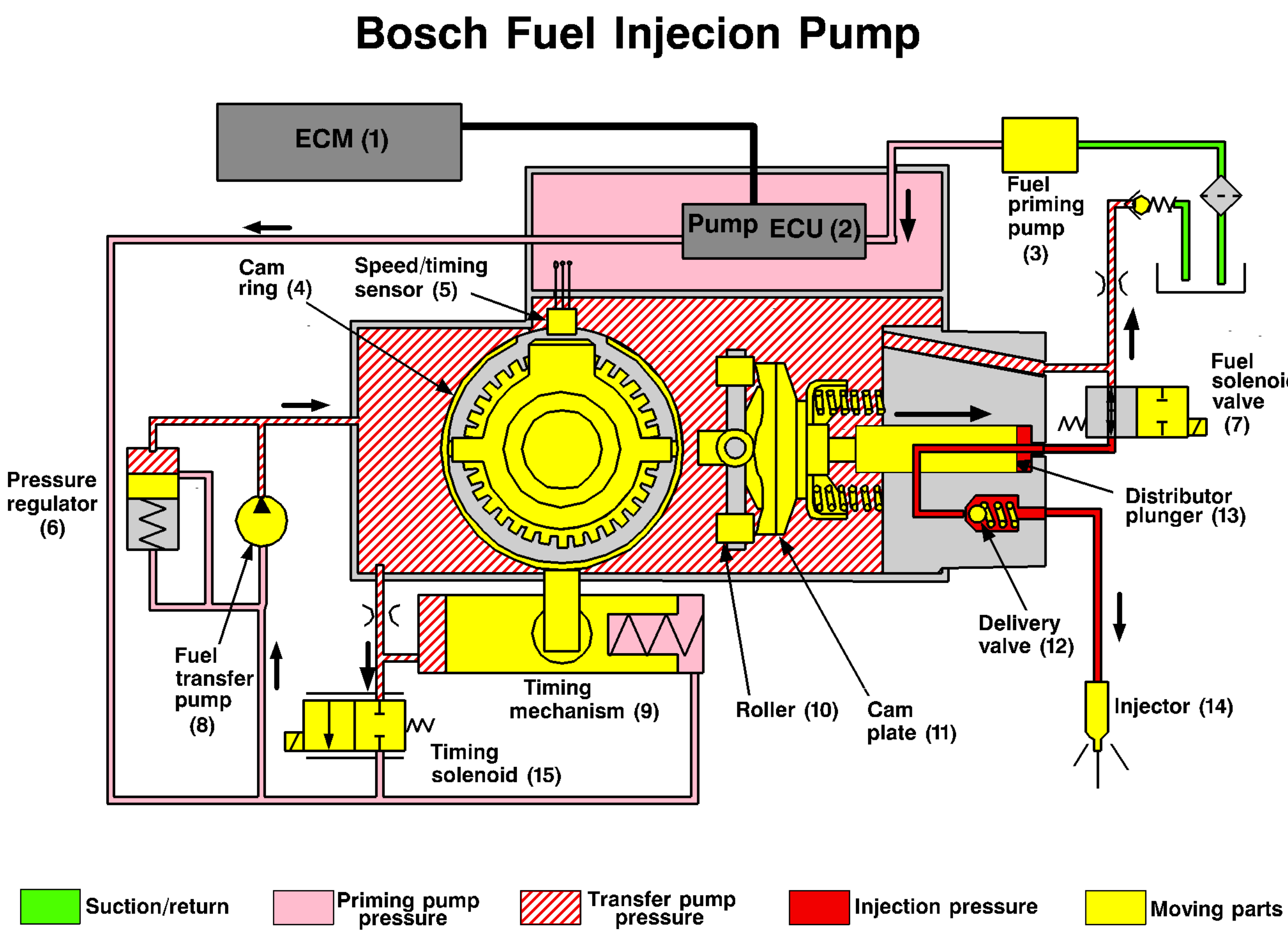

Illustration 25 g00953215

Schematic of the Bosch fuel injection pump

(1) ECM
(2) Electronic control unit (ECU) for the injection pump
(3) Fuel priming pump
(4) Cam ring
(5) Speed/timing sensor
(6) Pressure regulator
(7) Fuel solenoid valve
(8) Fuel transfer pump
(9) Timing mechanism
(10) Roller
(11) Cam plate
(12) Delivery valve
(13) Distributor plunger
(14) Injector
(15) Timing solenoid valve

The fuel injection pump has the following operations:

- Delivery
- Generation of high pressure
- Distribution and injection
- Timing
- Shutoff
- Control

Delivery

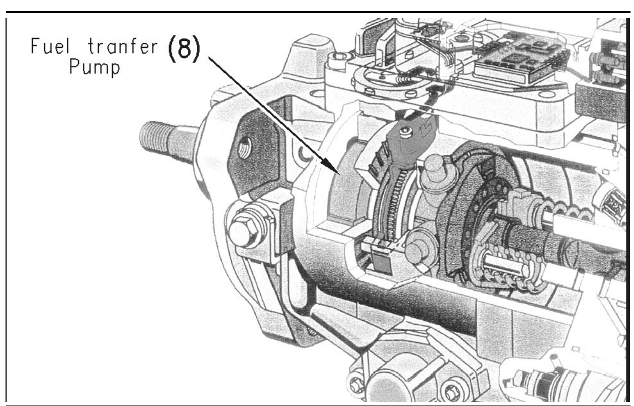

Illustration 26 g00897425

Center view of the Bosch VP30 fuel injection pump

(8) Fuel transfer pump

Fuel is supplied by the head pressure of the priming pump. The fuel enters the transfer pump (8) of the fuel injection pump. The fuel transfer pump is a vane type pump. Transfer pump (8) is driven by the fuel injection pump shaft. The pump supplies a constant amount of fuel to the interior of the fuel injection pump. The revolution of the transfer pump is directly related to the speed of the fuel injection pump shaft.

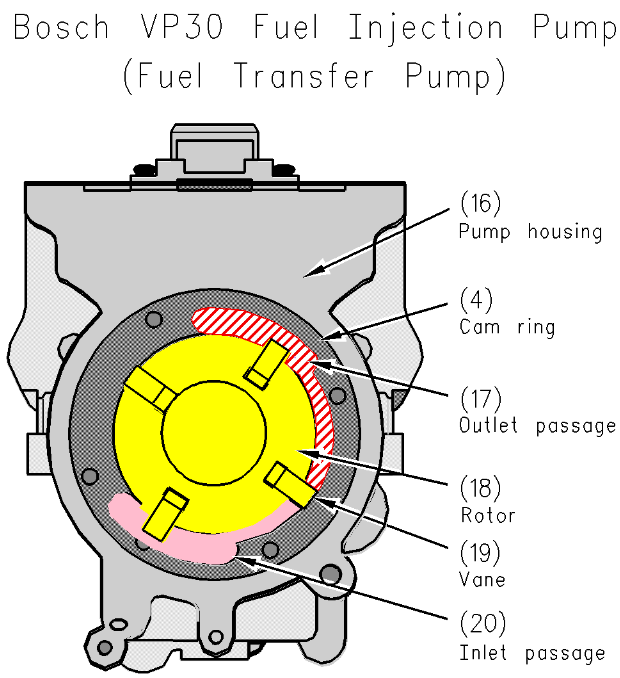

Illustration 27 g00917788

Fuel transfer pump for the Bosch VP30 fuel injection pump

(4) Cam ring
(16) Pump housing
(17) Outlet passage
(18) Rotor
(19) Vane
(20) Inlet passage

The rotor (18) rotates inside the cam ring (4). The cam ring is firmly attached to the pump housing (16). The vanes (19) are pressed against the cam ring by centrifugal force. The fuel flows through an inlet passage (20) then into a recess in the pump housing (16).

The eccentric position of the rotor (18) is relative to the cam ring (4). A volume is created between the following parts: vanes (19), rotor (18), and the cam ring (4). The fuel is transported by the eccentric position. The eccentric position is relative to the rotor (18) and the outlet passage (17). The fuel is transfered to outlet passage (17) into the distributor plunger (13). The volume of the fuel is reduced between the inlet passage (20) and the outlet passage (17). This creates pressure before the delivery to the distributor plunger (13).

The quantity of fuel increases as the speed of the engine increases. Increased engine speed increases the delivery pressure of the fuel. The pressure inside the fuel injection pump is limited by a pressure regulator (6). The pressure regulator (6) controls the fuel pressure. The fuel forces the valve spring open and The fuel flows back into the inlet passage (20) from the inside of the fuel injection pump.

Generation of High Pressure

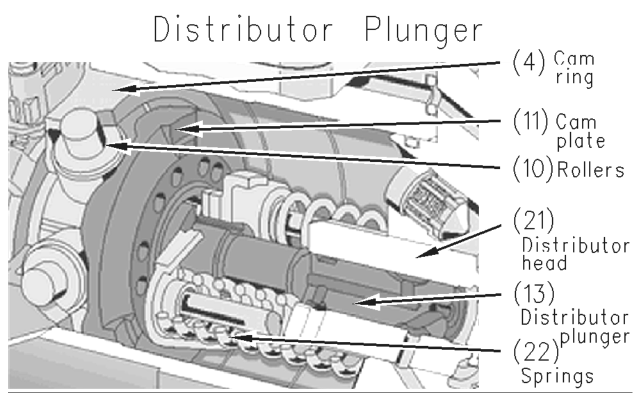

Illustration 28 g00897428

The distributor rotor and the cam plate of the Bosch VP30 fuel injection pump

(4) Cam ring
(10) Roller
(11) Cam plate
(13) Distributor plunger
(21) Distributor head
(22) Springs

The fuel comes from the outlet passage (17) of the fuel transfer pump . The high pressure is generated by the axial movement of the distributor plunger (13). The cam plate (11) is driven by the fuel injection pump shaft. The cam plate (11) has six cams. The number corresponds to the number of cylinders of the engine. The cams on the cam plate (11) run on the rollers (10). The rollers (10) are fixed on the cam ring (4). The rotating movement and the lifting movement of the cam plate (11) makes the generation of high pressure.

The cam plate (11) moves the distributor plunger (13) toward the distributor head (21). The high pressure is created by a decrease in the volume between the distributor plunger (13) and the distributor head (21). The cam plate (11) is pressed to the ring by two springs (22). This brings the distributor plunger (13) back to the original position. The fuel solenoid valve (7) closes the high pressure volume.

Distribution and Injection

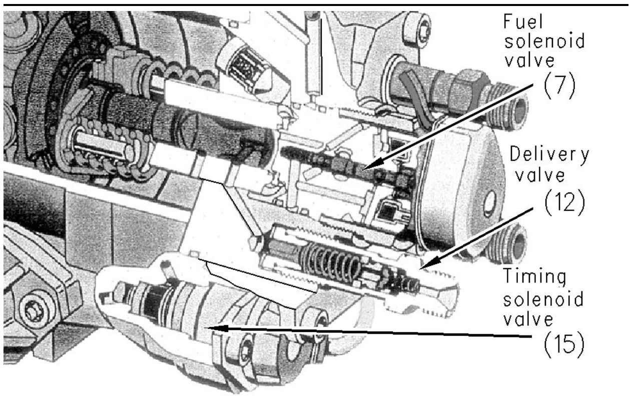

Illustration 29 g00897418

The rear view of the Bosch VP30 fuel injection pump

(7) Fuel solenoid valve
(12) Delivery valve
(15) Timing solenoid valve

The distribution of fuel to the injectors takes place through the rotating movement of the distributor plunger. The fuel solenoid valve (7) meters the amount of fuel by the following operations:

- Time of closure
- Duration time
- Start of injection
- Amount of fuel

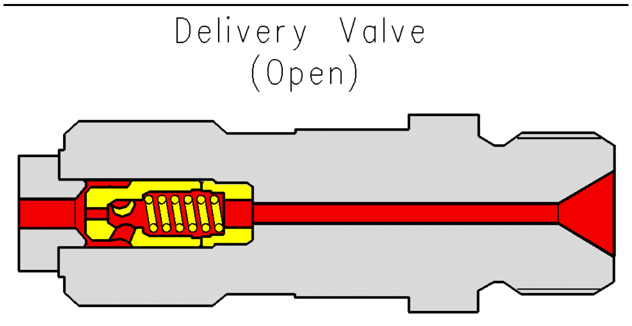

Illustration 30 g00897417

The delivery of fuel from the delivery valve for the Bosch VP30 fuel injection pump

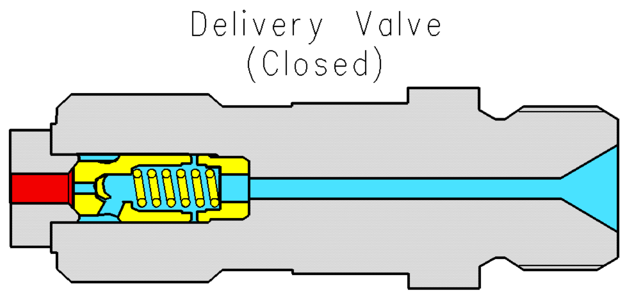

Illustration 31 g00897416

The closing of the delivery valve for the Bosch VP30 fuel injection pump

The delivery valve ensures that the pressure waves do not allow a reopening of the injector . The pressure waves are created at the end of the injection process. The valve cone is lifted by the fuel pressure.

The fuel is forced through the fuel line to the injector. The delivery ends and the fuel pressure drops. The valve spring presses the valve cone onto the valve seat. The reopening of a fuel injector has a negative effect on emissions.

Timing

Retarding of the fuel injection is the direct relationship between the start of injection and the position of the piston. The timing compensates for the higher RPM of the engine by advancing the start of injection.

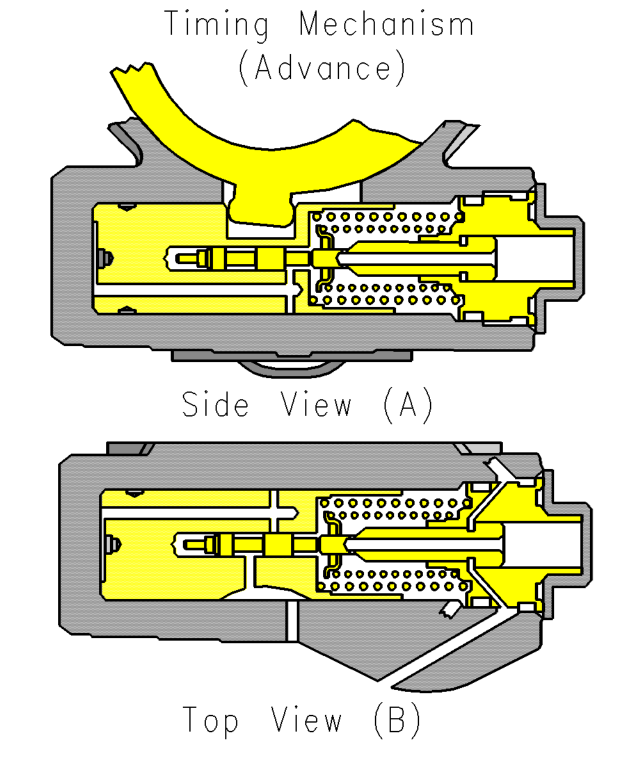

Illustration 32 g00944902

Timing advance for timing mechanism for the Bosch VP30

(A) Side View
(B) Top View

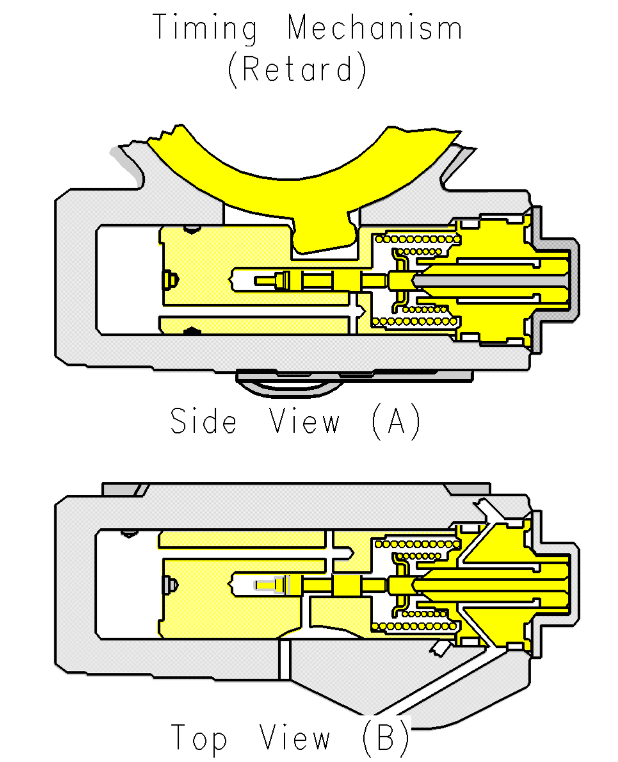

Illustration 33 g00944923

Timing retard for timing mechanism for the Bosch VP30

(A) Side View
(B) Top view

The timing advance or the timing retard of the fuel injection pump is shown in the following steps:

1. The ECU (2) sends a signal to the timing solenoid valve (15).

2. The timing mechanism (9) is triggered by the timing solenoid valve (15).

3. The timing solenoid valve (15) changes the pressure in the timing mechanism (9).

4. The timing mechanism (9) changes the position of the cam ring (4).

5. The cam ring (4) changes the position of the rollers (10).

6. The rollers (10) change the position of the cam plate (11).

7. The cam plate (11) changes the timing of the fuel delivery.

Shutoff

The engine shuts off by interrupting the fuel supply. The engine electronic control module (ECM) specifies the amount of fuel. The fuel solenoid valve is switched by the ECU (2) to zero.

Control

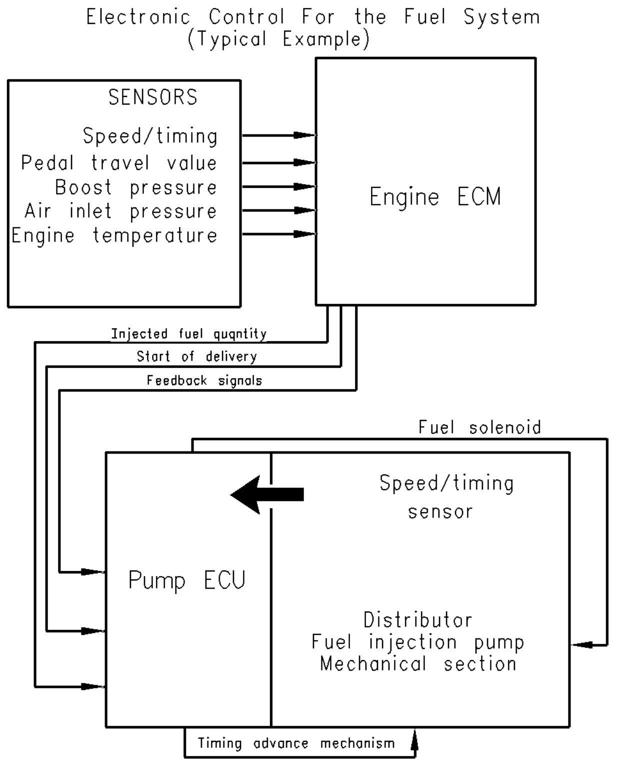

Illustration 34 g00891275

Electronic control for the fuel system (typical example)

The ECU for the injection pump (2) uses the command from the ECM and the measured values from the speed/timing sensor to actuate the fuel solenoid valve (7).

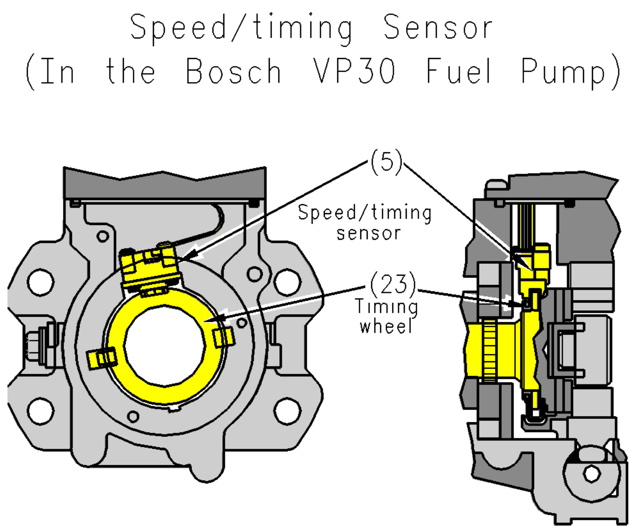

Illustration 35 g00897422

The wheel and the speed/timing sensor for the Bosch VP30

(5) Speed/timing sensor
(23) Timing wheel

The ECU for the injection pump (2) is mounted on the top of the pump. The ECU (2) has a connection to the engine ECM and a connection to the speed/timing sensor (5). ECU (2) has a connection for the two solenoid valves. The ECM functions as a control computer. The ECU (2) calculates the optimal parameters from the ECM data. The fuel solenoid actuates the valve accordingly.

