

Systems Operation Testing and Adjusting

1104E Engine

RF11-Up (Machine)
RH11-Up (Machine)
RK11-Up (Machine)

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.



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 have the most current information available.



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

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

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Systems Operation Section

General Information

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Introduction

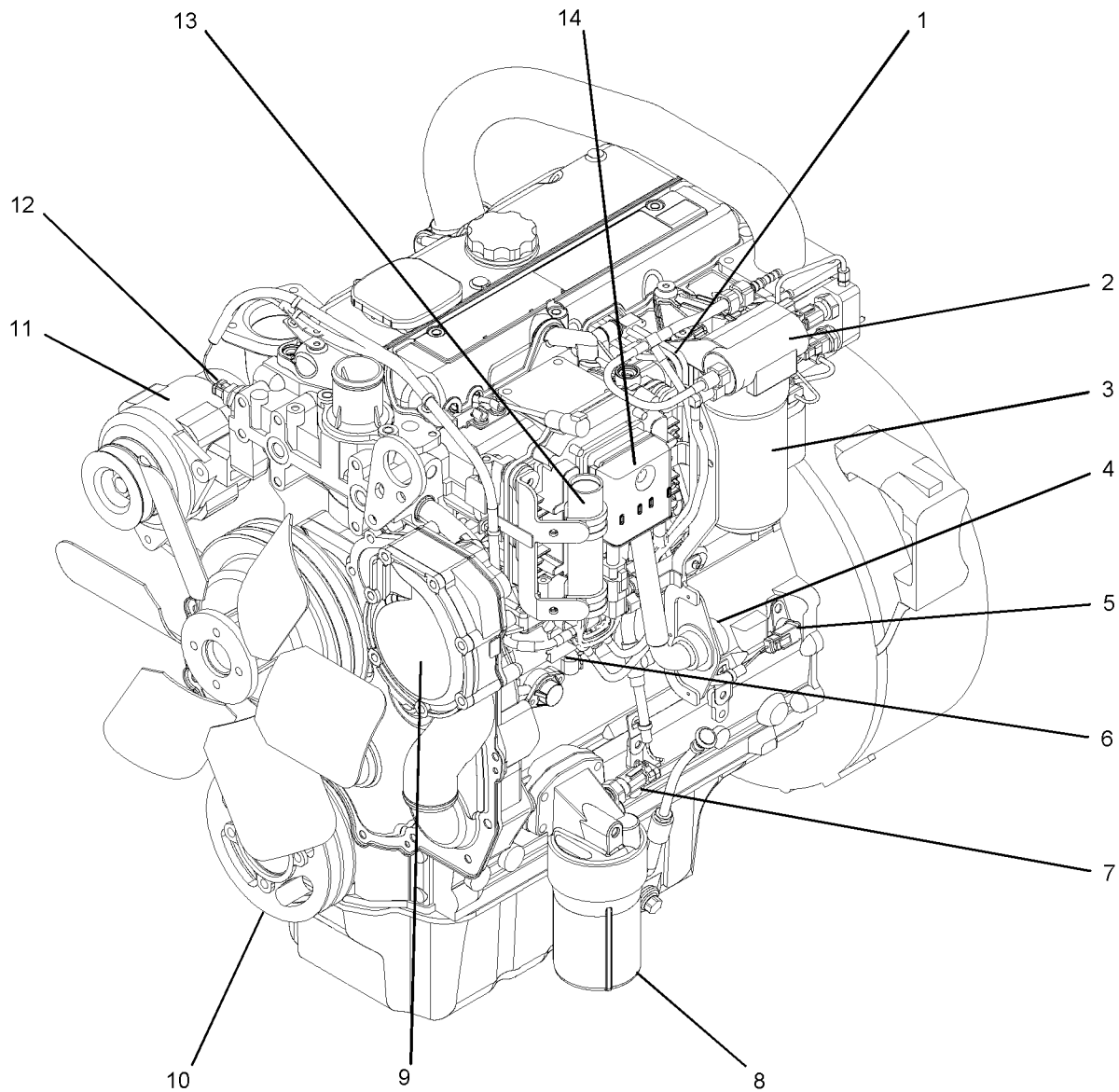


Illustration 1
Left side view of a typical 1104C electronic engine

- | | | |
|---------------------------------------|------------------------------------|--|
| (1) Fuel lines | (6) Electronic fuel injection pump | (11) Alternator |
| (2) Fuel Priming Pump | (7) Engine oil pressure sensor | (12) Engine coolant temperature sensor |
| (3) Fuel Filter | (8) Engine oil filter | (13) Voltage Load Protection Module |
| (4) Machine Interface Connector (MIC) | (9) Water Pump | (14) Electronic Control Module (ECM) |
| (5) Speed/timing sensor | (10) Crankshaft pulley | |