The speed/timing sensor (5) in the fuel injection pump determines the precise angular position and the speed of the fuel injection pump shaft. The timing wheel (23) is permanently connected to the fuel injection pump shaft. The speed/timing sensor gets information from the timing wheel (23). The sensor then sends electrical impulses to the ECU. The ECU also uses the information to determine the average speed of the pump and momentary speed of the pump.

The signal of the speed/timing sensor (5) is constant.

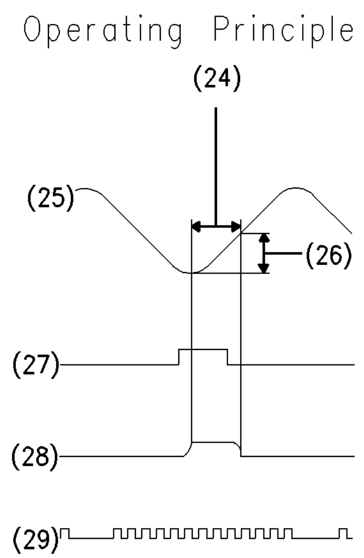

Illustration 36 g00897421

Operating principle

(24) Angle of fuel delivery
(25) Lift of the cam
(26) Stroke
(27) Pulse for actuating the fuel solenoid
(28) Valve lift
(29) Angle of the speed/timing sensor

The amount of fuel is proportional to the stroke of the piston. The effective stroke is proportional to the angle of fuel delivery . A temperature compensation takes place in the ECU (2). The compensation takes place in order to inject the precise amount of fuel.

Fuel Injectors

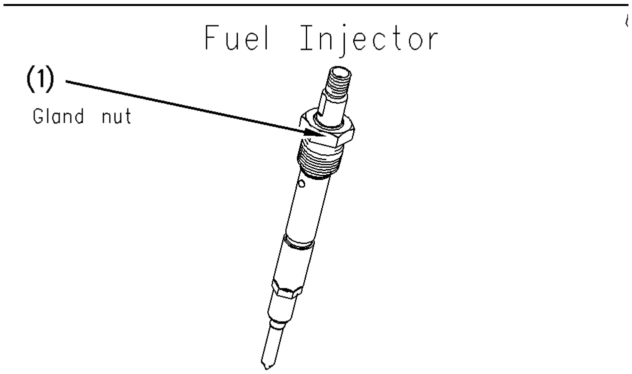

Illustration 37 g00888355

Fuel injector

(1) Gland nut

Each fuel injector is fastened to the cylinder head by a gland nut (1) on the holder of the fuel injector. The fuel injectors are not serviceable.

The fuel injection pump forces the fuel to flow under high pressure to the hole in the fuel inlet. The fuel then flows around a needle valve within the fuel injector holder which causes the fuel injection nozzle to fill with fuel. The pressure of the fuel pushes the needle valve and a spring. When the force of the fuel pressure is greater than the force of the spring, the needle valve will lift up.

When the needle valve opens, fuel under high pressure will flow through nozzle orifices into the cylinder. The fuel is injected into the cylinder through the orifices in the nozzle as a very fine spray. When the fuel is injected into the cylinder, the force of the fuel pressure in the nozzle body will decrease. The force of the spring will then be greater than the force of the fuel pressure that is in the nozzle body. The needle valve will move quickly to the closed position.

The needle valve has a close fit with the inside of the nozzle. This makes a positive seal for the valve.

i01854184

Electronic Control System

Introduction (Electronic Control System)

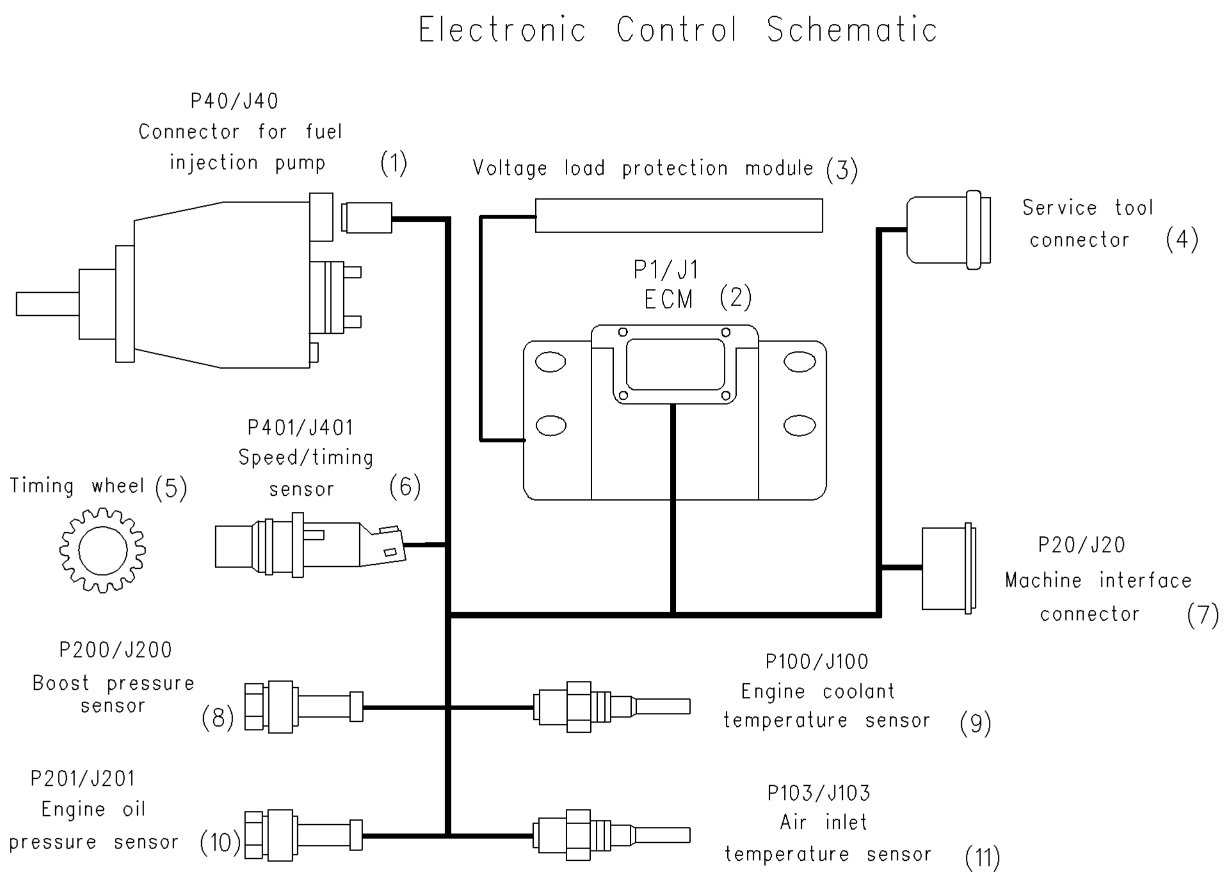

Illustration 38 g00947980

Schematic of the electronic control

(1) Connector for fuel injection pump
(2) ECM
(3) Voltage load protection module
(4) Service tool connector
(5) Timing wheel
(6) Speed/timing sensor
(7) Machine interface connector
(8) Boost pressure sensor
(9) Engine coolant temperature sensor
(10) Engine oil pressure sensor
(11) Air inlet temperature sensor

The electronic control system has the following components:

- ECM
- Pressure sensors
- Temperature Sensors
- Speed/timing sensor
- Voltage load protection module

ECM

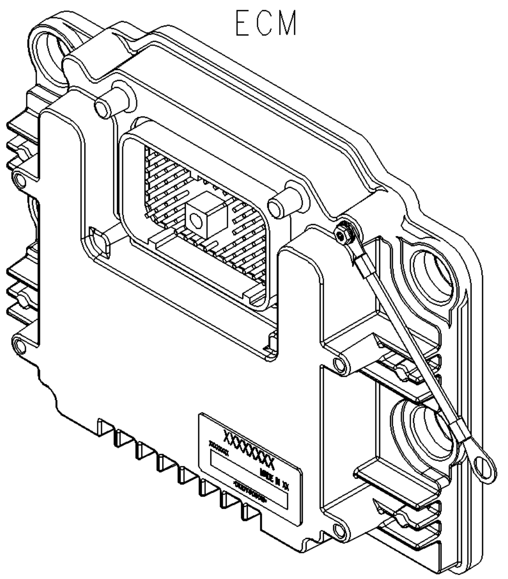

Illustration 39 g00908008

ECM

The ECM functions as the governor and the computer for the fuel system. The ECM receives all the signals from the sensors in order to control the timing and the engine speed.

The reasons for having passwords in an ECM are the following reasons:

- Reprogramming that is unauthorized
- Erasing of logged events that is unauthorized
- Allow the customer to control certain programmable engine parameters.

The factory passwords restrict changes to authorized personnel. Factory passwords are required to clear any event code. Refer to the following Troubleshooting, "Factory Passwords" For more information on the passwords.

The ECM has an excellent record of reliability. Any problems in the system are most likely to be the connectors and the wiring harness. The ECM should be the last item in troubleshooting the engine.

The personality module contains the software with all the fuel setting information. The information determines the engine performance. The personality module is installed behind the access panel on the ECM.

Flash programming is the method of programming or updating the personality module. Refer to the following Troubleshooting, RENR2417, "Flashing Programming " for the instructions on the flash programming of the personality module.

The ECM is sealed and the ECM needs no routine adjustment or maintenance.

Speed/Timing Sensor

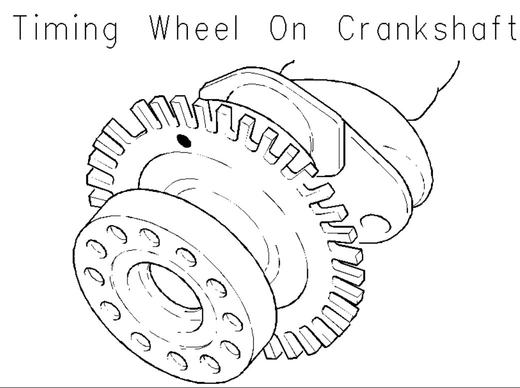

Illustration 40 g00909870

Timing wheel on crankshaft

The primary engine position is a passive sensor. The timing wheel is located on the crankshaft. The speed/timing sensor receives a signal from the teeth on timing wheel. The extra space on the timing wheel gives one revolution per space. The space is oriented so that the space is 40 degrees after top center.

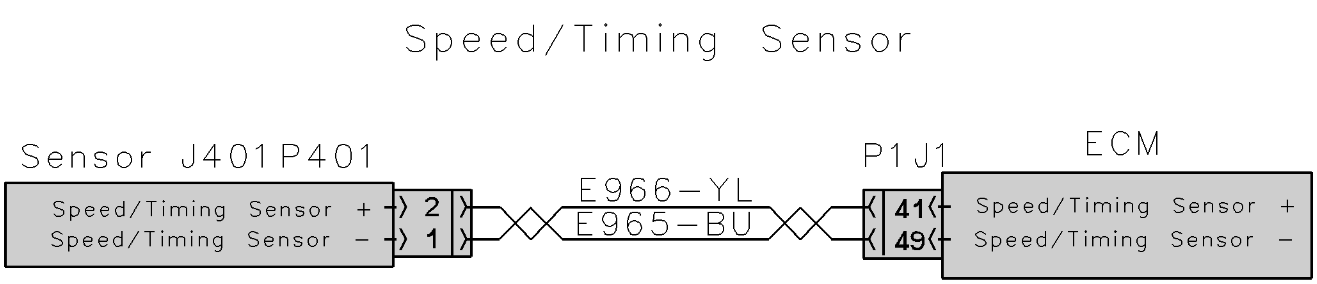

Illustration 41 g00908010

Schematic for speed/timing sensor

When the engine is cranking, the ECM uses the signal from the speed/timing sensor in the fuel injection pump. When the engine is running the ECM uses the signal from the speed/timing sensor on the crankshaft. This speed/timing sensor is the primary source of the engine position.

Pressure Sensors

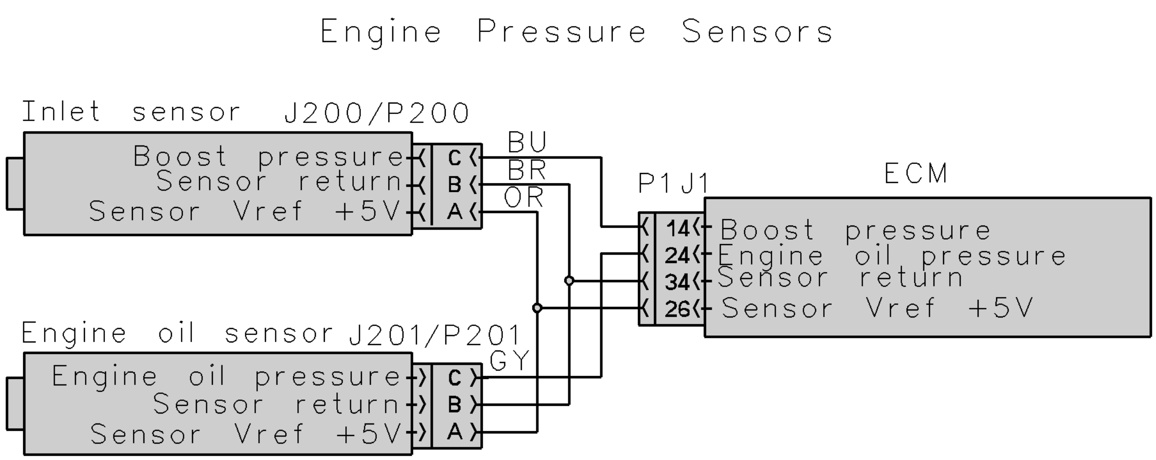

Illustration 42 g00896073

Schematic for pressure sensors

The boost pressure sensor and the engine oil pressure sensor are active sensors.

The boost pressure sensor provides the ECM with a measurement of inlet manifold pressure in order to control the air/fuel ratio. This will reduce the engine smoke during transient conditions.

The operating range for the boost pressure sensor .... 55 kPa to 339 kPa (8 psi to 50 psi)

The engine oil pressure sensor provides the ECM with a measurement of engine oil pressure. The ECM can warn the operator of possible conditions that can damage the engine. This includes the detection of an oil filter that is blocked.

The operating range for the engine oil pressure sensor .... 55 kPa to 339 kPa (8 psi to 50 psi)

Temperature Sensors

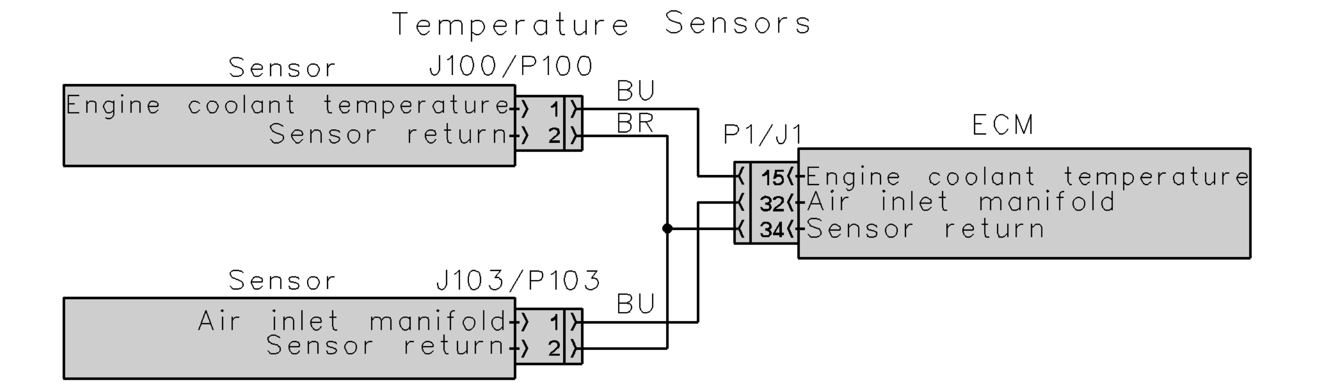

Illustration 43
g00908817

Schematic for the temperature sensors

The air inlet temperature sensor and the coolant temperature sensor are passive sensors. Each sensor provides a temperature input to the ECM. The ECM controls following operations:

- Fuel delivery
- Injection timing

The operating range for the sensors .... –40 °C to 150 °C (–40 °F to 302 °F)

The sensors are also used for engine monitoring.

Voltage Load Protection Module

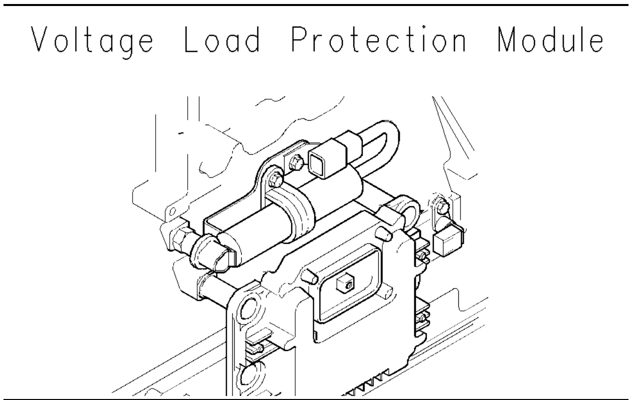

Illustration 44
g00909436

Voltage load protection module

The voltage load protection module monitors the voltage of the system. The voltage load protection module will shut down the fuel injection pump if there is a high voltage on the system.

i01854884

Power Sources

Introduction (Power Supplies)

The 1106 Engine has four supplies to the following components:

- ECM
- Fuel Injection Pump
- Pressure sensors
- Air inlet heater

ECM Power Supply

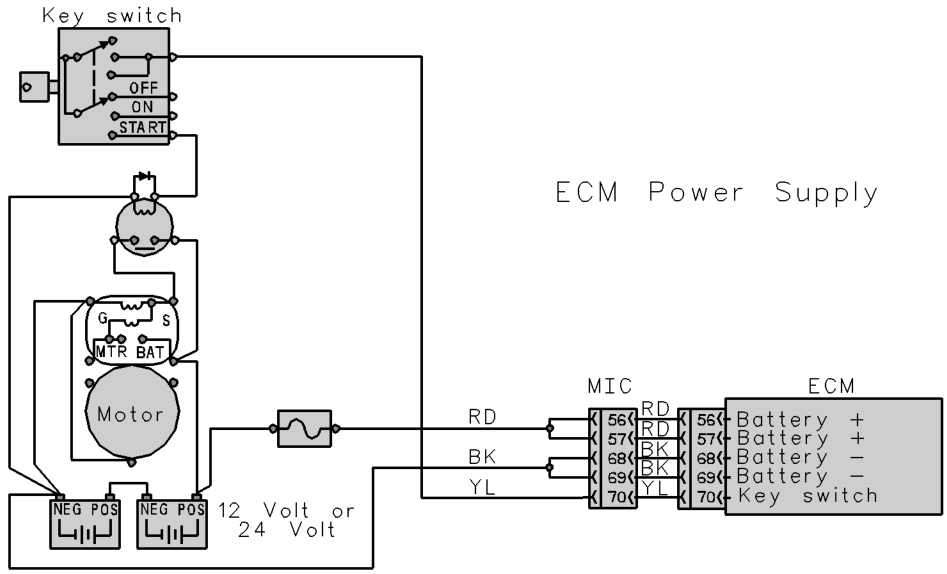

Illustration 45 g00947384

Schematic for ECM

The power supply to the ECM and the system is drawn from the 24 volt or the 12 volt battery. The power supply for the ECM has the following components:

- Battery
- disconnect switch
- Key start switch
- Fuses
- Ground bolt
- ECM connector
- Machine interface connector

Note: The ground bolt is the only component that is mounted on the engine.

The Schematic for the ECM shows the main components for a typical power supply circuit. Battery voltage is normally connected to the ECM. The input from the key start switch turns on the ECM.

The wiring harness can be bypassed for troubleshooting purposes.

The display screen on the electronic service tool can be used in order to check the voltage supply.

Note: Two wires are used to reduce resistance.

Power Supply for the Fuel Injection Pump

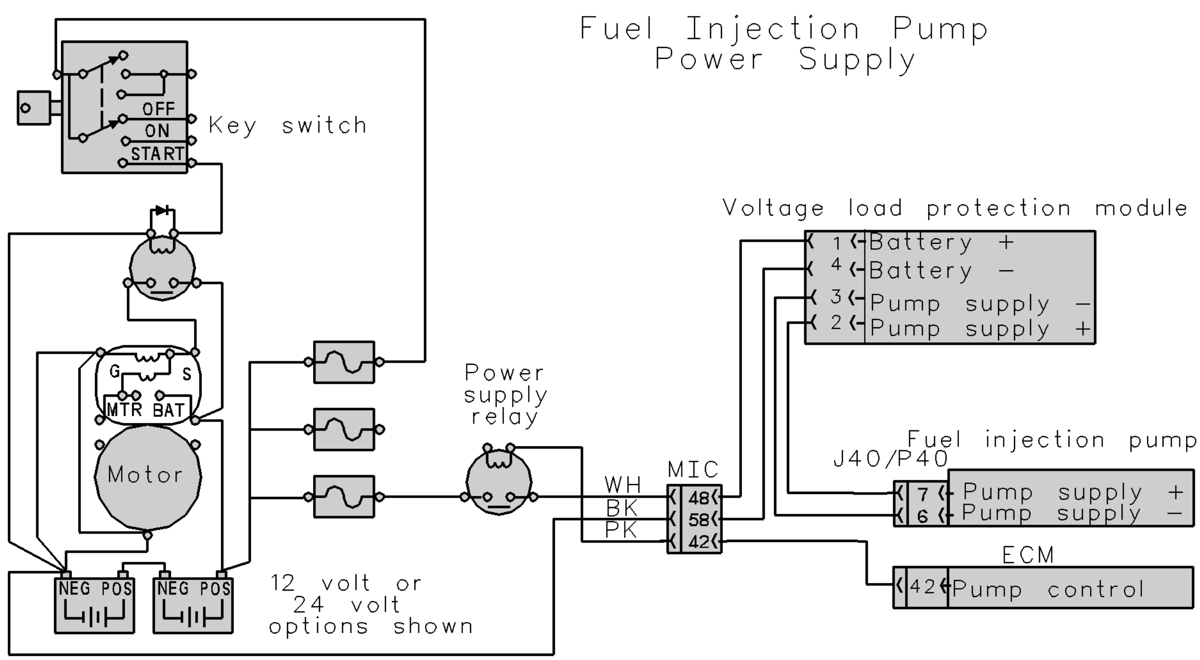

Illustration 46 g00895884

Schematic for the fuel injection pump

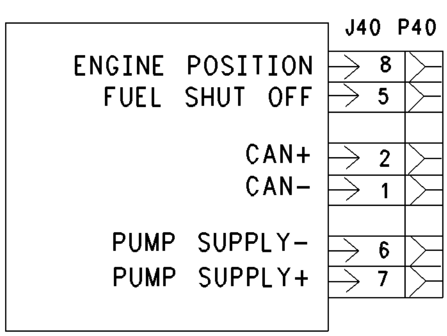

Illustration 47 g00896034

Connection for the fuel injection pump (J40/P40)

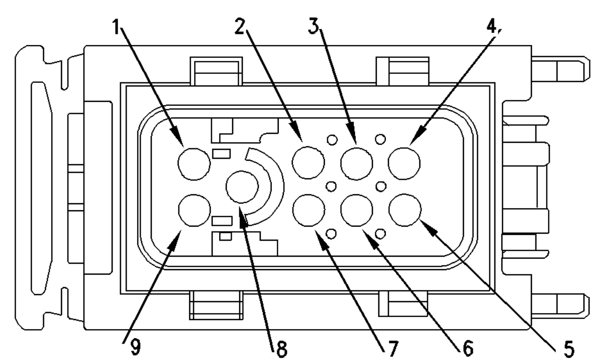

Illustration 48 g00896003

Connector for the fuel injection pump (J40)

(1) Can L
(2) Can H
(3) Extra connection
(4) Extra Connection
(5) Fuel shutoff
(6) Battery -
(7) Battery +
(8) Engine Position
(9) Extra connection

The power supply for the ECM comes from the Machine interface connector. The machine interface connector receives power from the power relay.

Power Supply for the Pressure Sensors

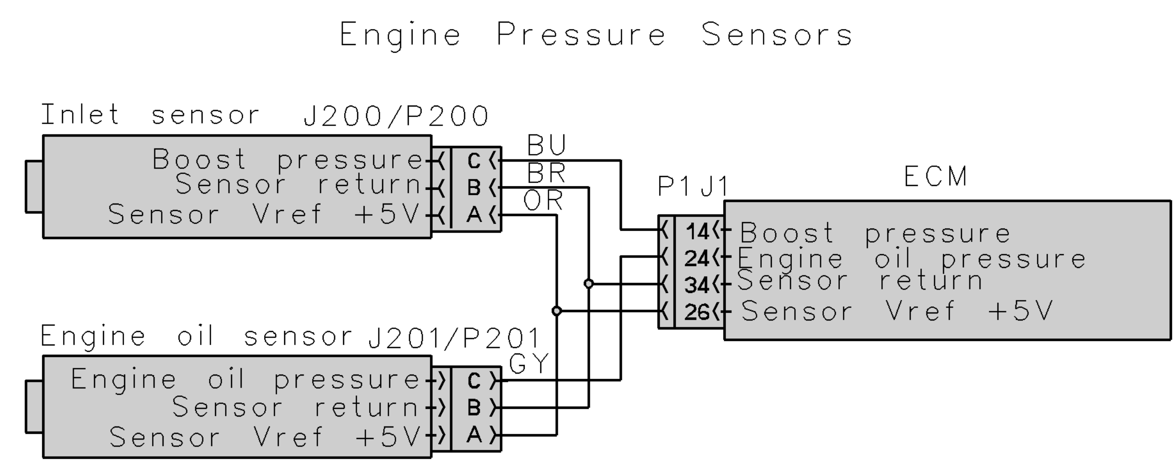

Illustration 49 g00896073

Schematic for pressure sensors

The ECM supplies 5.0 ± 0.2 DC volts through the ECM connector to each sensor. The power supply is protected against short circuits. A short in a sensor or a wiring harness will not cause damage to the ECM.

Power supply of the Air Inlet Heater

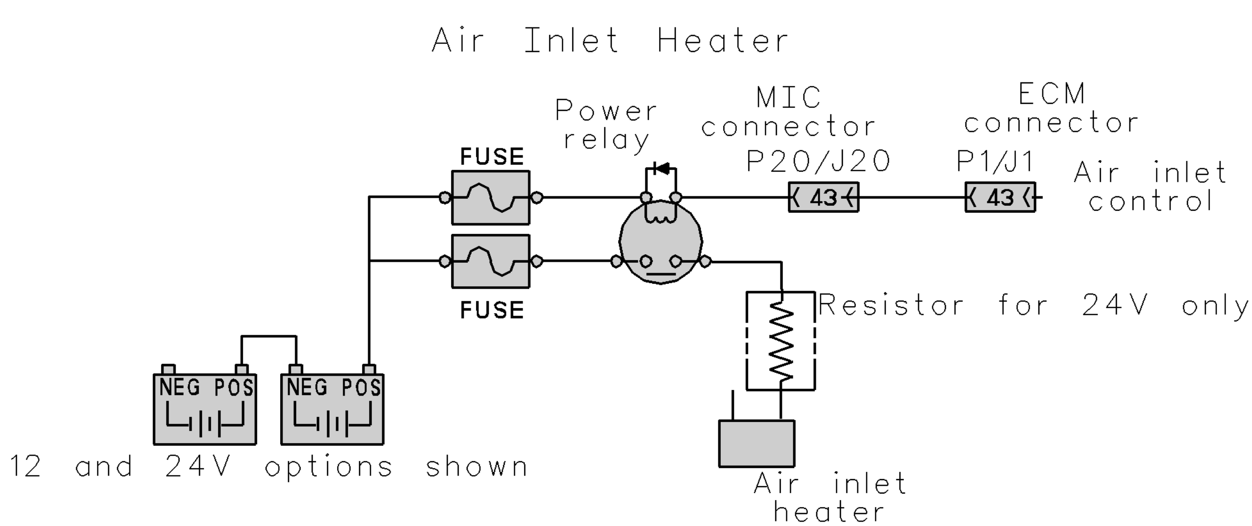

Illustration 50 g00919204

Schematic for air inlet heater

The Air inlet heater is powered from the power relay that is controlled by the ECM. A resistor is used On 24V systems.

i01874918

Glossary of Electronic Control Terms

Aftermarket Device – An aftermarket device is a device or an accessory that is installed by the customer after the engine is delivered.

Air-To-Air Aftercooler – An air-to-air aftercooler is a device that is used on turbocharged engines in order to cool inlet air that has undergone compression. The inlet air is cooled after the inlet air passes through the turbocharger. The inlet air is passed through an aftercooler (heat exchanger) that uses ambient air for cooling. The inlet air that has been cooled advances to the inlet manifold.

Before Top Center (BTC) – BTC is the 180 degrees of crankshaft rotation before the piston reaches the top center position in the normal direction of rotation.

Bypass Circuit – A bypass circuit is a circuit that is used as a substitute circuit for an existing circuit. A bypass circuit is typically used as a test circuit.

Coolant Temperature Sensor – The coolant temperature sensor measures the engine coolant temperature. The sensor sends a signal to the ECM. The engine's coolant temperature is used in Cold Mode operation. Coolant temperature is also used in order to optimize engine performance.

Code – See the Diagnostic Code.

Customer Specified Parameters – A customer specified parameter is a parameter that can be changed. A customer specified parameter's value is set by the customer. These parameters are protected by customer passwords.

Data Link – The data link is an electrical connection that is used to communicate with other electronic devices that have microprocessors. The data link is also the communication medium that is used for programming with the electronic service tool. The data link is also used for troubleshooting with the electronic service tool.

Desired RPM – The desired rpm is input to the electronic governor within the ECM. The electronic governor uses the signal from the Accelerator Pedal Position Sensor, the Engine Speed Sensor, the Cruise Control, and the Customer Parameters in order to determine desired rpm.

Diagnostic Code – A diagnostic code is sometimes called a fault code. A diagnostic code is an indication of a problem or event in the electrical engine systems.

Diagnostic Lamp – A diagnostic lamp is sometimes called the check engine light. The diagnostic lamp is used to warn the operator of the presence of an active diagnostic code.

Direct Current (DC) – Direct current is the type of current that flows consistently in only one direction.

Duty Cycle – See Pulse Width Modulation.

Electronic Service Tool – The Electronic Service Tool is used for diagnosing a variety of electronic controls and the Electronic Service Tool is also used for programming a variety of electronic controls.

Engine Control Module (ECM) – The ECM is the engine's control computer. The ECM provides power to the electronics. The ECM monitors data that is input from the engine's sensors. The ECM acts as a governor in order to control engine rpm.

Estimated Dynamic Timing – Estimated dynamic timing is the estimate of the actual injection timing that is calculated by the ECM.

Enable Signal for the Exhaust Brake – The exhaust brake enable signal interfaces the ECM to the engine retarder. This prevents the operation of the exhaust brake under unsafe engine operating conditions.

Failure Mode Identifier (FMI) – The FMI describes the type of failure that was experienced by the component. The codes for the FMI were adopted from the standard practices of SAE (J1587 diagnostics).

Flash Memory – See the Personality Module.

Fuel Ratio Control (FRC) – The FRC is a limit that is based on the control of the fuel to the air ratio. The FRC is used for emission control. When the ECM senses a higher turbocharger outlet pressure, the ECM increases the limit for the FRC in order to allow more fuel into the cylinders.

Fuel Position – The fuel position is a signal within the ECM. The signal is from the electronic governor. The signal goes to the fuel injection control. The signal is based on the desired engine speed, the FRC, the rated position, and the actual engine speed.

Harness – The harness is the bundle of wiring that connects all the components of the electrical engine system.

Hertz (Hz) – Hz is the measure of frequency in cycles per second.

Inlet manifold temperature sensor – The inlet air temperature sensor is a sensor that measures the inlet air temperature. The sensor also sends a signal to the ECM.

Open Circuit – An open circuit is a broken electrical wire connection. The signal or the supply voltage cannot reach the intended destination.

Original Equipment Manufacturer (OEM) – An OEM is the manufacturer of a vehicle that utilizes a Perkins engine.

Parameter – A parameter is a programmable value which affects the characteristics or the behavior of the engine and/or vehicle.

Parameter Identifier (PID) – A PID is a numerical code that contains two digits or three digits. A numerical code is assigned to each component. The numerical code identifies data via the data link to the ECM.

Password – A password is a group of numeric characters or alphanumeric characters. A password is designed to restrict the changing of information in the ECM. The electrical engine systems require correct customer passwords in order to change customer specified parameters. The electrical engine systems require correct factory passwords in order to clear certain logged events. Factory passwords are also required in order to change certain engine specifications.

Personality Module – The personality module is the module in the ECM which contains all the instructions (software) for the ECM and performance maps for a specific horsepower family. Updates and rerates are accomplished by electronically flashing in new data. The updates and rerates are flashed in using the electronic service tool.

Power Take-Off (PTO) – The PTO is operated with the cruise control switches or dedicated inputs from the PTO. This mode of operation permits setting constant engine rpm when the vehicle is not moving or when the vehicle is moving at slow speeds.

Pulse Width Modulation (PWM) – A PWM is a digital type of electronic signal that corresponds to a measured variable. The length of the pulse (signal) is controlled by the measured variable. The variable is quantified by a certain ratio. This ratio is the percent of "on-time" that is divided by the percent of "off-time". A PWM signal is generated by the Throttle Position Sensor.

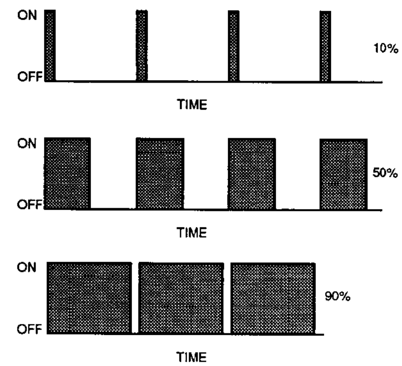

Illustration 51 g00284479

Example Of Pulse Width Modulation

Rated Fuel Position ("Rated Fuel Pos") – The rated fuel position indicates the maximum allowable fuel position (longest injection pulse). The rated fuel position will produce rated power for this engine configuration.

Reference Voltage – The reference voltage is a regulated voltage that is used by the sensor in order to generate a signal voltage.

Sensor – A sensor is used to detect a change in the pressure, in the temperature, or in mechanical movement. When any of these changes are detected, a sensor converts the change into an electrical signal.

Service Program Module (SPM) – The SPM is a software program on a computer chip that was programmed at the factory.

Short Circuit – A short circuit is an electrical circuit that is mistakenly connected to an undesirable point. For example, an electrical contact is made with the frame whenever an exposed wire rubs against a vehicle's frame.

Signal – A signal is a voltage or a wave that is used to transmit information that is typically from a sensor to the ECM.

Speed Surge – A speed surge is a sudden brief change in engine rpm.

Speed-timing Sensor – The speed-timing sensor is a sensor that provides a Pulse Width Modulated signal to the ECM. The ECM interprets this signal as the crankshaft position and the engine speed.

Subsystem – A subsystem is a part of the engine system that relates to a particular function.

Supply Voltage – Supply voltage is a constant voltage that is supplied to a component in order to provide electrical power for operation. Supply voltage may be generated by the ECM. Supply voltage may also be the battery voltage of the vehicle that is supplied by the vehicle wiring.

"T" Harness – This harness is a test harness that is designed to permit normal circuit operation and the measurement of the voltage simultaneously. Typically, the harness is inserted between the two ends of a connector.

Throttle Position – The Throttle position is sent from the accelerator pedal. This signal is interpreted by the ECM. The throttle position may be used as part of a power take-off control.

Total Tattletale – The total tattletale is the total number of changes to all system parameters.

Testing and Adjusting Section

Fuel System

i01854188

Fuel System - Inspect

A problem with the components that send fuel to the engine can cause low fuel pressure. This can decrease engine performance.

1. Check the fuel level in the fuel tank. Ensure that the vent in the fuel cap is not filled with dirt.

2. Check all fuel lines for fuel leakage. The fuel lines must be free from restrictions and faulty bends. Verify that the fuel return line is not collapsed.

3. Install a new fuel filter.

4. Cut the old filter open with a suitable oil filter cutter. Inspect the filter for excess contamination. Determine the source of the contamination. Make the necessary repairs.

5. Service the primary fuel filter (if equipped).

6. Operate the hand priming pump (if equipped). If excessive resistance is felt, inspect the fuel pressure regulating valve. If uneven resistance is felt, test for air in the fuel. Refer to Testing and Adjusting, "Air in Fuel - Test" for more information.

7. Remove any air that may be in the fuel system. Refer to Testing and Adjusting, "Fuel System - Prime".

i01854200

Air in Fuel - Test

This procedure checks for air in the fuel system. This procedure also assists in finding the source of the air.

1. Examine the fuel system for leaks. Ensure that the fuel line fittings are properly tightened. Check the fuel level in the fuel tank. Air can enter the fuel system on the suction side between the fuel transfer pump and the fuel tank.

⚠ WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

2. Install a suitable fuel flow tube with a visual sight gauge in the fuel return line. When possible, install the sight gauge in a straight section of the fuel line that is at least 304.8 mm (12 inches) long. Do not install the sight gauge near the following devices that create turbulence:

   * Elbows
   * Relief valves
   * Check valves

   Observe the fuel flow during engine cranking. Look for air bubbles in the fuel. If there is no fuel that is present in the sight gauge, prime the fuel system. Refer to Testing and Adjusting, "Fuel System - Prime" for more information. If the engine starts, check for air in the fuel at varying engine speeds. When possible, operate the engine under the conditions which have been suspect.

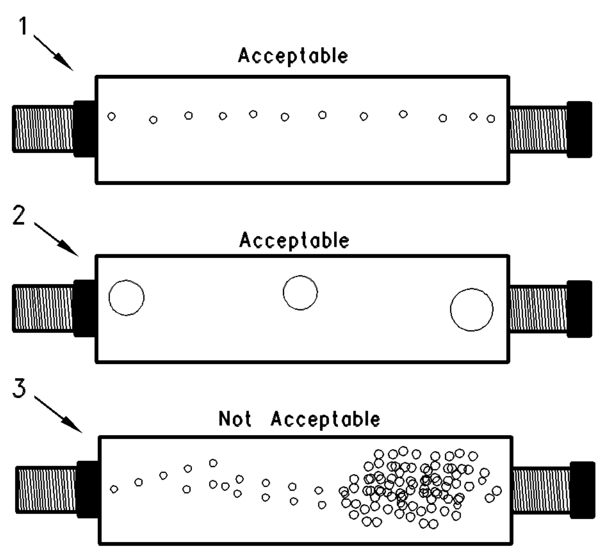

Illustration 52 g00578151

(1) A steady stream of small bubbles with a diameter of approximately 1.60 mm (0.063 inch) is an acceptable amount of air in the fuel.
(2) Bubbles with a diameter of approximately 6.35 mm (0.250 inch) are also acceptable if there is two seconds to three seconds intervals between bubbles.
(3) Excessive air bubbles in the fuel are not acceptable.

3. If excessive air is seen in the sight gauge in the fuel return line, install a second sight gauge at the inlet to the fuel transfer pump. If a second sight gauge is not available, move the sight gauge from the fuel return line and install the sight gauge at the inlet to the fuel transfer pump. Observe the fuel flow during engine cranking. Look for air bubbles in the fuel. If the engine starts, check for air in the fuel at varying engine speeds.

If excessive air is not seen at the inlet to the fuel transfer pump, the air is entering the system after the fuel transfer pump. Refer to the Testing and Adjusting, "Fuel System - Prime".

If excessive air is seen at the inlet to the fuel transfer pump, air is entering through the suction side of the fuel system.

WARNING

To avoid personal injury, always wear eye and face protection when using pressurized air.

NOTICE

To avoid damage, do not use more than 55 kPa (8 psi) to pressurize the fuel tank.

4. Pressurize the fuel tank to 35 kPa (5 psi). Do not use more than 55 kPa (8 psi) in order to avoid damage to the fuel tank. Check for leaks in the fuel lines between the fuel tank and the fuel transfer pump. Repair any leaks that are found. Check the fuel pressure in order to ensure that the fuel transfer pump is operating properly. For information about checking the fuel pressure, see Testing and Adjusting, "Fuel System Pressure - Test".

5. If the source of the air is not found, disconnect the supply line from the fuel tank and connect an external fuel supply to the inlet of the fuel transfer pump. If this corrects the problem, repair the fuel tank or the stand pipe in the fuel tank.

i01847622

Finding Top Center Position for No. 1 Piston

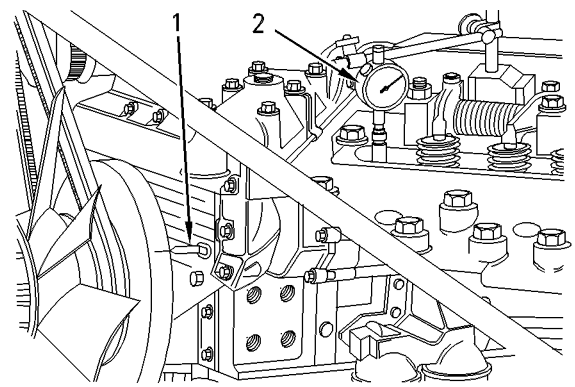

Illustration 53

g00309726

The engine that is shown may not reflect your application.