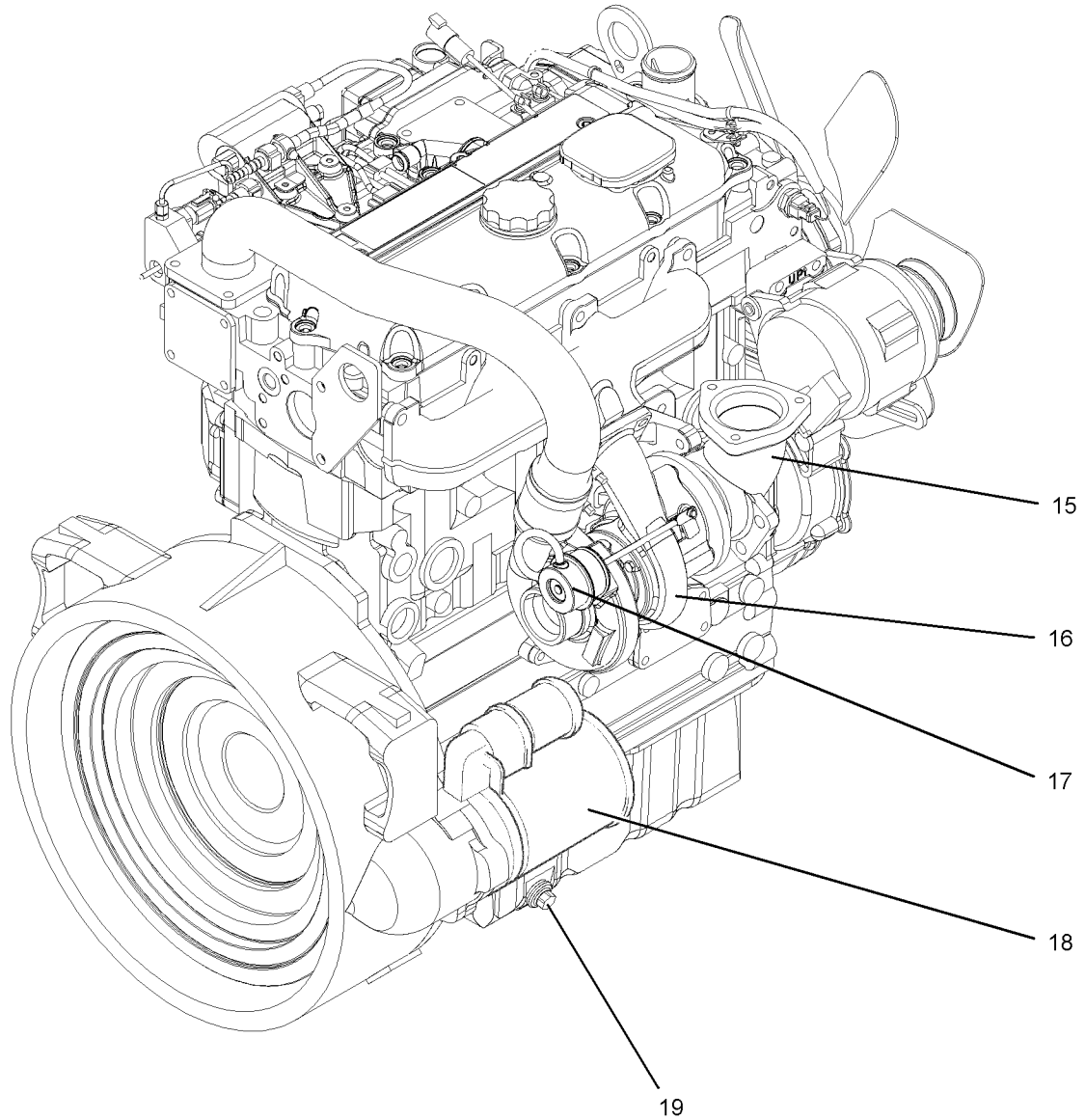


Illustration 2

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Right side view of a typical 1104C electronic engine

- | | | |
|--------------------|-------------------------|---------------------|
| (15) Exhaust elbow | (17) Wastegate actuator | (19) Oil drain plug |
| (16) Turbocharger | (18) Starter motor | |

The 1104C electronic engine is electronically controlled. The 1104C electronic engine uses an Electronic Control Module (ECM) to control a fuel injection pump. The pump supplies fuel to the fuel injectors.