Setting top center position

(1) Temporary pointer
(2) Dial indicator

1. Fasten a temporary pointer (1) to the front of the front cover. Put the tip of the pointer close to the edge of the damper on the crankshaft or close to the edge of the pulley.

2. Remove the fuel injection nozzles and the valve mechanism cover. Refer to Disassembly and Assembly Manual, "Fuel Injection Nozzles - Remove" and Disassembly and Assembly Manual, "Valve Mechanism Cover - Remove and Install".

3. Rotate the crankshaft clockwise when you face the front of the engine. Rotate the crankshaft until the pushrod for the inlet valve of the rear cylinder begins to tighten.

Note: Be careful when you rotate the crankshaft. The No. 1 inlet valve will be held in position on top of the piston. If the crankshaft is not positioned properly, the valve may fall from the cylinder head.

4. Rotate the crankshaft further by 1/8 of a turn in a clockwise direction. Insert a suitable lever between the rocker lever and the valve spring cap of the No. 1 inlet valve. Open the inlet valve. Put a spacer that is approximately 5 mm (0.2 inch) thick between the valve stem and the rocker lever.

5. Slowly rotate the crankshaft in a counterclockwise direction until the piston makes contact with the open valve. Make a temporary mark on the damper or the pulley in order to align accurately with the tip of the pointer.

6. Rotate the crankshaft in a clockwise direction by one or two degrees. Remove the spacer that is between the valve stem and the rocker lever. Rotate the crankshaft by 1/4 of a turn in a counterclockwise direction. Put a spacer that is approximately 5 mm (0.2 inch) thick between the valve stem and the rocker lever.

7. Slowly rotate the crankshaft clockwise until the piston makes contact with the open valve. Make another temporary mark on the damper or the pulley in order to align accurately with the tip of the pointer.

8. Make a temporary mark at the center point between the two marks on the damper or the pulley. Remove the other two marks. Rotate the crankshaft by 1/8 of a turn in a counterclockwise direction. Remove the spacer between the valve stem and the rocker lever.

9. Slowly rotate the crankshaft in a clockwise direction until the mark on the damper or the pulley, which was made in Step 8, aligns with the tip of the pointer. The No. 1 piston is now at the top center on the compression stroke.

10. Install the valve mechanism cover and the fuel injection nozzles.

11. Remove the temporary pointer (1) from the front of the front cover.

i01847625

Fuel Injection Timing - Check

Table 1

Required Tools		
Part Number	**Part Name**	**Quantity**
27610032	Timing Pin (Bosch)	1
27610218	Tool (piston displacement)	1

This procedure must be done before any of the following reasons:

- Removal of the fuel injection pump
- The bolts that hold the fuel injection pump to the front housing are loosened.

The fuel injection pump is timed at four degrees after top center on the compression stroke of the number one cylinder. The timing is important in order to conform to the correct emissions.

1. Set the number one piston at the top center piston on the compression stroke. Refer to Testing and Adjusting, "Finding Top Center Position for the No. 1 Pistion" for the procedure.

2. Remove the number two fuel injection nozzle. Refer to Disassembly and Assembly, "Fuel Injection Nozzles - Remove" for the procedure.

Note: Number five fuel injection nozzle can be used, if number five fuel injection nozzle is more suitable for the application.

3. Ensure that the seat washer for the fuel injection nozzle is removed.

4. Check the bore of the fuel injection nozzle and check the seat for the fuel injection nozzle.

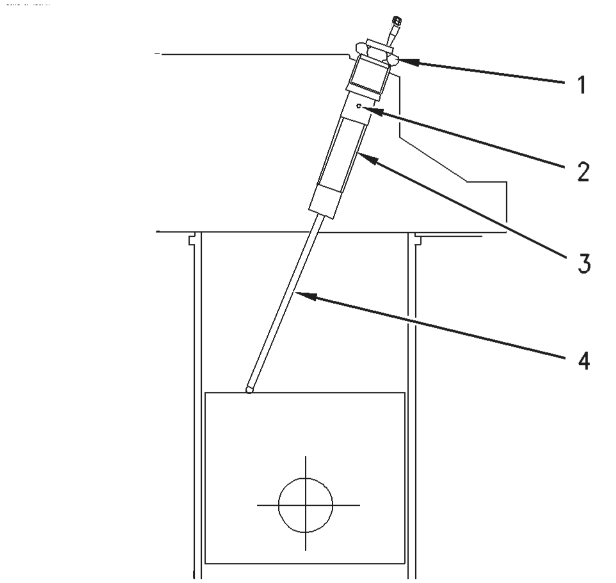

Illustration 54 g00902838

27610218 tool (piston displacement) is installed in the fuel injection nozzle hole.

(1) Gland nut
(2) Alignment pin
(3) Main body
(4) Probe

5. Align alignment pin (2) of main body (3) to the slot in the fuel injection nozzle hole.

6. Place main body (3) into the fuel injection nozzle hole and install gland nut (1).

7. Apply clean engine oil to probe (4).

8. Insert probe (4) into main body (3). Then, gently lower probe (4) onto the piston crown.

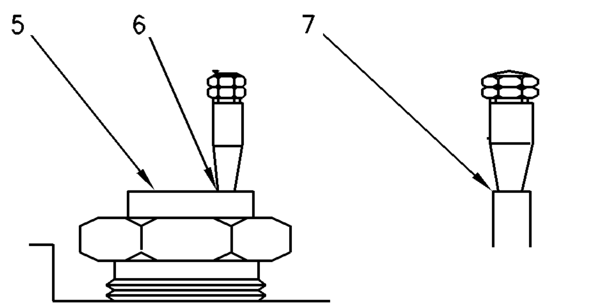

Illustration 55 g00902855

Top portion of the 27610218 tool (piston displacement) and the gland nut

(5) Top of the main body
(6) The probe is aligned with the main body.
(7) Machined face of the probe

9. Rotate the crankshaft clockwise until the machined face of the probe (7) aligns with the top of the main body (5).

Note: When step **9** is complete do not rotate the crankshaft until the fuel injection pump is installed on the engine.

10. The number one piston is at four degrees after top center compression stroke.

11. Remove probe (4) from main body (3).

12. Remove gland nut (1).

13. Remove the main body (3) from the cylinder head.

14. Replace the fuel injection nozzle.

i01855574

Fuel Quality - Test

Use the following procedure to test for problems regarding fuel quality:

1. Determine if water and/or contaminants are present in the fuel. Check the water separator (if equipped). If a water separator is not present, proceed to Step **2**. Drain the water separator, if necessary. A full fuel tank minimizes the potential for overnight condensation.

Note: A water separator can appear to be full of fuel when the water separator is actually full of water.

2. Determine if contaminants are present in the fuel. Remove a sample of fuel from the bottom of the fuel tank. Visually inspect the fuel sample for contaminants. The color of the fuel is not necessarily an indication of fuel quality. However, fuel that is black, brown, and/or similar to sludge can be an indication of the growth of bacteria or oil contamination. In cold temperatures, cloudy fuel indicates that the fuel may not be suitable for operating conditions.

Refer to Operation and Maintenance Manual, “Fuel Recommendations” for more information.

3. If fuel quality is still suspected as a possible cause to problems regarding engine performance, disconnect the fuel inlet line, and temporarily operate the engine from a separate source of fuel that is known to be good. This will determine if the problem is caused by fuel quality. If fuel quality is determined to be the problem, drain the fuel system and replace the fuel filters. Engine performance can be affected by the following characteristics:

- Cetane number of the fuel
- Air in the fuel
- Other fuel characteristics

i01742724

Fuel System - Prime

If air enters the fuel system, the air must be purged before the engine can be started. Air can enter the fuel system when the following events occur:

- The fuel tank is empty or the tank has been partially drained.
- The low pressure fuel lines are disconnected.
- A leak exists in the low pressure fuel system.
- The fuel filter is replaced.

Use the following procedure in order to remove air from the fuel system:

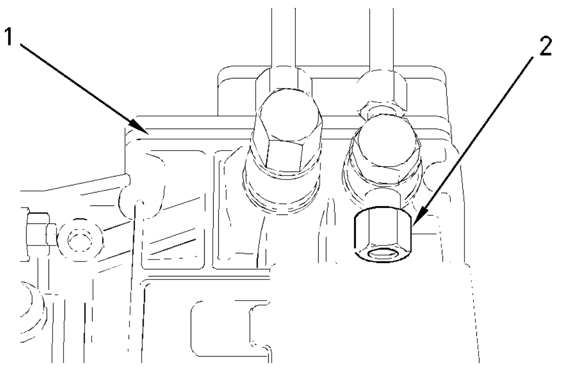

Illustration 56 g00898190

Side of the fuel injection pump

(1) Fuel injection pump
(2) nut

1. Loosen nut (2) on the fuel injection pump.

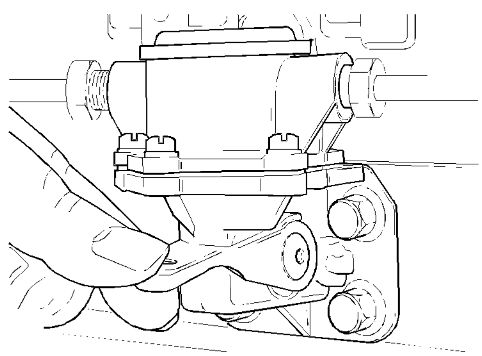

Illustration 57 g00898194

Hand priming lever for the priming pump

Note: If the drive cam of the fuel priming pump is in the position of maximum cam lift, the priming lever will not operate. Rotate the crankshaft by hand one revolution.

2. Operate the priming lever on the priming pump until fuel flows out of nut (2).

3. Tighten nut (2) to a torque of 23 N·m (17 lb ft).

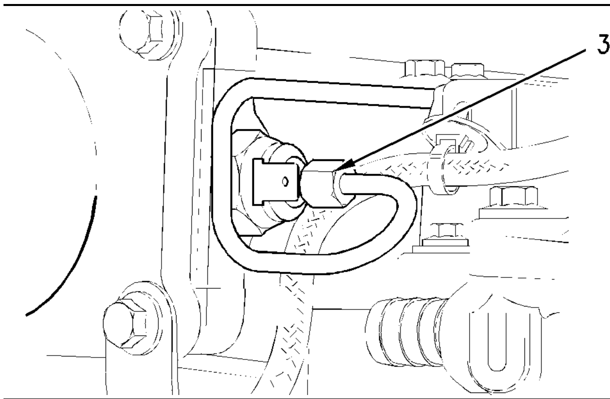

Illustration 58 g00905440

Air inlet heater on the air inlet manifold

(3) Flare nut

4. If the fuel line for the air inlet heater has been drained, loosen nut (3). Operate the priming lever on the fuel priming pump until fuel is free of air from the fuel line.

5. Tighten nut (3) to a torque of 22 N·m (16 lb ft).

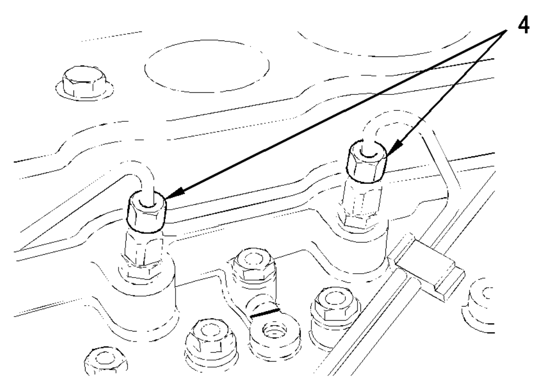

Illustration 59 g00898197

Fuel injection nozzles in the cylinder head

(4) Flare nut

Note: Damage to the fuel injection pump, to the battery, and to the starter motor can occur if the starter motor is used excessively to purge the air from the fuel system.

6. Loosen flare nuts (4) for the high pressure fuel lines on two fuel injection nozzles.

7. Operate the starting motor until fuel is flowing from the fuel lines.

8. Tighten flare nuts (4) to a torque of 22 N·m (16 lb ft).

NOTICE

Do not crank the engine continuously for more than 30 seconds. Allow the starting motor to cool for two minutes before cranking the engine again.

9. The engine is now ready to start. Operate the engine at low idle for a minimum of five minutes immediately after air has been removed from the fuel system.

Note: Running the engine for this period of time will help ensure that the pump is completely free of air. Damage to the internal parts of the pump, which is caused by metal to metal contact, will be prevented. If the engine stops or if the engine runs roughly, check for air in the fuel system. If air is in the fuel system, leakage in the low pressure fuel system probably exists.

i01742803

Fuel System Pressure - Test

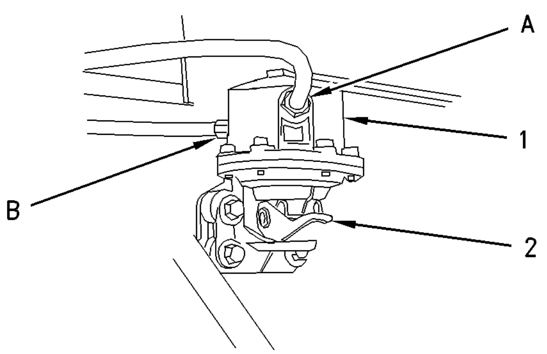

Illustration 60 g00761195

The fuel priming pump is located on the right hand side of the cylinder block.

(1) Fuel priming pump
(2) Priming lever
(A) Fuel inlet
(B) Fuel outlet

The pressure test measures the output pressure of the fuel priming pump. Low fuel pressure and starting difficulty may be indications of problems with the fuel priming pump.

1. Disconnect the line for the fuel outlet (B).

2. Put a pressure gauge in the fuel outlet (B) of the fuel priming pump (1).

3. Prime the fuel system in order to eliminate air from the fuel priming pump. Refer to Testing and Adjusting, "Fuel System - Prime" for the proper procedure.

4. Disconnect the fuel injection pump solenoid wire (if equipped). Put the fuel shutoff lever in the fuel shutoff position.

5. Crank the engine for ten seconds. Record the maximum pressure. The pressure indication on the gauge should be in the following range:

Maximum pressure ...... 35 to 55 kPa (5 to 8 psi)

Minimum pressure .... 26 kPa (3.8 psi)

6. If the pressure is less than the minimum pressure, the fuel priming pump must be replaced.

7. Observe the rate that the pressure drops. If the pressure drops to one half of the maximum pressure in less than 30 seconds, the fuel priming pump must be replaced.

8. Remove the pressure gauge from the fuel priming pump. Connect the outlet line to the fuel priming pump (1). Prime the fuel system in order to eliminate air from the fuel system. Refer to Testing and Adjusting, "Fuel System - Prime" for the proper procedure.

9. Connect the fuel injection pump solenoid wire.

i01771267

Gear Group (Front) - Time

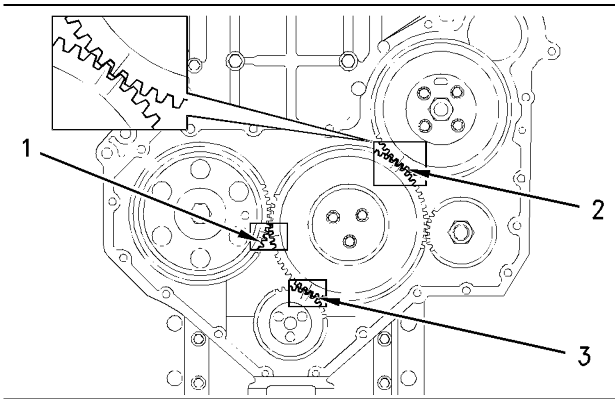

Illustration 61 g00905589

(1) Timing marks for the idler gear and the camshaft gear
(2) Timing marks for the idler gear and the fuel injection pump drive gear
(3) Timing marks for the idler gear and the crankshaft gear

1. Make sure that the timing marks on the gears are in alignment.

2. Measure the backlash between the camshaft gear and the idler gear. Refer to Specifications, "Gear Group (Front)" for the correct value.

3. Measure the backlash between the fuel injection pump gear and the idler gear. Refer to Specifications, “Gear Group (Front)” for the correct value.

4. If the backlash is not within the specification, the gears must be replaced. Check the backlash again.

Air Inlet and Exhaust System

i01592413

Air Inlet and Exhaust System - Inspect

A general visual inspection should be made to the air inlet and exhaust system. Make sure that there are no signs of leaks in the system.

There will be a reduction in the performance of the engine if there is a restriction in the air inlet system or the exhaust system.

WARNING

Hot engine components can cause injury from burns. Before performing maintenance on the engine, allow the engine and the components to cool.

WARNING

Making contact with a running engine can cause burns from hot parts and can cause injury from rotating parts.

When working on an engine that is running, avoid contact with hot parts and rotating parts.

1. Inspect the engine air cleaner inlet and ducting in order to ensure that the passageway is not blocked or collapsed.

2. Inspect the engine air cleaner element. Replace a dirty engine air cleaner element with a clean engine air cleaner element.

3. Check for dirt tracks on the clean side of the engine air cleaner element. If dirt tracks are observed, contaminants are flowing past the engine air cleaner element and/or the seal for the engine air cleaner element.

4. For engines with plastic valve mechanism covers, if you experience excessive crankcase pressure, remove the valve mechanism cover and check the end of the shroud for a skin of plastic. If the end of the shroud has a skin of plastic, remove the skin of plastic. Ensure that all of the debris is removed.

5. If the breather tube is made of plastic, use low pressure air to check for a blockage in the breather tube. If a blockage is inside of the connector, the cover assembly must be replaced. A broken valve mechanism cover will result if you try to remove the connection.

i01848443

Turbocharger - Inspect

WARNING

Hot engine components can cause injury from burns. Before performing maintenance on the engine, allow the engine and the components to cool.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

Care must be taken to ensure that fluids are contained during performance of inspection, maintenance, testing, adjusting and repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

Before you begin inspection of the turbocharger, be sure that the inlet air restriction is within the specifications for your engine. Be sure that the exhaust system restriction is within the specifications for your engine. Refer to Testing and Adjusting, "Air Inlet and Exhaust System - Inspect".

The condition of the turbocharger will have definite effects on engine performance. Use the following inspections and procedures to determine the condition of the turbocharger.

- Inspection of the compressor and the compressor housing

- Inspection of the turbine wheel and the turbine housing

- Inspection of the wastegate

Inspection of the Compressor and the Compressor Housing

Remove the air cleaner from the compressor inlet.

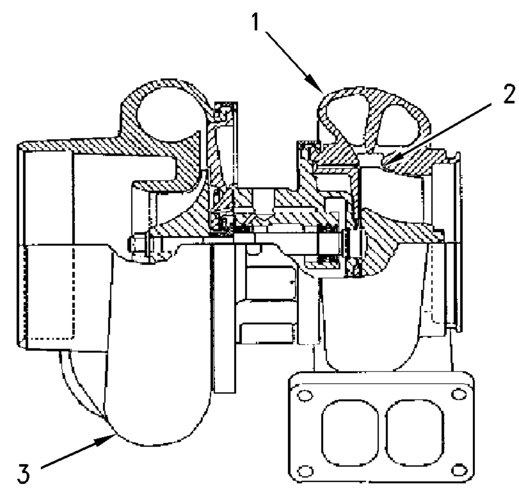

Illustration 62 g00766001

Typical example of a turbocharger

(1) Turbine housing
(2) Turbine wheel
(3) Turbocharger

1. Inspect the compressor wheel for damage from a foreign object. If there is damage, determine the source of the foreign object. As required, clean the inlet system and repair the intake system. Replace the turbocharger. If there is no damage, go to Step **3**.

2. Clean the compressor wheel and clean the compressor housing if you find buildup of foreign material. If there is no buildup of foreign material, go to Step **3**.

3. Turn the rotating assembly by hand. While you turn the assembly, push the assembly sideways. The assembly should turn freely. The compressor wheel should not rub the compressor housing. The turbocharger must be replaced if the compressor wheel rubs the compressor wheel housing. If there is no rubbing or scraping, go to Step **4**.

4. Inspect the compressor and the compressor wheel housing for oil leakage. An oil leak from the compressor may deposit oil in the aftercooler. Drain and clean the aftercooler if you find oil in the aftercooler.

  a. Check the oil level in the crankcase. If the oil level is too high, adjust the oil level.

  b. Inspect the air cleaner element for restriction. If restriction is found, correct the problem.

  c. Inspect the engine crankcase breather. Clean the engine crankcase breather or replace the engine crankcase breather if the engine crankcase breather is plugged.

  d. Remove the turbocharger oil drain line. Inspect the drain opening. Inspect the oil drain line. Inspect the area between the bearings of the rotating assembly shaft. Look for oil sludge. Inspect the oil drain hole for oil sludge. Inspect the oil drain line for oil sludge in the drain line. If necessary, clean the rotating assembly shaft. If necessary, clean the oil drain hole. If necessary, clean the oil drain line.

  e. If Steps **4.a** through **4.d** did not reveal the source of the oil leakage, the turbocharger has internal damage. Replace the turbocharger.

Inspection of the Turbine Wheel and the Turbine Housing

Remove the air piping from the turbine housing.

1. Inspect the turbine for damage by a foreign object. If there is damage, determine the source of the foreign object. Replace turbocharger (3). If there is no damage, go to Step **2**.

2. Inspect turbine wheel (2) for buildup of carbon and other foreign material. Inspect turbine housing (1) for buildup of carbon and foreign material. Clean turbine wheel (2) and clean turbine housing (1) if you find buildup of carbon or foreign material. If there is no buildup of carbon or foreign material, go to Step **3**.

3. Turn the rotating assembly by hand. While you turn the assembly, push the assembly sideways. The assembly should turn freely. Turbine wheel (2) should not rub turbine wheel housing (1). Replace turbocharger (3) if turbine wheel (2) rubs turbine housing (1). If there is no rubbing or scraping, go to Step **4**.

4. Inspect the turbine and turbine housing (1) for oil leakage. Inspect the turbine and turbine housing (1) for oil coking. Some oil coking may be cleaned. Heavy oil coking may require replacement of the turbocharger. If the oil is coming from the turbocharger center housing go to Step **4.a**. Otherwise go to “Inspection of the Wastegate”.

a. Remove the turbocharger oil drain line. Inspect the drain opening. Inspect the area between the bearings of the rotating assembly shaft. Look for oil sludge. Inspect the oil drain hole for oil sludge. Inspect the oil drain line for oil sludge. If necessary, clean the rotating assembly shaft. If necessary, clean the drain opening. If necessary, clean the drain line.

b. If crankcase pressure is high, or if the oil drain is restricted, pressure in the center housing may be greater than the pressure of turbine housing (1). Oil flow may be forced in the wrong direction and the oil may not drain. Check the crankcase pressure and correct any problems.

c. If the oil drain line is damaged, replace the oil drain line.

d. Check the routing of the oil drain line. Eliminate any sharp restrictive bends. Make sure that the oil drain line is not too close to the engine exhaust manifold.

e. If Steps **4.a** through **4.d** did not reveal the source of the oil leakage, turbocharger (3) has internal damage. Replace turbocharger (3).

Inspection of the Wastegate

The wastegate controls the amount of exhaust gas that is allowed to bypass the turbine side of the turbocharger. This valve then controls the rpm of the turbocharger.

When the engine operates in conditions of low boost (lug), a spring presses against a diaphragm in the canister. The actuating rod will move and the wastegate will close. Then, the turbocharger can operate at maximum performance.

When the boost pressure increases against the diaphragm in the canister, the wastegate will open. The rpm of the turbocharger becomes limited. The rpm limitation occurs because a portion of the exhaust gases bypass the turbine wheel of the turbocharger.

The following levels of boost pressure indicate a problem with the wastegate:

- Too high at full load conditions
- Too low at all lug conditions

Table 2

Turbocharger Boost Pressures	
Number That Is Stamped On The Turbocharger	**Boost Pressures**
2674A342	145 ± 3 kPa (21.03 ± 0.4 psi)
2674A343	145 ± 3 kPa (21.03 ± 0.4 psi)
2674A344	145 ± 3 kPa (21.03 ± 0.4 psi)
2674A345	145 ± 3 kPa (21.03 ± 0.4 psi)
2674A346	145 ± 3 kPa (21.03 ± 0.4 psi)
2674A347	145 ± 3 kPa (21.03 ± 0.4 psi)
2674A348	145 ± 3 kPa (21.03 ± 0.4 psi)
2674A349	127.5 ± 3 kPa (18.50 ± 0.4 psi)

The boost pressure controls the maximum rpm of the turbocharger, because the boost pressure controls the position of the wastegate. The following factors also affect the maximum rpm of the turbocharger:

- The engine rating
- The horsepower demand on the engine
- The high idle rpm
- Inlet air restriction
- Exhaust system restriction

Check the Wastegate for Proper Operation

Table 3

Tools Needed		
Part Number	**Part Name**	**Qty**
	Dial Indicator	1

1. Remove the heat shield from the turbocharger. Remove the guard for the wastegate.

2. Remove the boost line from the wastegate. Connect an air supply to the wastegate that can be adjusted accurately.

3. Fasten a dial indicator to the turbocharger so that the end of the actuator rod is in contact with the dial indicator. This will measure axial movement of the actuator rod.

4. Slowly apply air pressure to the wastegate so that the actuator rod moves 1.0 mm (0.039 inch). The air pressure should be within 107 to 117 kPa (15.5 to 17.0 psi). Ensure that the dial indicator returns to zero when the air pressure is released. Repeat the test several times. This will ensure that an accurate reading is obtained.

5. Consult your nearest approved Perkins dealer or your nearest approved Perkins distributor if the operation of the wastegate is not correct.

i01297498

Compression - Test

The cylinder compression test should only be used in order to compare the cylinders of an engine. If one or more cylinders vary by more than 350 kPa (51 psi), the cylinder and related components may need to be repaired.

A compression test should not be the only method which is used to determine the condition of an engine. Other tests should also be conducted in order to determine if the adjustment or the replacement of components is required.

Before the performance of the compression test, make sure that the following conditions exist:

- The battery is in good condition.
- The battery is fully charged.
- The starting motor operates correctly.
- The valve lash is set correctly.
- All fuel injection nozzles are removed.
- The fuel supply is disconnected.

1. Install a gauge for measuring the cylinder compression in the hole for a fuel injection nozzle.

2. Operate the starting motor in order to turn the engine. Record the maximum pressure which is indicated on the compression gauge.

3. Repeat Steps 1 and 2 for all cylinders.

i01854567

Engine Valve Lash - Inspect/Adjust

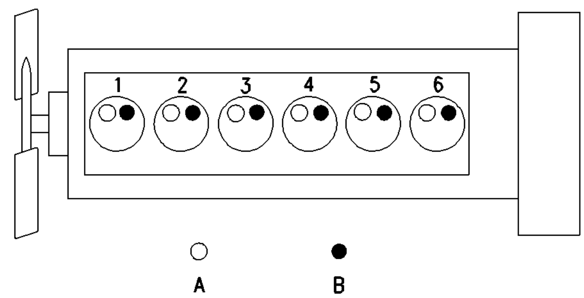

Illustration 63 g00939480

Cylinder and valve location

(A) Inlet valve
(B) Exhaust valve

If the valve lash requires adjustment several times in a short period of time, excessive wear exists in a different part of the engine. Find the problem and make necessary repairs in order to prevent more damage to the engine.

Not enough valve lash can be the cause of rapid wear of the camshaft and valve lifters. Not enough valve lash can indicate that the seats for the valves are worn.

Valves become worn due to the following causes:

- Fuel injection nozzles that operate incorrectly
- Excessive dirt and oil are present on the filters for the inlet air.
- Incorrect fuel settings on the fuel injection pump.
- The load capacity of the engine is frequently exceeded.

Too much valve lash can cause broken valve stems, springs, and spring retainers. Too much valve lash can be an indication of the following problems:

- Worn camshaft and valve lifters
- Worn rocker arms
- Bent pushrods
- Broken socket on the upper end of a pushrod
- Loose adjustment screw for the valve lash

If the camshaft and valve lifters show rapid wear, look for fuel in the lubrication oil or dirty lubrication oil as a possible cause.

Valve Lash Check

An adjustment is NOT NECESSARY if the measurement of the valve lash is in the acceptable range. Check the valve lash while the engine is stopped. The temperature of the engine does not change the valve lash setting.

If the measurement is not within the acceptable clearance, adjustment is necessary. Refer to "Valve Lash Adjustment".

Valve Lash Adjustment

Table 4

	Inlet Valves	Exhaust Valves
Valve Lash	0.20 mm (0.008 inch)	0.45 mm (0.018 inch)
TC Compression Stroke	1-2-4	1-3-5
TC Exhaust Stroke(1)	3-5-6	2-4-6
Firing Order	1-5-3-6-2-4(2)	

(1) 360° from TC compression stroke
(2) The No. 1 Cylinder is at the front of the engine.

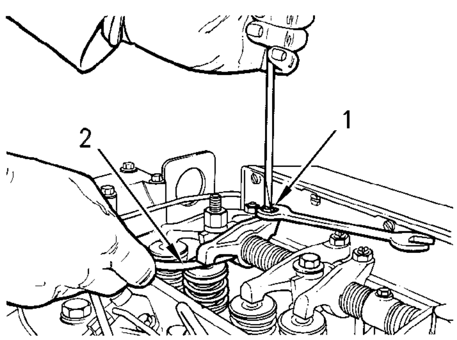

Illustration 64 g00323903

Setting the valve lash

(1) Adjustment screw
(2) Feeler gauge

WARNING

Accidental engine starting can cause injury or death to personnel.

To prevent accidental engine starting, turn the ignition switch to the OFF position and place a do not operate tag at the ignition switch location.

1. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove" For the removal procedure.

2. Rotate the crankshaft in the direction of engine rotation until the inlet valve of the No. 6 cylinder has opened and the exhaust valve of the No. 6 cylinder has not completely closed. The engine is now at TC compression stroke.

Table 5

TC Compression Stroke	Inlet Valves	Exhaust Valves
Valve Lash	0.20 mm (0.008 inch)	0.45 mm (0.018 inch)
Cylinders	1-2-4	1-3-5

3. Measure the valve lash for the valve when the engine is at TC compression stroke according to Table 5. If necessary, make an adjustment to the valves according to Table 5.

    a. Loosen the valve adjustment screw locknut that is on the adjustment screw (1).

    b. Place an appropriate feeler gauge (2) between the rocker arm and the valve. Turn the adjustment screw (1) while the valve adjustment screw locknut is being held from turning. Adjust the valve lash until the correct specification is achieved.

    c. After each adjustment, tighten the valve adjustment screw locknut while you hold the valve adjustment screw (1) from turning.

4. Rotate the crankshaft in the direction of engine rotation to TC exhaust stroke (360° from TC compression stroke).

Table 6

TC Exhaust Stroke(1)	Inlet Valves	Exhaust Valves
Valve Lash	0.20 mm (0.008 inch)	0.45 mm (0.018 inch)
Cylinders	3-5-6	2-4-6

(1) 360° from TC compression stroke

5. Measure the valve lash for the valves when the engine is at TC exhaust stroke according to Table 6. If necessary, make an adjustment to the valves according to Table 6.

a. Loosen the valve adjustment screw locknut that is on the adjustment screw (1).

b. Place an appropriate feeler gauge (2) between the rocker arm and the valve. Turn the adjustment screw (1) while the valve adjustment screw locknut is being held from turning. Adjust the valve lash until the correct specification is achieved.

c. After each adjustment, tighten the valve adjustment screw locknut while you hold the valve adjustment screw (1) from turning.

6. Install the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Install" for the installation procedure.

i01872196

Valve Depth - Inspect

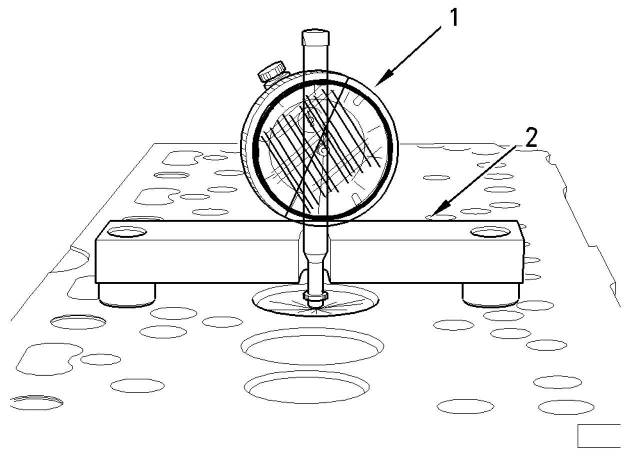

Illustration 65 g00953530

Valve Depth

(1) 21825617 Dial gauge
(2) 21825496 Dial gauge holder

1. Ensure that the face of the valves are clean. Ensure that the bottom face of the cylinder head is clean. Ensure that the cylinder head is not distorted. Refer to Testing and Adjusting, "Cylinder Head - Inspect" for the procedure to measure flatness of the cylinder head.

2. Use the dial gauge (1) with the dial gauge holder (2) in order to check the depths of the inlet valve and the exhaust valve below the face of the cylinder head. Use the cylinder head face to zero the dial gauge (1).

3. Measure the depth of the inlet valve and the exhaust valve below the cylinder head face. The minimum and maximum limits for a new engine follow:

Inlet valves

Minimum .... 1.40 mm (0.055 inch)
Maximum .... 1.70 mm (0.067 inch)

Exhaust valves

Minimum .... 1.50 mm (0.059 inch)
Maximum .... 1.80 mm (0.071 inch)

4. Service wear occurs on an engine which has been in operation. If the valve depth below the cylinder head face on a used engine exceeds the specification for service wear, the following components must be replaced.

   - Valves
   - Valve inserts

   Wear limit for inlet valves .. 1.95 mm (0.077 inch)

   Wear limit for exhaust valves .... 2.05 mm (0.081 inch)

5. Check each valve for cracks. Check the stems of the valves for wear. Ensure that the valves are the correct fit in the valve guides. Refer to Testing and Adjusting, "Valve Guide - Inspect" for the procedure to inspect the valve guides.

6. Check the load on the valve springs. Refer to Specifications, "Cylinder Head Valves" for the correct lengths and specifications for the valve springs.

i01854998

Valve Guide - Inspect

Perform this test in order to determine if a valve guide should be replaced.

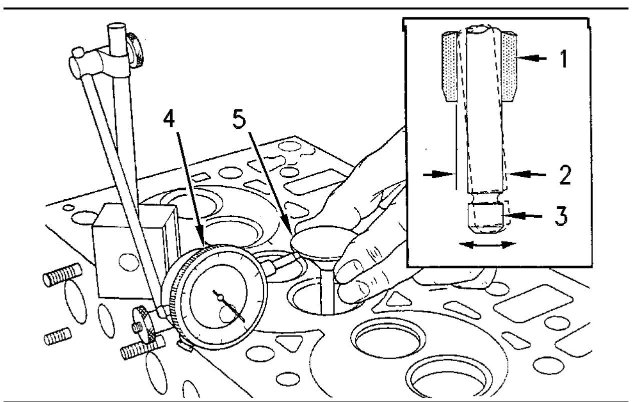

Illustration 66 g00314806

Measure the radial movement of the valve in the valve guide.

(1) Valve guide
(2) Radial movement of the valve in the valve guide
(3) Valve stem
(4) Dial indicator
(5) Valve head

1. Place a new valve in the valve guide.

2. Place a dial indicator with a magnetic base on the face of the cylinder head.

3. Lift the edge of the valve head to a distance of 15.0 mm (0.60 inch).

4. Move the valve in a radial direction away from the dial indicator. Make sure that the valve moves away from the dial indicator as far as possible. Position the contact point of the dial indicator on the edge of the valve head. Set the position of the needle of the dial indicator to zero.

5. Move the valve in a radial direction toward the dial indicator as far as possible. Note the distance of movement which is indicated on the dial indicator. If the distance is greater than the maximum clearance of the valve in the valve guide, replace the valve guide.

   The maximum clearance for the inlet valve stem in the valve guide with a valve lift of 15.0 mm (0.60 inch) is the following value. .... 0.100 mm (0.0039 inch)

   The maximum clearance for the exhaust valve stem in the valve guide with a valve lift of 15.0 mm (0.60 inch) is the following value. .... 0.121 mm (0.0048 inch)

When new valve guides are installed, new valves and new valve seat inserts must be installed. Valve guides and valve seat inserts are supplied as an unfinished part. The unfinished valve guides and unfinished valve seat inserts are installed in the cylinder head. Then, the valve guides and valve inserts are cut and reamed in one operation with special tooling.

Refer to Disassembly and Assembly, "Inlet and Exhaust Valve Guides - Remove and install" for the replacement of the valve guides.

Lubrication System

i01854908

Engine Oil Pressure - Test

Low Oil Pressure

The following conditions will cause low oil pressure.

- The oil level is low in the crankcase.
- A restriction exists on the oil suction screen.
- Connections in the oil lines are leaking.
- The connecting rod or the main bearings are worn.
- The rotors in the oil pump are worn.
- The oil pressure relief valve is operating incorrectly.

A worn oil pressure relief valve can allow oil to leak through the valve which lowers the oil pressure. Refer to the Specifications Module, "Engine Oil Relief Valve" for the correct operating pressure and other information.

When the engine runs at the normal temperature for operation and at high idle, the oil pressure must be a minimum of 280 kPa (40 psi). A lower pressure is normal at low idle.

A suitable pressure gauge can be used in order to test the pressure of the lubrication system.

High Oil Pressure

High oil pressure can be caused by the following conditions.

- The spring for the oil pressure relief valve is installed incorrectly.
- The plunger for the oil pressure relief valve becomes jammed in the closed position.
- Excessive sludge exists in the oil which makes the viscosity of the oil too high.

i01456927

Engine Oil Pump - Inspect

If any part of the oil pump is worn enough in order to affect the performance of the oil pump, the oil pump must be replaced.

Perform the following procedures in order to inspect the oil pump. Refer to the Specifications Module, "Engine Oil Pump" for clearances and torques.

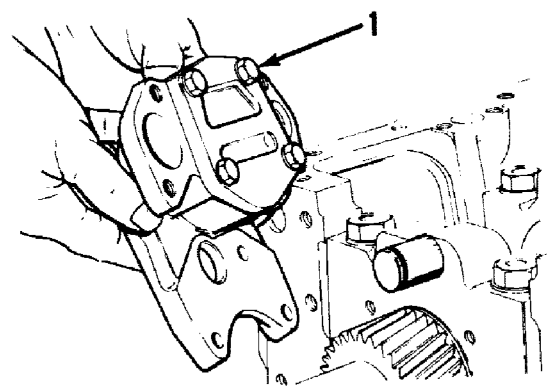

Illustration 67 g00295506

Oil pump cover

(1) Cover bolts

1. Remove the oil pump from the engine. Remove the cover of the oil pump.
2. Remove the outer rotor. Clean all of the parts. Look for cracks in the metal or other damage.

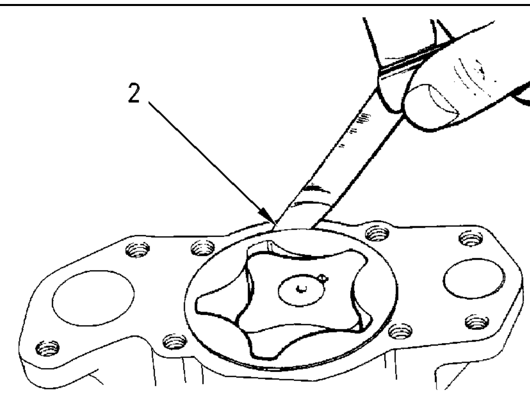

Illustration 68 g00578755

Clearance for the outer rotor body

(2) Measure the clearance of the outer rotor to the body.

3. Install the outer rotor. Measure the clearance of the outer rotor to the body (2).

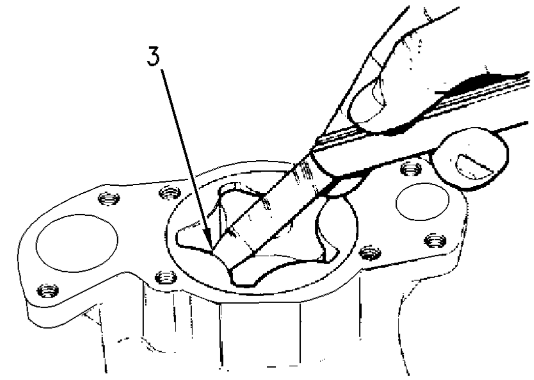

Illustration 69 g00578757

Clearance for the inner rotor body

(3) Measure the clearance of the inner rotor to the outer rotor.

4. Measure the clearance of the inner rotor to the outer rotor (3).

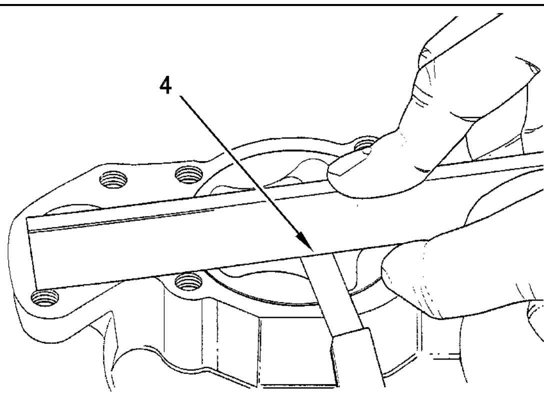

Illustration 70 g00578719

End play measurement of the rotor

(4) Measure the end play of the rotor.