The four 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 valves are on the left side of the cylinder head. The ports for 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 hardened insert in order to reduce wear of the ring 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. Six 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 five 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 have holes which align with holes in the front flange of the crankshaft and the camshaft 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, a temporary timing pin is inserted through the crankshaft gear and the hole in the front flange of the crankshaft. A second temporary timing pin is inserted through the camshaft gear and the hole in 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 has an open top deck. The cylinders are only connected to the cylinder block at the bottom.

Bosch VP30

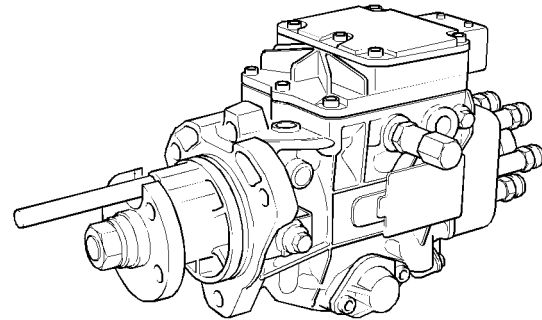


Illustration 3

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The Bosch VP30 fuel injection pump is installed on the engine. The fuel injection pump conforms to current emissions. Both the pump timing and the high idle are preset at the factory. The fuel injection pump is not serviceable. Adjustments to the fuel injection 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.

For the specifications of the 1104C electronic engine, refer to the Specifications, "Engine Design".

Engine Operation

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Basic Engine

Cylinder Block and Cylinder Head

The cylinder block for the 1104 engine has four cylinders which are arranged in-line.

The cylinder block for the 1104 engine has five main bearings which support the crankshaft. Thrust washers on both sides of the center main bearing control the end play of the crankshaft.

A cylinder head gasket is used between the engine block and the cylinder head in order to seal combustion gases, water, and oil.

The engine has a cast iron cylinder head. The inlet manifold is integral within the cylinder head. An inlet valve and an exhaust valve for each cylinder are controlled by a pushrod valve system. The ports for the inlet valves are on the left side of the cylinder head. The ports for the exhaust valves are on the right side of the cylinder head.

Pistons, Rings, and Connecting Rods

The pistons have a 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.

Engines are equipped with connecting rods that have bearing caps that are fracture split. The bearing caps on fracture split connecting rods are retained with torx screws. Connecting rods with bearing caps 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

The connecting rod is matched to each cylinder. The piston height is controlled by the length of the connecting rod. Six 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.

Crankshaft

The crankshaft changes the linear energy of the pistons and connecting rods into rotary torque in order to power external equipment.

A gear at the front of the crankshaft drives the timing gears. The crankshaft gear turns the idler gear which then turns the following gears:

- Camshaft gear

- Fuel injection pump
- Lower idler gear which turns the gear of the lubricating oil pump

Lip type seals are used on both the front of the crankshaft and the rear of the crankshaft.

Camshaft

The engine has a single camshaft. The camshaft is driven by an idler gear in the front housing. The camshaft uses only one bearing on the front journal. The other journals rotate in the bore of the cylinder block. The front bearing and the camshaft bores in the cylinder block support the camshaft. As the camshaft turns, the camshaft lobes move the valve system components. The valve system components move the inlet and exhaust valves in each cylinder. 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 be opened and closed 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.

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Air Inlet and Exhaust System

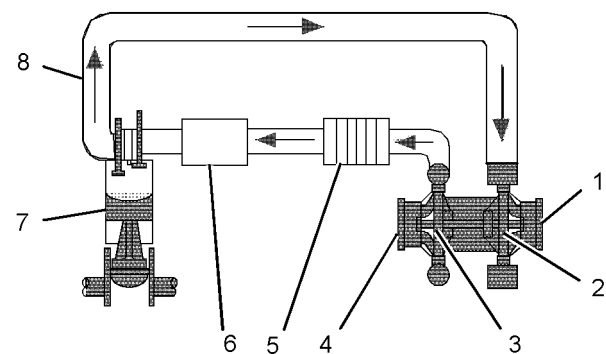


Illustration 4

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Air inlet and exhaust system (typical example)

- (1) Exhaust outlet
- (2) Turbocharger turbine wheel
- (3) Turbocharger compressor wheel
- (4) Air intake
- (5) Aftercooler
- (6) Intake manifold
- (7) Engine cylinders
- (8) Exhaust manifold

Engines which are naturally aspirated pull outside air through an air cleaner directly into the inlet manifold (6). The air flows from the intake manifold to the engine cylinders (7). The fuel is mixed with the air in the engine cylinders. After the fuel combustion occurs in the engine cylinder, the exhaust gases flow directly to the outside air through the exhaust manifold (8).