5. Measure the end play of the rotor with a straight edge and a feeler gauge (4).

6. Clean the top face of the oil pump and the bottom face of the cover. Install the cover on the oil pump. Install the oil pump on the engine.

i01126690

Excessive Bearing Wear - Inspect

When some components of the engine show bearing wear in a short time, the cause can be a restriction in an oil passage.

An engine oil pressure indicator may show that there is enough oil pressure, but a component is worn due to a lack of lubrication. In such a case, look at the passage for the oil supply to the component. A restriction in an oil supply passage will not allow enough lubrication to reach a component. This will result in early wear.

i01794028

Excessive Engine Oil Consumption - Inspect

Engine Oil Leaks on the Outside of the Engine

Check for leakage at the seals at each end of the crankshaft. Look for leakage at the gasket for the engine oil pan and all lubrication system connections. Look for any engine oil that may be leaking from the crankcase breather. This can be caused by combustion gas leakage around the pistons. A dirty crankcase breather will cause high pressure in the crankcase. A dirty crankcase breather will cause the gaskets and the seals to leak.

Engine Oil Leaks into the Combustion Area of the Cylinders

Engine oil that is leaking into the combustion area of the cylinders can be the cause of blue smoke. There are several possible ways for engine oil to leak into the combustion area of the cylinders:

- Leaks between worn valve guides and valve stems
- Worn components or damaged components (pistons, piston rings, or dirty return holes for the engine oil)
- Incorrect installation of the compression ring and/or the intermediate ring
- Leaks past the seal rings in the turbocharger shaft
- Overfilling of the crankcase
- Wrong dipstick or guide tube
- Sustained operation at light loads

Excessive consumption of engine oil can also result if engine oil with the wrong viscosity is used. Engine oil with a thin viscosity can be caused by fuel leakage into the crankcase or by increased engine temperature.

i01462628

Increased Engine Oil Temperature - Inspect

Look for a restriction in the oil passages of the oil cooler. The oil temperature may be higher than normal when the engine is operating. In such a case, the oil cooler may have a restriction. A restriction in the oil cooler will not cause low oil pressure in the engine.

Determine if the oil cooler bypass valve is held in the open position. This condition will allow the oil to pass through the valve instead of the oil cooler. The oil temperature will increase.

Cooling System

i01874899

Cooling System - Check

Engine And Cooling System Heat Problems

1. The following conditions indicate that a heat problem exists.

a. Hot coolant is released through the pressure cap during the normal operation of the engine. Hot coolant can also be released when the engine is stopped.

b. Hot coolant is released from the coolant system but not through the pressure cap during normal operation of the engine. Hot coolant can also be released when the engine is stopped.

c. Coolant must be added frequently to the cooling system. The coolant is not released through the pressure cap or through an outside leak.

2. If any of the conditions in Step 1 exist, perform the following procedures:

a. Run the engine at medium idle, which is approximately 1200 rpm, for three minutes after the high idle shuts off. Running the engine at medium idle will allow the engine to cool before the engine is stopped.

b. Refer to the Testing And Adjusting, “Belt Tension Chart”. Check the tension of all belts on the engine.

3. Refer to “Visual Inspection Of The Cooling System” in order to determine if a leak exists in the cooling system.

a. Refer to “Testing The Radiator And Cooling System For Leaks” procedures.

4. If the coolant does not flow through the radiator and through other components of the cooling system, perform the following procedures.

a. Perform the “Testing The Water Temperature Regulator ” procedures.

b. Clean the radiator and other components with hot water or steam at low pressure. Detergent in the water may also be used. Compressed air may be used to remove materials from the cooling system. Identify the cause of the restriction before you choose the method for cleaning.

c. Straighten any fins of the radiator if the fins are bent.

5. Check the high idle of the engine. The engine may overheat if the high idle rpm is set too high.

i01626003

Cooling System - Inspect

This engine has a pressure type cooling system. A pressure type cooling system gives two advantages:

- The pressure type cooling system can operate safely at a higher temperature than the boiling point of water at a range of atmospheric pressures.
- The pressure type cooling system prevents cavitation in the water pump.

Cavitation is the sudden generation of low pressure bubbles in liquids by mechanical forces. The generation of an air or steam pocket is much more difficult in a pressure type cooling system.

Regular inspections of the cooling system should be made in order to identify problems before damage can occur. Visually inspect the cooling system before tests are made with the test equipment.

Visual Inspection Of The Cooling System

1. Check the coolant level in the cooling system.

2. Look for leaks in the system.

Note: A small amount of coolant leakage across the surface of the water pump seals is normal. This leakage is required in order to provide lubrication for this type of seal. A hole is provided in the water pump housing in order to allow this coolant/seal lubricant to drain from the pump housing. Intermittent leakage of small amounts of coolant from this hole is not an indication of water pump seal failure.

3. Inspect the radiator for bent fins and other restriction to the flow of air through the radiator.

4. Inspect the drive belt for the fan.

5. Inspect the blades of the fan for damage.

6. Look for air or combustion gas in the cooling system.

7. Inspect the radiator cap for damage. The sealing surface must be clean.

8. Look for large amounts of dirt in the radiator core. Look for large amounts of dirt on the engine.

9. Shrouds that are loose or missing cause poor air flow for cooling.

i01876572

Cooling System - Test

Remember that temperature and pressure work together. When a diagnosis is made of a cooling system problem, temperature and pressure must be checked. The cooling system pressure will have an effect on the cooling system temperature. For an example, refer to Illustration 71. This will show the effect of pressure on the boiling point (steam) of water. This will also show the effect of height above sea level.

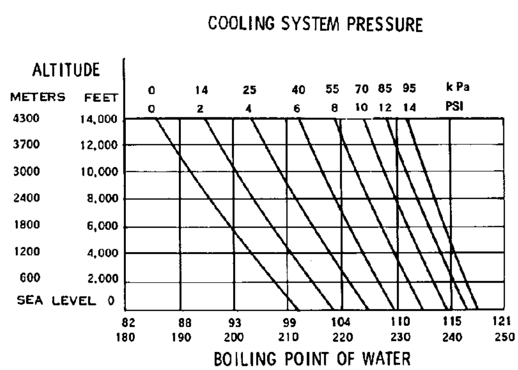

Illustration 71 g00286266

Cooling system pressure at specific altitudes and boiling points of water

WARNING

Personal injury can result from hot coolant, steam and alkali.

At operating temperature, engine coolant is hot and under pressure. The radiator and all lines to heaters or the engine contain hot coolant or steam. Any contact can cause severe burns.

Remove filler cap slowly to relieve pressure only when engine is stopped and radiator cap is cool enough to touch with your bare hand.

The coolant level must be to the correct level in order to check the coolant system. The engine must be cold and the engine must not be running.

After the engine is cool, loosen the pressure cap in order to relieve the pressure out of the cooling system. Then remove the pressure cap.

The level of the coolant should not be more than 13 mm (0.5 inch) from the bottom of the filler pipe. If the cooling system is equipped with a sight glass, the coolant should be to the correct level in the sight glass.

Making the Correct Antifreeze Mixtures

Do not add pure 21825166 POWERPART antifreeze to the cooling system in order to adjust the concentration of antifreeze. The pure antifreeze increases the concentration of antifreeze in the cooling system. The increased concentration increases the concentration of dissolved solids and undissolved chemical inhibitors in the cooling system.

The antifreeze mixture must consist of equal quantities of antifreeze and clean soft water. The corrosion inhibitor in the antifreeze will be diluted if a concentration of less than 50% of antifreeze is used. Concentrations of more than 50% of antifreeze may have the adverse effect on the performance of the coolant.

Checking the Filler Cap

One cause for a pressure loss in the cooling system can be a faulty seal on the radiator pressure cap.

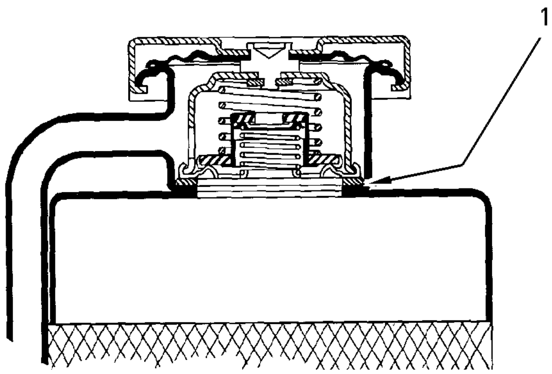

Illustration 72 g00296067

Typical schematic of filler cap

(1) Sealing surface between the pressure cap and the radiator

WARNING

Personal injury can result from hot coolant, steam and alkali.

At operating temperature, engine coolant is hot and under pressure. The radiator and all lines to heaters or the engine contain hot coolant or steam. Any contact can cause severe burns.

Remove filler cap slowly to relieve pressure only when engine is stopped and radiator cap is cool enough to touch with your bare hand.

To check for the amount of pressure that opens the filler cap, use the following procedure:

1. After the engine cools, carefully loosen the filler cap. Slowly release the pressure from the cooling system. Then, remove the filler cap.

2. Inspect the pressure cap carefully. Look for damage to the seal. Look for damage to the surface that seals. Remove any debris on the cap, the seal, or the sealing surface.

   Carefully inspect the filler cap. Look for any damage to the seals and to the sealing surface. Inspect the following components for any foreign substances:

   - Filler cap
   - Seal
   - Surface for seal

   Remove any deposits that are found on these items, and remove any material that is found on these items.

3. Install the pressure cap onto a suitable pressurizing Pump.

4. Observe the exact pressure that opens the filler cap.

5. Compare the pressure to the pressure rating that is found on the top of the filler cap.

6. If the filler cap is damaged, replace the filler cap.

Testing The Radiator And Cooling System For Leaks

Use the following procedure to test the radiator and the cooling system for leaks.

WARNING

Personal injury can result from hot coolant, steam and alkali.

At operating temperature, engine coolant is hot and under pressure. The radiator and all lines to heaters or the engine contain hot coolant or steam. Any contact can cause severe burns.

Remove filler cap slowly to relieve pressure only when engine is stopped and radiator cap is cool enough to touch with your bare hand.

1. When the engine has cooled, loosen the filler cap to the first stop. Allow the pressure to release from the cooling system. Then remove the filler cap.

2. Make sure that the coolant covers the top of the radiator core.

3. Put a suitable pressurizing Pump onto the radiator.

4. Use the pressurizing pump to increase the pressure to an amount of 20 kPa (3 psi) more than the operating pressure of the filler cap.

5. Check the radiator for leakage on the outside.

6. Check all connections and hoses of the cooling system for leaks.

   The radiator and the cooling system do not have leakage if all of the following conditions exist:

   - You do NOT observe any leakage after five minutes.
   - The dial indicator remains constant beyond five minutes.

The inside of the cooling system has leakage only if the following conditions exist:

- The reading on the gauge goes down.
- You do NOT observe any outside leakage.

Make any repairs, as required.

i01874900

Engine Oil Cooler - Inspect

⚠ WARNING

Hot oil and hot components can cause personal injury. Do not allow hot oil or hot components to contact the skin.

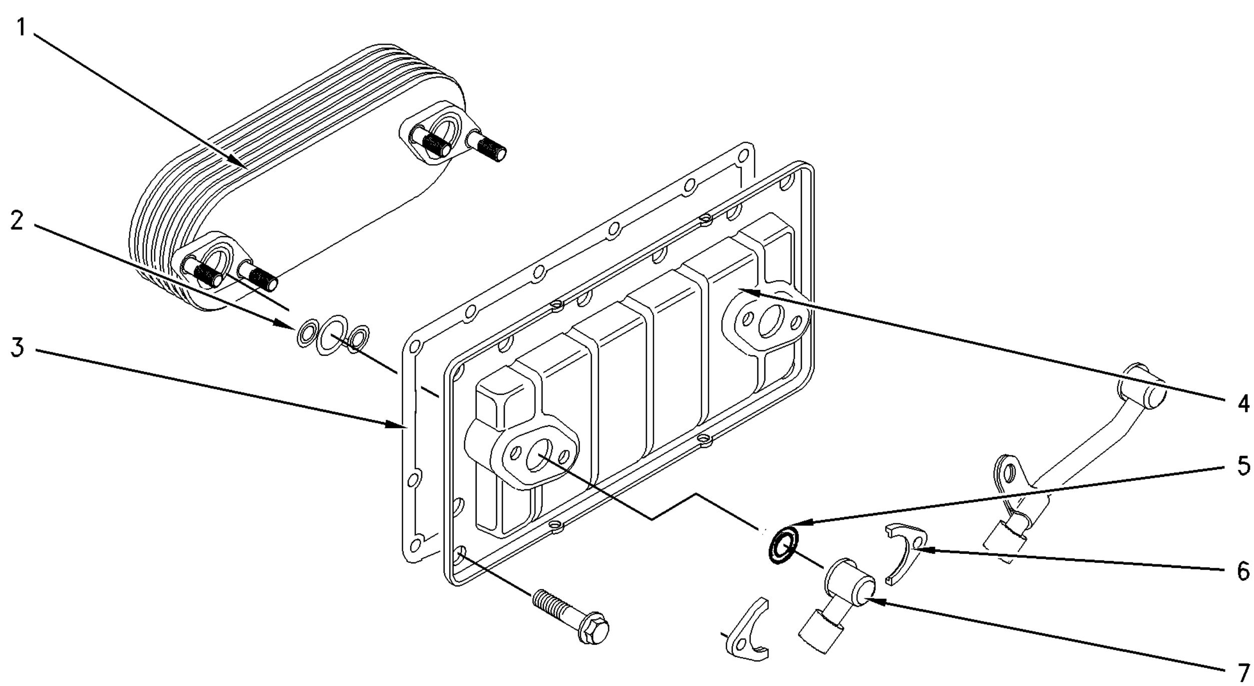

Illustration 73

g00954224

(1) Cooling plate
(2) Seal
(3) Gasket
(4) Cover plate
(5) O ring
(6) Two-piece flange
(7) Oil hose

Perform the following procedure in order to inspect the engine oil cooler:

1. Place a container under the oil cooler in order to collect any engine oil or coolant that drains from the oil cooler. Remove one of the oil hoses. Do not remove both of the oil hoses at the same time in order to ensure that the cooling plate (1) remains fastened to the cover plate (4).

Before the second oil hose is removed, install the two-piece flange (6) and the nuts on the studs for flange (6) without the oil hose.

2. Refer to Disassembly and Assembly, “Engine Oil Cooler - Remove” for removal of the engine oil cooler.

3. Thoroughly clean the flange face of the cover plate and the cylinder block.

WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

4. Inspect the cooling plate (1) for cracks and dents. Replace the cooling plate if cracks or dents exist.

   If necessary, clean the outside of the cooling plate and clean the inside of the cooling plate. Use a solvent that is not corrosive on copper. Ensure that no restrictions for the flow of lubricating oil exist in the cooling plate.

   Dry the cooling plate with low pressure air. Flush the inside of the cooling plate with clean lubricating oil.

5. Refer to Disassembly and Assembly, "Engine Oil Cooler - Install" for installation of the engine oil cooler.

6. Ensure that the cooling system of the engine is filled to the correct level. Operate the engine.

Note: Refer to the Operation And Maintenance Manual for additional information.

   Check for oil or coolant leakage.

i01666401

Water Temperature Regulator - Test

WARNING

Personal injury can result from escaping fluid under pressure.

If a pressure indication is shown on the indicator, push the release valve in order to relieve pressure before removing any hose from the radiator.

1. Remove the water temperature regulator from the engine.

2. Heat water in a pan until the temperature of the water is equal to the fully open temperature of the water temperature regulator. Refer to Specifications, "Water Temperature Regulator" for the fully open temperature of the water temperature regulator. Stir the water in the pan. This will distribute the temperature throughout the pan.

3. Hang the water temperature regulator in the pan of water. The water temperature regulator must be below the surface of the water. The water temperature regulator must be away from the sides and the bottom of the pan.

4. Keep the water at the correct temperature for ten minutes.

5. After ten minutes, remove the water temperature regulator. Immediately measure the opening of the water temperature regulator. Refer to Specifications, "Water Temperature Regulator" for the minimum opening distance of the water temperature regulator at the fully open temperature.

If the distance is less than the amount listed in the manual, replace the water temperature regulator.

i01628133

Water Pump - Inspect

1. Inspect the water pump for leaks at vent hole. The water pump seal is lubricated by coolant in the cooling system. It is normal for a small amount of leakage to occur as the engine cools down and the parts contract.

2. Refer to Disassembly and Assembly, "Water Pump - Remove " and Disassembly and Assembly, "Water Pump - Install".

3. Inspect the water pump shaft for unusual noise, excessive looseness and/or vibration of the bearings.

Basic Engine

i01853436

Piston Ring Groove - Inspect

Inspect the Piston and the Piston Rings

1. Check the piston for wear and other damage.

2. Check that the piston rings are free to move in the grooves and that the rings are not broken.

Inspect the Clearance of the Piston Ring

1. Remove the piston rings and clean the grooves and the piston rings.

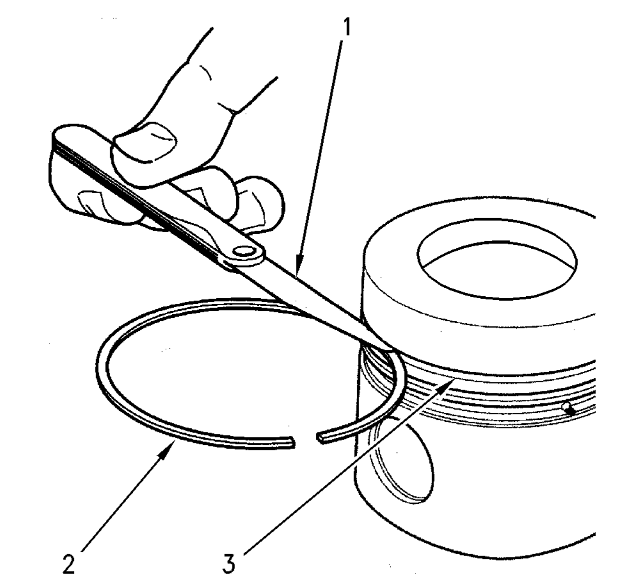

Illustration 74 g00905732

(1) Feeler gauge
(2) Piston ring
(3) Piston grooves

2. Fit new piston rings (2) in the piston grooves (3).

3. Check the clearance for the piston ring by placing a suitable feeler gauge (1) between piston groove (3) and the top of piston ring (2). Refer to Specifications, "Piston and Rings" for the dimensions.

Note: Some pistons have a tapered top groove and the piston ring is wedged. The clearance for the top piston ring cannot be checked by the above method when this occurs.

Inspect the Piston Ring End Gap

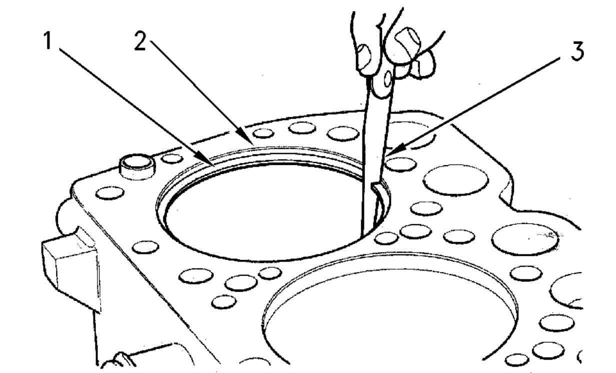

Illustration 75 g00782363

(1) Piston ring
(2) Cylinder ring ridge
(3) Feeler gauge

1. Clean all carbon from the top of the cylinder bores.

2. Place each piston ring (1) in the cylinder bore just below the cylinder ring ridge (2).

3. Use a suitable feeler gauge (3) to measure piston ring end gap. Refer to Specifications, "Piston and Rings" for the dimensions.

Note: The coil spring must be removed from the oil control ring before the gap of the oil control ring is measured.

i01874902

Connecting Rod - Inspect

These procedures determine the following characteristics of the connecting rod:

- The length of the connecting rod
- The distortion of the connecting rod
- The parallel alignment of the bores of the connecting rod

Note: If the crankshaft or the cylinder block are replaced, the piston height for all cylinders must be measured. The grade of length of the connecting rods may need to be changed in order to obtain the correct piston height.

If the grade of length must be changed, one of the following actions must be taken:

- New connecting rod assemblies that are the correct grade of length must be installed. Refer to "Length Of The Connecting Rod".

- New piston pin bearings must be bored after installation in the original connecting rods. Refer to “Piston Pin Bearings”.

Note: When the piston pin is installed, always install new retaining rings on each end of the piston pin. If the piston pin cannot be removed by hand, heat the piston to a temperature of 45° ± 5 °C (113° ± 9 °F) in order to aid the removal of the piston pin. Heating the piston to this temperature may also aid the installation of the piston pin.

Length of The Connecting Rod

CRL is the length of the connecting rod. Refer to Table 7 for each grade of length of connecting rod.

In order to ensure that the piston height above the cylinder block is correct, six grades of connecting rods “F” to “L”are used during manufacture at the factory. Replacement connecting rods are available in four grades. These grades of connecting rod are “H” to “L”. The grade of length is identified by a letter or a color which is marked on the side of the connecting rod. The longest grade is marked with the letter “H”. The shortest grade is marked with the letter “L”. The difference in length between each grade of connecting rods is the following value: 0.046 mm (0.0018 inch)

The grade of length of a connecting rod is determined in the factory by machining an eccentric hole in a semi-finished piston pin bushing. Therefore, the grade of length is determined by the position of the center of the hole in the piston pin bearing.

If the connecting rod must be replaced, a new connecting rod assembly must be purchased and installed. Refer to Table 7 for more information.

A new piston pin bearing is installed in the new connecting rod at the factory. The bore of the piston pin bearing is reamed to the correct eccentricity.

Piston Pin Bearings

Note: This procedure requires personnel with the correct training and the use of specialized equipment for machining.

If the piston pin bearing requires replacement but the original connecting rod is not replaced, the following procedures must be performed:

1. Determine the grade of length of the connecting rod. Use one of the following characteristics:

   - The mark
   - The color
   - Measuring the length

2. Ensure that the connecting rod is aligned parallel and that the connecting rod is not distorted. Refer to “Distortion Of A Connecting Rod” in this service module.

3. Remove the piston pin bearing from the connecting rod. Install a new bearing in the connecting rod. The new bearing is partially finished. The new bearing must be bored off-center to the correct diameter. This off-center position is determined by the grade of length of the connecting rod. Refer to Table 7. The correct diameter of the bore in the piston pin bearing is given in the Specifications Module, “Connecting Rod”.

   Surface finish of the bored hole in the piston pin bearing .... Ra 0.8 micrometers

4. Machine the ends of the piston pin bearing to the correct length. Remove any sharp edges. Refer to the Specifications Module, “Connecting Rod”.

5. If the grade of length of the connecting rod is changed, the letter that is stamped on the connecting rod must be removed. Etch a letter that is for the new grade of length on the side of the connecting rod.

Note: Do not stamp a new letter on the connecting rod. The force of stamping may damage the connecting rod.

Table 7 references the following information: Grade of letter of the connecting rod, the color code of the connecting rods, and the lengths of the connecting rods.

Table 7

Grade Letter	Color Code	Length Of The Connecting Rod (CRL)
“H”	White	165.637 to 165.670 mm (6.5211 to 6.5229 inch)
“J”	Green	165.591 to 165.624 mm (6.5193 to 6.5211 inch)
“K”	Purple	165.545 to 165.578 mm (6.5175 to 6.5193 inch)
“L”	Blue	165.499 to 165.532 mm (6.5157 to 6.5175 inch)

Measure The Length Of The Connecting Rod

If the mark or the color of the grade of length cannot be observed on the connecting rod, perform the following procedure:

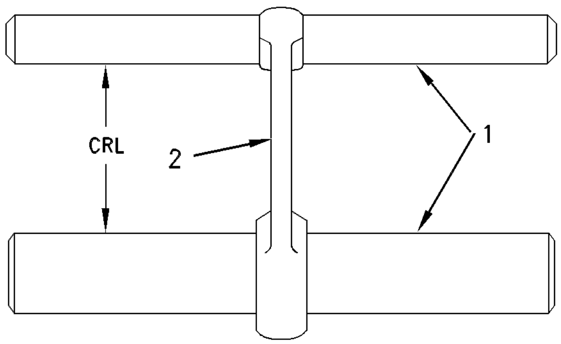

Illustration 76 g00326546

Measure the length of the connecting rod.

(1) Measuring pins
(2) Connecting rod
(CRL) Connecting Rod Length

1. Refer to Illustration 76. Use the following tools in order to measure the length of the connecting rod:

   - Appropriate gauges for measuring distance

   - Measuring pins (1)

2. Ensure that the measuring pins (1) are parallel. "CRL" is measured when the bearing for the crankshaft journal is removed and the original piston pin bearing is installed.

   Measure "CRL". Compare the "CRL" that is given in Table 7. The grade of length of the connecting rod is determined by the "CRL". Refer to Table 7 for the correct grade of length.

Distortion of The Connecting Rod

1. Use the following tools in order to measure the distances for the connecting rod (2) which are specified in Illustration 76:

   - Appropriate gauges for measuring distance

   - Measuring pins (1)

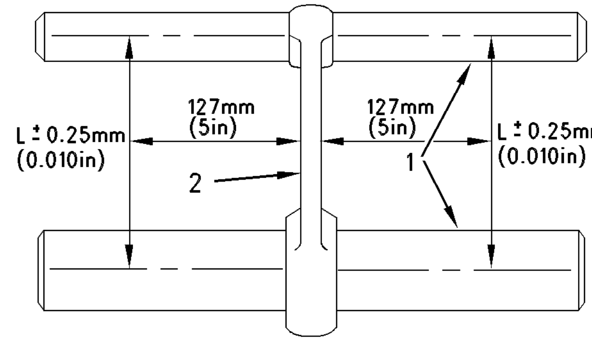

Illustration 77 g00326423

Measure the connecting rod for distortion.

(1) Measuring pins
(2) Connecting rod
(L) The length between the centers of the piston pin bearing and the crankshaft journal bearing is shown in Illustration 77.

2. Measure the connecting rod for distortion and parallel alignment between the bores.

   The bores for the crankshaft bearing and the bearing for the piston pin must be square and parallel with each other within the required limits. If the piston pin bearing is removed, the limit "L" is the following value: ± 0.25 mm (± 0.010 inch)

   The limits are measured at a distance of 127 mm (5.0 inch) from each side of the connecting rod.

   If the piston pin bearing is not removed, the limit "L" is the following value: ± 0.06 mm (± 0.0024 inch)

   L is equal to 219.08 ± 0.03 mm (8.625 ± 0.001 inch).

3. Inspect the piston pin bearing and the piston pin for wear.

4. Measure the clearance of the piston pin in the piston pin bearing. Refer to the Specifications Module, "Connecting Rod" for dimensions.

i01463492

Cylinder Block - Inspect

1. Clean all of the coolant passages and the oil passages.

2. Check the cylinder block for cracks and damage.

3. The top deck of the cylinder block must not be machined. This will affect the depth of the cylinder liner flange and the piston height above the cylinder block.

4. Check the camshaft bearings for wear. If a new bearing is needed, use a suitable adapter to press the bearing out of the bore. Ensure that the oil hole in the new bearing faces the front of the block. The oil hole in the bearing must be aligned with the oil hole in the cylinder block. The bearing must be aligned with the face of the recess.

5. Refer to Testing and Adjusting, "Cylinder Liner Projection - Inspect" for information on the inspection of the cylinder liner.

i01873079

Cylinder Head - Inspect

1. Remove the cylinder head from the engine.

2. Remove the water temperature regulator housing.

3. Inspect the cylinder head for signs of gas or coolant leakage.

4. Remove the valve springs and valves.

5. Clean the bottom face of the cylinder head thoroughly. Clean the coolant passages and the lubricating oil passages. Make sure that the contact surfaces of the cylinder head and the cylinder block are clean, smooth and flat.

6. Inspect the bottom face of the cylinder head for pitting, corrosion, and cracks. Inspect the area around the valve seat inserts and the holes for the fuel injection nozzles carefully.

7. Test the cylinder head for leaks at a pressure of 200 kPa (29 psi).

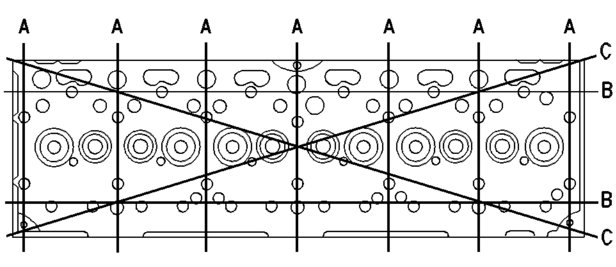

Illustration 78 g00295372

Flatness of the cylinder head (typical example)

(A) Side to side
(B) End to end
(C) Diagonal

8. Measure the cylinder head for flatness. Use a straight edge and a feeler gauge to check the cylinder head for flatness.

   - Measure the cylinder head from one side to the opposite side (A).
   - Measure the cylinder head from one end to the opposite end (B).
   - Measure the cylinder head from one corner to the opposite corner (C).

   Refer to Specifications, "Cylinder Head" for the requirements of flatness.

Resurfacing the Cylinder Head

The bottom face of cylinder head can be resurfaced if any of the following conditions exist:

- The bottom face of the cylinder head is not flat within the specifications.
- The bottom face of the cylinder head is damaged by pitting, corrosion, or wear.

Note: The thickness of the cylinder head must not be less than 102.48 mm (4.035 inch) after the cylinder head has been machined.

If the bottom face of the cylinder head is resurfaced, the recesses in the cylinder head for the valve seat inserts must be machined. The valve seat inserts must be ground on the side which is inserted into the cylinder head. Grinding this surface will ensure that no protrusion exists above the bottom face of the cylinder head. Refer to Specifications, "Cylinder Head Valves" for the correct dimensions.

i01873045

Cylinder Liner Projection - Inspect

1. Use the **21825617** dial gauge and the **21825496** dial gauge holder in order to measure the flange projection of the cylinder liner. Use the cylinder block face in order to zero the dial gauge (3).

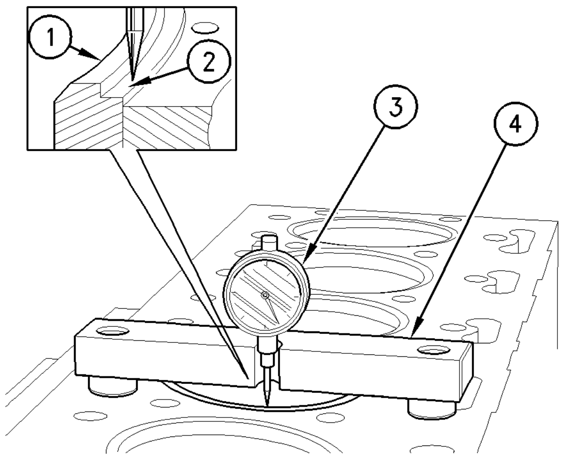

Illustration 79 g00953917

Measure the liner projection.

(1) Flame ring of cylinder liner
(2) Flange of cylinder liner
(3) 21825617 Dial gauge
(4) 21825496 Dial gauge holder

2. Position the dial gauge (3) and the dial gauge holder (4) on the flange of the cylinder liner (2). Measure the projection of the flange of the cylinder liner (2) in four locations around the cylinder liner. Do not measure the projection from the flame ring (1), if equipped.

The four measurements should not vary more than 0.03 mm (0.001 inch) from each other. The average projection between adjacent cylinders must not vary more than 0.03 mm (0.001 inch).

Refer to the Specifications Module, "Cylinder Block" for the tolerance for the projection of the flange of the cylinder liner (2).

Inspection Of The Cylinder Liner

The condition of a cylinder liner is determined by the following criteria:

- Check the extent and the location of any polished areas that are on the bore of the cylinder liner. If the bore of the cylinder liner is polished, an engine can have oil consumption that is high with very little wear on the bore. Observe the area that is near the top of the bore of the cylinder liner. The area is just below the ring of carbon. The thrust from the top piston ring is the maximum in this area.

- Check the wear that is on the bore of the cylinder liner. Refer to the Specifications Module, "Cylinder Block" for the dimensions of the cylinder liner.

- Check for damage to the cylinder liner such as cracks and deep scratches.

The cylinder liner does not need to be replaced if the following conditions exist:

- The honed finish can be clearly seen on the area of the cylinder liner.

- The engine performance and the oil consumption are acceptable.

If the cylinder liner requires replacement, refer to the Disassembly and Assembly, "Cylinder Liner - Remove " and the Disassembly and Assembly, "Cylinder Liner - Install" for the correct procedures.

A new cylinder liner is partially finished. Personnel with the correct training are required in order to finish a new cylinder liner. Special equipment and tools are also required. Refer to the Specifications Module for additional information.

Note: If a new cylinder liner is installed, new piston rings must be installed.

i01872303

Piston Height - Inspect

If the height of the piston above the cylinder block is not within the tolerance that is given in the Specifications Module, "Piston and Rings", the bearing for the piston pin must be checked. Refer to Testing and Adjusting, "Connecting Rod - Inspect". If any of the following components are replaced or remachined, the piston height above the cylinder block must be measured:

- Crankshaft

- Cylinder head

- Connecting rod

- Bearing for the piston pin

The correct piston height must be maintained in order to ensure that the engine conforms to the standards for emissions.

Note: The top of the piston should not be machined. If the original piston is installed, be sure that the original piston is assembled to the correct connecting rod and installed in the original cylinder.

Six grades of length of connecting rods determine the piston height above the cylinder block. The grade of length of a connecting rod is identified by a letter or a color. The letter or the color is marked on the side of the connecting rod. Refer to Testing and Adjusting, "Connecting Rod - Inspect" and Specifications, "Connecting Rod" for additional information.

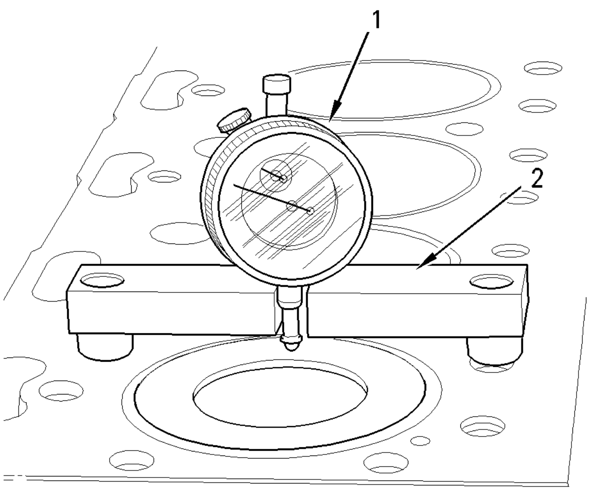

Illustration 80 g00953648

(1) 21825617 Dial gauge
(2) 21825496 Dial gauge holder

1. Use the dial gauge (1) and the dial gauge holder (2) in order to measure the piston height above the cylinder block. Use the cylinder block face to zero the dial gauge (1).

2. Rotate the crankshaft until the piston is at the approximate top center. Ensure that the flame ring of the cylinder liner does not interfere with the dial gauge holder (2) or the dial gauge (1).

3. Position the dial gauge holder (2) and the dial gauge (1) in order to measure the piston height above the cylinder block. Slowly rotate the crankshaft in order to determine when the piston is at the highest position. Record this dimension. Compare this dimension with the dimensions that are given in Specifications, "Piston and Rings".

i01785937

Flywheel - Inspect

Table 8

Required Tools		
Part Number	Part Description	Qty
8T-5096	Dial Indicator Group	1

Alignment of the Flywheel Face

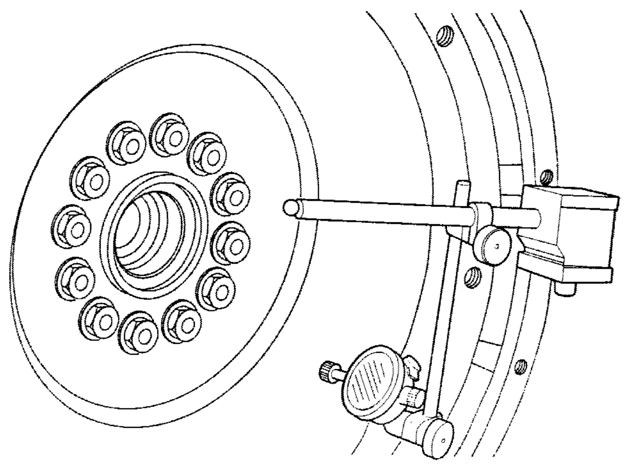

Illustration 81 g00295952

1. Install the dial indicator in Illustration 81, as shown.

2. Set the pointer of the dial indicator to 0 mm (0 inch).

3. Turn the flywheel. Read the dial indicator for every 90 degrees.

Note: During the check, keep the crankshaft pressed toward the front of the engine in order to remove any end clearance.

4. Calculate the difference between the lowest measurement and the highest measurement of the four locations. This difference must not be greater than 0.03 mm (0.001 inch) for every 25 mm (1.0 inch) of the radius of the flywheel. The radius of the flywheel is measured from the axis of the crankshaft to the contact point of the dial indicator.

Flywheel Runout

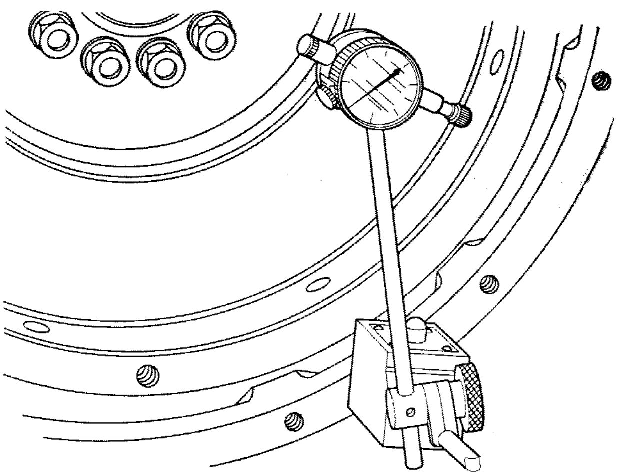

Illustration 82 g00295954

1. Install the dial indicator in Illustration 82, as shown.

2. Set the pointer of the dial indicator to 0 mm (0 inch).

3. Turn the flywheel. Read the dial indicator for every 90 degrees.

4. Calculate the difference between the lowest measurement and the highest measurement of the four locations. This difference must not be greater than 0.30 mm (0.012 inch).

i01862421

Flywheel Housing - Inspect

Concentricity of the Flywheel Housing

Note: This check must be made with the flywheel and the starter removed and the bolts for the flywheel housing tightened lightly.

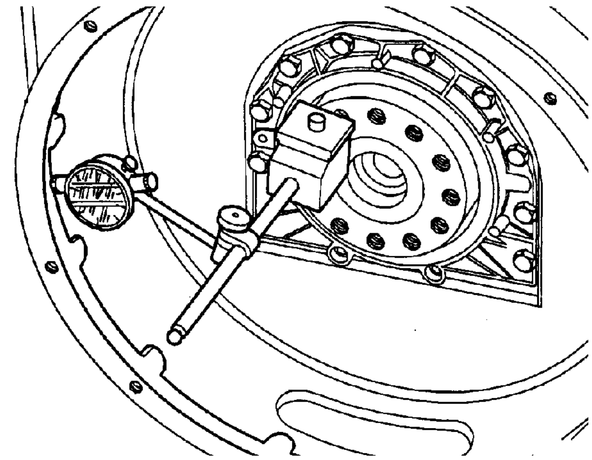

Illustration 83 g00913387

1. Install the 21825617 dial gauge. See Illustration 83.

2. Set the pointer of the 21825617 dial gauge to 0 mm (0 inch).

3. Check the concentricity at intervals of 90 degrees around the flywheel housing.

4. Calculate the difference between the lowest measurement and the highest measurement. This difference must not be greater than the limit that is given in Table 9.

Note: Any necessary adjustment must be made on the flywheel housing. Then, recheck the concentricity.

Alignment of the Flywheel Housing

Note: This check must be made with the flywheel and the starter removed and the bolts for the flywheel housing tightened to the correct torque.

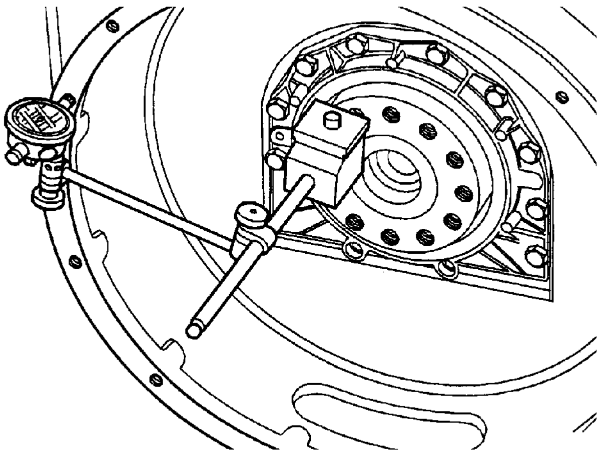

Illustration 84 g00913389

1. Install the 21825617 dial gauge. See Illustration 84.

2. Set the pointer of the 21825617 dial gauge to 0 mm (0 inch).

3. Check the alignment at intervals of 90 degrees around the flywheel housing.

4. Calculate the difference between the lowest measurement and the highest measurement. This difference must not be greater than the limit that is given in Table 9.