Turbocharged engines pull outside air through an air cleaner into the air intake (4) of the turbocharger. The suction is caused by the turbocharger compressor wheel (3). Then, the turbocharger compressor wheel compresses the air. The air flows through the aftercooler (5). Cooling the inlet air increases combustion efficiency. Increased combustion efficiency helps achieve the following benefits:

- Fuel consumption is reduced.
- Power output is increased.
- Emissions from the engine are reduced.

From the aftercooler (5), the air flows to the intake manifold (6) which directs an even distribution of the air to each engine cylinder (7). Air is pulled into the engine cylinder (7) during the intake stroke of the piston. Then, the air is mixed with fuel from the fuel injectors.

Each piston makes four strokes:

1. Intake
2. Compression
3. Power
4. Exhaust

The sequence of the strokes by all of the pistons in all of the engine cylinders provide constant air flow through the inlet system during the engine operation.

The exhaust stroke and the timing of the valve mechanism pushes combustion gases through the open exhaust valve into the exhaust manifold (8). The exhaust gases flow through the blades of the turbocharger turbine wheel (2) which causes the turbine wheel and the compressor wheel to turn. Then, the exhaust gases flow through the exhaust outlet (1) of the turbocharger to the outside.

The air inlet system is also equipped with a crankcase ventilation system. The intake strokes of the pistons pull in atmospheric air to the crankcase.

Turbocharger

Note: The turbocharger is not serviceable.

A turbocharger increases the temperature and the density of the air that is sent to the engine cylinder. This condition causes a lower temperature of ignition to develop earlier in the compression stroke. The compression stroke is also timed in a more accurate way with the fuel injection. Surplus air lowers the temperature of combustion. This surplus air also provides internal cooling.

A turbocharger improves the following aspects of engine performance:

- Power output is increased.
- Fuel efficiency is improved.
- Engine torque is increased.
- Durability of the engine is improved.
- Emissions from the engine are reduced.

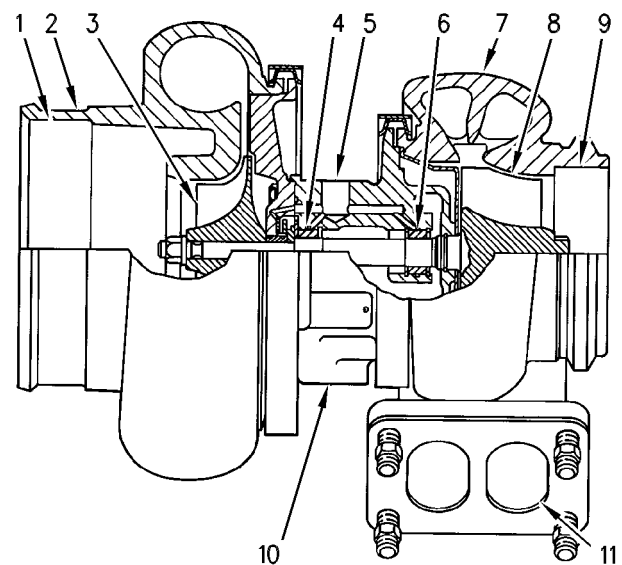


Illustration 5

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Components of a turbocharger (typical example)

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

A turbocharger is installed between the exhaust and intake manifolds. The turbocharger is driven by exhaust gases which flow through the exhaust inlet (11). The energy of the exhaust gas turns the turbine wheel (8). Then, the exhaust gas flows out of the turbine housing (7) through the exhaust outlet (9).

The turbine wheel and the compressor wheel (3) are installed on the same shaft. Therefore, the turbine wheel and the compressor wheel rotate at the same rpm. The compressor wheel is enclosed by the compressor housing (2). The compressor wheel compresses the intake air (1). The intake air flows into the engine cylinders through the inlet valves of the cylinders.

The oil from the main gallery of the cylinder block flows through the oil inlet port (5) in order to lubricate the turbocharger bearings (4) and (6). The pressurized oil passes through the bearing housing of the turbocharger. The oil is returned through the oil outlet port (10) to the oil pan.