Note: Any necessary adjustment must be made on the flywheel housing.

Table 9

Limits for Flywheel Housing Runout and Alignment (Total Indicator Reading)	
Bore of the Housing Flange	**Maximum Limit (Total Indicator Reading)**
410 mm (16.14 inch)	0.25 mm (0.010 inch)
448 mm (17.63 inch)	0.28 mm (0.011 inch)

i01771501

Gear Group - Inspect

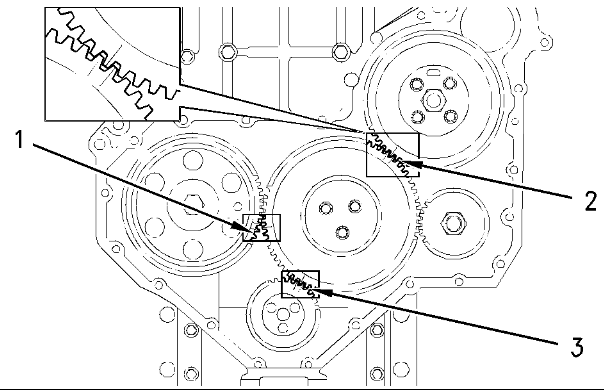

Illustration 85 g00905589

(1) Camshaft gear
(2) Fuel injection pump gear
(3) Crankshaft gear
(4) Idler gear

Note: If one or more of the gears need to be removed for repair, refer to the Disassembly and Assembly, "Gear Group (Front) - Remove" topic in order to properly remove the gears. Refer to the Disassembly and Assembly, "Gear Group (Front) - Install" topic in order to properly install the gears.

1. Inspect the gears for wear or for damage. If the gears are worn or damaged, use new parts for replacement.

2. Measure the backlash on camshaft gear (1). Refer to the Specifications, "Gear Group (Front)" topic for the backlash measurement.

3. Measure the backlash on idler gear (4). Refer to the Specifications, "Gear Group (Front)" topic for the backlash measurement.

4. Measure the backlash on fuel injection pump gear (2). Refer to the Specifications, "Gear Group (Front)" topic for the backlash measurement.

5. Measure the end play on idler gear (4). Refer to the Specifications, "Gear Group (Front)" topic for the end play measurement.

i01878712

Vibration Damper - Check

The vibration damper is installed on the front of the crankshaft or the rear of the crankshaft. The vibration damper is balanced in order to help remove torsional vibration in the engine.

Replace the vibration damper if any of the following conditions exist:

- There is any impact damage to the outer casing.
- There is leakage of the viscous fluid from the cover plate.
- There is movement of the pulley or the outer ring on the hub.
- There is a large amount of gear train wear that is not caused by lack of oil.
- Analysis of the engine oil has revealed that the front main bearing is badly worn.
- The engine has had a failure because of a broken crankshaft.

Check the areas around the holes for the bolts in the vibration damper for cracks or for wear and for damage.

Use the following steps in order to check the alignment and the runout of the vibration damper:

1. Remove any debris from the front face of the vibration damper. Remove any debris from the circumference of the vibration damper.

2. Use a suitable lever in order to move the vibration damper forward. This will eliminate the end play of the crankshaft. Do not use excessive force to move the vibration damper away from the engine.

3. Mount the dial indicator on the front cover. Use the dial indicator to measure the outer face of the vibration damper. Set the dial indicator to read 0.00 mm (0.00 inch).

4. Rotate the crankshaft at intervals of 90 degrees and read the dial indicator.

5. The difference between the lower measurements and the higher measurements that are read on the dial indicator at all four points must not be more than 0.18 mm (0.007 inch).

   If the reading on the dial indicator is more than 0.18 mm (0.007 inch), inspect the pulley and the vibration damper for damage. If the pulley or the vibration damper are damaged, use new parts for replacement.

6. Move the dial indicator so that the dial indicator will measure the circumference of the vibration damper. Set the dial indicator to read 0.00 mm (0.00 inch).

7. Slowly rotate the crankshaft in order to measure the runout of the circumference of the vibration damper. Use the highest reading and the lowest reading on the dial indicator. The maximum and the minimum readings on the dial indicator should not vary more than 0.12 mm (0.005 inch).

   If the reading on the dial indicator is more than 0.12 mm (0.005 inch), inspect the pulley and the vibration damper for damage. If the pulley or the vibration damper are damaged, use new parts for replacement.

Electrical System

i01854888

Air Inlet Heater - Test

Tests For The Air Inlet Heater

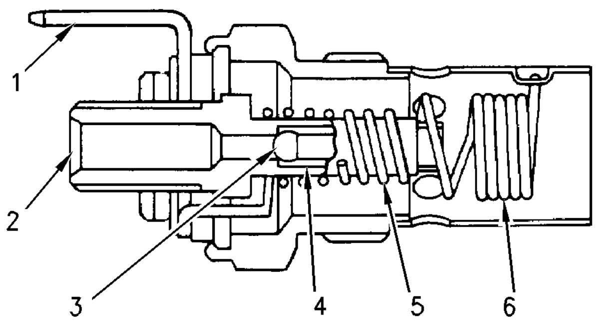

Illustration 86 g00910925

(1) Electrical connection
(2) Fuel inlet
(3) Ball valve
(4) Valve holder
(5) Wire coil
(6) Ignition coil

The air inlet heater (1) is located in the air inlet manifold on the right side of the engine.

Basic Operation

The air inlet heater frequently appears to leak because the ignition coil (6) is wet. The air inlet heater may be wet because the diesel fuel does not burn completely. This condition is normal. This condition does not indicate that the ball valve (3) has fuel leakage. If a leak is suspected, perform the leakage test.

Check the heater operation by determining if the inlet manifold is warm to the touch near the heater after approximately ten seconds of operation. The inlet manifold should be warm.

Inspect the fuel tank and the fuel supply line (2) to the air inlet heater for restrictions and leakage of fuel. Fuel flow through the heater should be 3.5 to 5.9 cc/min (0.21 to 0.36 cu in/min).

Check the fuel shutoff valve for correct operation. A poor seal on the fuel shutoff valve can cause air to enter the system which will cause extra cranking of the engine before starting. Be sure that all fuel connections are not leaking air.

Make sure that the battery condition and the battery charge are satisfactory. Make sure that all electrical connections are tight. The electrical system can have reduced voltage if the following conditions exist:

- A discharged battery
- A loose connection

Reduced voltage may cause slow cranking of the starter motor and failure of the heater unit to be activated.

NOTICE

If operated for a long period of time, The air inlet heater can create excessive heat. Excessive heat can damage the air inlet heater.

Leak Test For The Air Inlet Heater On The Engine

Use the following procedure in order to test for a leak in the air inlet heater.

1. Disconnect the fuel supply line (2) and the electrical connection on the air inlet heater. Be sure that the electrical connector is insulated from contact with metal engine components. Remove the air inlet heater from the manifold. Place a suitable plug in the manifold in order to prevent debris from entering the air inlet manifold.

2. Connect the fuel supply line to the air inlet heater. Loosely tighten the connection fitting. Operate the priming lever of the fuel transfer pump until only fuel which is free of air flows from the connection. Tighten the connection fitting.

WARNING

Work carefully around an engine that is running. Engine parts that are hot, or parts that are moving, can cause personal injury.

3. Start the engine and operate the engine at low speed. Check that there is no fuel leakage from the valve of the air inlet heater.

4. If leakage exists, the air inlet heater must be replaced. If no fuel leakage occurs, remove the plug from the inlet manifold and disconnect the fuel supply line from the air inlet heater. Install the air inlet heater in the air inlet manifold. Connect the fuel supply line to the heater. Operate the priming lever of the fuel transfer pump until only fuel which is free of air flows from the connection. Connect the electrical wire connector.

Leak Test For The Air Inlet Heater Off The Engine

Use this test in order to test for leakage of fuel in the air inlet heater if a pressurized air supply is available.

NOTICE

The air inlet heater may be damaged if more than 140 kPa (20 psi) of air pressure is used.

WARNING

Pressurized air can cause personal injury. When pressurized air is used for cleaning, wear a protective face shield, protective clothing, and protective shoes.

1. Remove the air inlet heater from the inlet manifold. Connect an air supply to the fuel inlet passage. The maximum pressure of the air supply should be 140 kPa (20 psi).

2. Put the air inlet heater in a container of clean diesel fuel for ten seconds. No air bubbles should be visible from the air inlet heater. If the air inlet heater is not faulty, remove the fuel from the air inlet heater. Reinstall the air inlet heater in the air inlet manifold. If leakage of air occurs, install a new air inlet heater.

Electrical Test

Conduct this test in order to determine if sufficient electrical current is provided to the air inlet heater for proper operation.

1. Disconnect the electrical wire from the air inlet heater.

2. Connect the clamp lead of a suitable voltage tester to a good ground connection.

3. Connect the probe end of the tester to the disconnected electrical wire.

4. The light of the tester turns on in order to indicate that electrical continuity to the air inlet heater exists.

5. Connect a suitable ammeter between the electrical supply and the air inlet heater. Turn the ignition switch to the ON position. Activate the switch for the air inlet heater. The normal current is 16 to 18 amperes at 12 volts.

Note: A cold engine should start after the heater coil has operated for 20 seconds. If the engine does not start but the air inlet heater and the area of the inlet manifold around the air inlet heater are warm, either the starting procedure has not been done correctly or the problem is not caused by the air inlet heater.

i01854848

Alternator - Test

1. Put the positive lead “+” of a suitable multimeter on the “Bat” terminal of the alternator. Put the negative “-” lead on the ground terminal or on the frame of the alternator. Put a suitable ammeter around the positive output wire of the alternator.

2. Turn off all electrical accessories. Turn off the fuel to the engine. Crank the engine for 30 seconds. Wait for two minutes in order to cool the starting motor. If the electrical system appears to operate correctly, crank the engine again for 30 seconds.

Note: Cranking the engine for 30 seconds partially discharges the batteries in order to do a charging test. If the battery has a low charge, do not perform this step. Jump start the engine or charge the battery before the engine is started.

3. Start the engine and run the engine at full throttle.

4. Check the output current of the alternator. The initial charging current should be equal to the minimum full load current or greater than the minimum full load current. Refer to Specifications, “Alternator and Regulator” for the correct minimum full load current.

Table 10

Fault Conditions And Possible Causes			
Current At Start-up	**The Voltage Is Below Specifications After 10 Minutes.**	**The Voltage Is Within Specifications After 10 Minutes.**	**The Voltage Is Above Specifications After 10 Minutes.**
Less than the specifications	Replace the alternator. Check the circuit of the ignition switch.	Turn on all accessories. If the voltage decreases below the specifications, replace the alternator.	-
Decreases after matching specifications	Replace the alternator.	The alternator and the battery match the specifications. Turn on all accessories in order to verify that the voltage stays within specifications.	Replace the alternator.
The voltage consistently exceeds specifications.	Test the battery. Test the alternator again.	The alternator operates within the specifications. Test the battery.	Replace the alternator. Inspect the battery for damage.

5. After approximately ten minutes of operating the engine at full throttle, the output voltage of the alternator should be 14.0 ± 0.5 volts for a 12 volt system. After approximately ten minutes of operating the engine at full throttle, the output voltage of the alternator should be 28.0 ± 1 volts for a 24 volt system. Refer to the Fault Conditions And Possible Causes in Table 10.

6. After ten minutes of engine operation, the charging current should decrease to approximately 10 amperes. The actual length of time for the decrease to 10 amperes depends on the following conditions:

- The battery charge
- The ambient temperature
- The rpm of the engine

Refer to the Fault Conditions And Possible Causes in Table 10.

i01126605

Battery - Test

Most of the tests of the electrical system can be done on the engine. The wiring insulation must be in good condition. The wire and cable connections must be clean, and both components must be tight.

WARNING

Never disconnect any charging unit circuit or battery circuit cable from the battery when the charging unit is operated. A spark can cause an explosion from the flammable vapor mixture of hydrogen and oxygen that is released from the electrolyte through the battery outlets. Injury to personnel can be the result.

The battery circuit is an electrical load on the charging unit. The load is variable because of the condition of the charge in the battery.

NOTICE

The charging unit will be damaged if the connections between the battery and the charging unit are broken while the battery is being charged. Damage occurs because the load from the battery is lost and because there is an increase in charging voltage. High voltage will damage the charging unit, the regulator, and other electrical components.

See Special Instruction, SEHS7633, "Battery Test Procedure" for the correct procedures to use to test the battery. This publication also contains the specifications to use when you test the battery.

i01861334

V-Belt - Test

Table 11

Belt Tension Chart			
Size of Belt	**Width of Belt**	**Gauge Reading**	
		Initial Belt Tension(1)	**Used Belt Tension(2)**
1/2	13.89 mm (0.547 Inch)	535 N (120 lb)	355 N (80 lb)
Measure the tension of the belt that is farthest from the engine.			

(1) Initial Belt Tension refers to a new belt.
(2) Used Belt Tension refers to a belt that has been in operation for 30 minutes or more at the rated speed.

1. Check the belts for wear and check the belts for damage. Belts must always be changed as a pair.

2. Fit a suitable Burroughs gauge at the center of the longest free length of belt and check the tension on both belts. Check and adjust the tension on the tightest belt. To adjust the belt tension, see Disassembly and Assembly Manual, "Alternator - Install".

i01461457

Charging System - Test

The condition of charge in the battery at each regular inspection will show if the charging system is operating correctly. An adjustment is necessary when the battery is constantly in a low condition of charge or a large amount of water is needed. There are no adjustments on maintenance free batteries. A large amount of water would be more than one ounce of water per cell per week or per every 100 service hours.

When it is possible, make a test of the charging unit and voltage regulator on the engine, and use wiring and components that are a permanent part of the system. Off-engine testing or bench testing will give a test of the charging unit and voltage regulator operation. This testing will give an indication of needed repair. After repairs are made, perform a test in order to prove that the units have been repaired to the original condition of operation.

Alternator Regulator

The charging rate of the alternator should be checked when an alternator is charging the battery too much or not charging the battery enough.

Alternator output should be 28 ± 1 volt on a 24 volt system and 14 ± 0.5 volt on a 12 volt system. No adjustment can be made in order to change the rate of charge on the alternator regulators. If the rate of charge is not correct, a replacement of the regulator is necessary. For individual alternator output, refer to Specification, "Alternator and Regulator".

See Special Instruction, REHS0354, "Charging System Troubleshooting" for the correct procedures to use to test the charging system. This publication also contains the specifications to use when you test the charging system.

i01854593

Electric Starting System - Test

General Information

All electrical starting systems have four elements:

- Ignition switch
- Start relay
- Starting motor solenoid
- Starting motor

Start switches have a capacity of 5 to 20 amperes. The coil of a start relay draws about 1 ampere between test points. The switch contacts of the start relay for the starting motor are rated between 100 and 300 amperes. The start relay can easily switch the load of 5 to 50 amperes for the starting motor solenoid.

The starting motor solenoid is a switch with a capacity of about 1000 amperes. The starting motor solenoid supplies power to the starter drive. The starting motor solenoid also engages the pinion to the flywheel.

The starting motor solenoid has two coils. The pull-in coil draws about 40 amperes. The hold-in coil requires about 5 amperes.

When the magnetic force increases in both coils, the pinion gear moves toward the ring gear of the flywheel. Then, the solenoid contacts close in order to provide power to the starting motor. When the solenoid contacts close, the ground is temporarily removed from the pull-in coil. Battery voltage is supplied on both ends of the pull-in coil while the starting motor cranks. During this period, the pull-in coil is out of the circuit.

Cranking of the engine continues until current to the solenoid is stopped by releasing the ignition switch.

Power which is available during cranking varies according to the temperature and condition of the batteries. The following chart shows the voltages which are expected from a battery at the various temperature ranges.

Table 12

Typical Voltage Of Electrical System During Cranking At Various Ambient Temperatures		
Temperature	**12 Volt System**	**24 Volt System**
–23 to –7°C (–10 to 20°F)	6 to 8 volts	12 to 16 volts
–7 to 10°C (20 to 50°F)	7 to 9 volts	14 to 18 volts
10 to 27°C (50 to 80°F)	8 to 10 volts	16 to 24 volts

The following table shows the maximum acceptable loss of voltage in the battery circuit. The battery circuit supplies high current to the starting motor. The values in the table are for engines which have service of 2000 hours or more.

Table 13

Maximum Acceptable Voltage Drop In The Starting Motor Circuit During Cranking		
Circuit	**12 Volt System**	**24 Volt System**
Battery post "-" to the starting motor terminal "-"	0.7 volts	1.4 volts
Drop across the disconnect switch	0.5 volts	1.0 volts
Battery post "+" to the terminal of the starting motor solenoid "+"	0.5 volts	1.0 volts
Solenoid terminal "Bat" to the solenoid terminal "Mtr"	0.4 volts	0.8 volts

Voltage drops that are greater than the amounts in Table 13 are caused most often by the following conditions:

- Loose connections
- Corroded connections
- Faulty switch contacts

Diagnosis Procedure

The procedures for diagnosing the starting motor are intended to help the technician determine if a starting motor needs to be replaced or repaired. The procedures are not intended to cover all possible problems and conditions. The procedures serve only as a guide.

NOTICE

If equipped with electric start, do not crank the engine for more than 30 seconds. Allow the starter to cool for two minutes before cranking again.

Never turn the disconnect switch off while the engine is running. Serious damage to the electrical system can result.

If the starting motor does not crank or cranks slow, perform the following procedure:

1. Measure the voltage of the battery.

Measure the voltage across the battery posts with the multimeter when you are cranking the engine or attempting to crank the engine. Do not measure the voltage across the cable post clamps.

a. If the voltage is equal or greater than the voltage in Table 12, then go to Step **2**.

b. The battery voltage is less than the voltage in Table 12.

A low charge in a battery can be caused by several conditions.

- Deterioration of the battery
- A shorted starting motor
- A faulty alternator
- Loose drive belts
- Current leakage in another part of the electrical system

2. Measure the current that is sent to the starting motor solenoid from the positive post of the battery.

Note: If the following conditions exist, do not perform the test in Step **2** because the starting motor has a problem.

- The voltage at the battery post is within 2 volts of the lowest value in the applicable temperature range of Table 12.
- The large starting motor cables get hot.

Use a suitable ammeter in order to measure the current. Place the jaws of the ammeter around the cable that is connected to the "bat" terminal. Refer to the Specifications Module, "Starting Motor" for the maximum current that is allowed for no load conditions.

The current and the voltages that are specified in the Specifications Module are measured at a temperature of 27°C (80°F). When the temperature is below 27°C (80°F), the voltage will be lower through the starting motor. When the temperature is below 27°C (80°F), the current through the starting motor will be higher. If the current is too great, a problem exists in the starting motor. Repair the problem or replace the starting motor.

If the current is within the specification, proceed to Step **3**.

3. Measure the voltage of the starting motor.

a. Use the multimeter in order to measure the voltage of the starting motor, when you are cranking or attempting to crank the engine.

b. If the voltage is equal or greater than the voltage that is given in Table 12, then the battery and the starting motor cable that goes to the starting motor are within specifications. Go to Step **5**.

c. The starting motor voltage is less than the voltage specified in Table 12. The voltage drop between the battery and the starting motor is too great. Go to Step **4**.

4. Measure the voltage.

a. Measure the voltage drops in the cranking circuits with the multimeter. Compare the results with the voltage drops which are allowed in Table 13.

b. Voltage drops are equal to the voltage drops that are given in Table 13 or the voltage drops are less than the voltage drops that are given in Table 13. Go to Step **5** in order to check the engine.

c. The voltage drops are greater than the voltage drops that are given in Table 13. The faulty component should be repaired or replaced.

5. Rotate the crankshaft by hand in order to ensure that the crankshaft is not stuck. Check the oil viscosity and any external loads that could affect the engine rotation.

a. If the crankshaft is stuck or difficult to turn, repair the engine.

b. If the engine is not difficult to turn, go to Step **6**.

6. Attempt to crank the starting motor.

a. The starting motor cranks slowly.

Remove the starting motor for repair or replacement.

b. The starting motor does not crank.

Check for the blocked engagement of the pinion gear and flywheel ring gear.

Note: Blocked engagement and open solenoid contacts will give the same electrical symptoms.

Index

G

I

L

P

S

T

V

W