The turbocharger has a wastegate. The wastegate is controlled by the boost pressure. This allows some of the exhaust to bypass the turbocharger at higher engine speeds. The wastegate is a type of valve that automatically opens at a preset level of boost pressure in order to allow exhaust gas to flow around the turbine. The wastegate allows the design of the turbocharger to be more effective at lower engine speeds.

The wastegate is controlled by a diaphragm. One side of this diaphragm is open to the atmosphere. The other side of this diaphragm is open to the manifold pressure.

Cylinder Head And Valves

The valves and the valve mechanism control the flow of the air and the exhaust gases in the cylinder during engine operation. The cylinder head assembly has two valves for each cylinder. Each valve has one valve spring. The ports for the inlet valves are on the left side of the cylinder head. The ports for the exhaust valves are on the right side of the cylinder head. Steel valve seat inserts are installed in the cylinder head for both the inlet and the exhaust valves. The valve seat inserts can be replaced.

The valves are installed in valve guides. The valve guides can be replaced. The exhaust valve guide has a counterbore in order to prevent the seizure of the valve stem. The seizure of the valve stem is caused by a buildup of carbon under the head of the valve.

The inlet and the exhaust valves are opened and closed by the rotation and movement of the following components:

- Crankshaft
- Camshaft
- Valve lifters
- Pushrods

- Rocker arms
- Valve springs

The camshaft gear is driven by the crankshaft gear. The camshaft and the crankshaft are timed together. When the camshaft turns, the valve lifters and the pushrods are moved up and down. The pushrods move the rocker arms. The movement of the rocker arms open the valves. The opening and closing of the valves is timed with the firing sequence of the engine. The valve springs push the valves back to the closed position.

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Cooling System

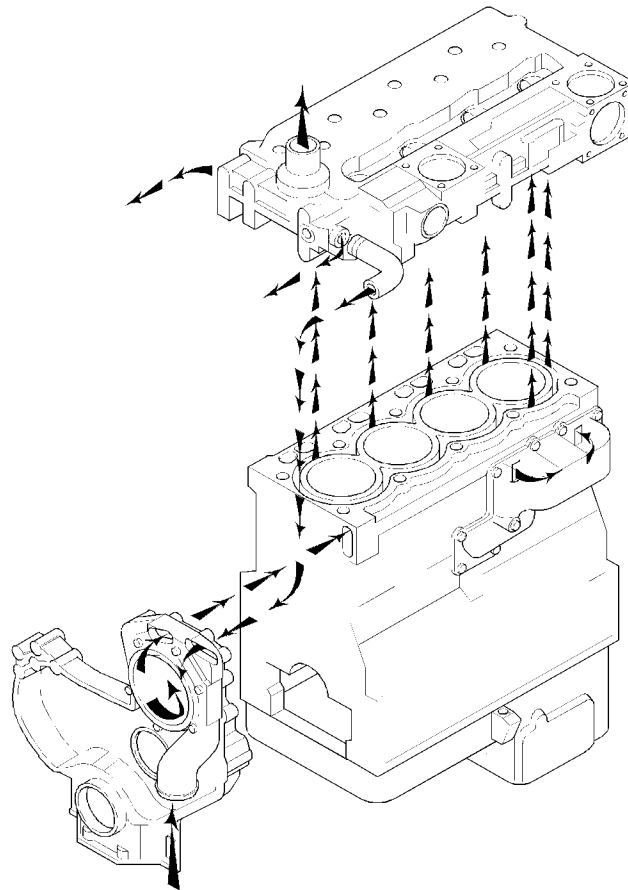


Illustration 6

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Flow diagram of the cooling system

The coolant flows from the bottom of the radiator to the centrifugal water pump. The water pump assists in the flow of the coolant through the system. The water pump is installed on the front of the timing case. The water pump is gear-driven by the fuel injection pump gear.

The water pump forces the coolant through a passage in the front of the timing case to the water jacket in the top left side of the cylinder block. The coolant continues to the rear of the cylinder block.

The main flow of the coolant passes from the rear of the cylinder block into the rear of the cylinder head. The coolant flows forward through the cylinder head and into the water temperature regulator housing. If the water temperature regulator is closed, the coolant goes directly through a bypass to the inlet side of the water pump. If the water temperature regulator is open, the bypass is closed and the coolant flows to the top of the radiator.

From the rear of the cylinder block, some of the coolant passes into the oil cooler. The oil cooler is located on the left side of the cylinder block with no external lines. The coolant flows around the element of the oil cooler before being returned to the rear of the cylinder block.

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Lubrication System

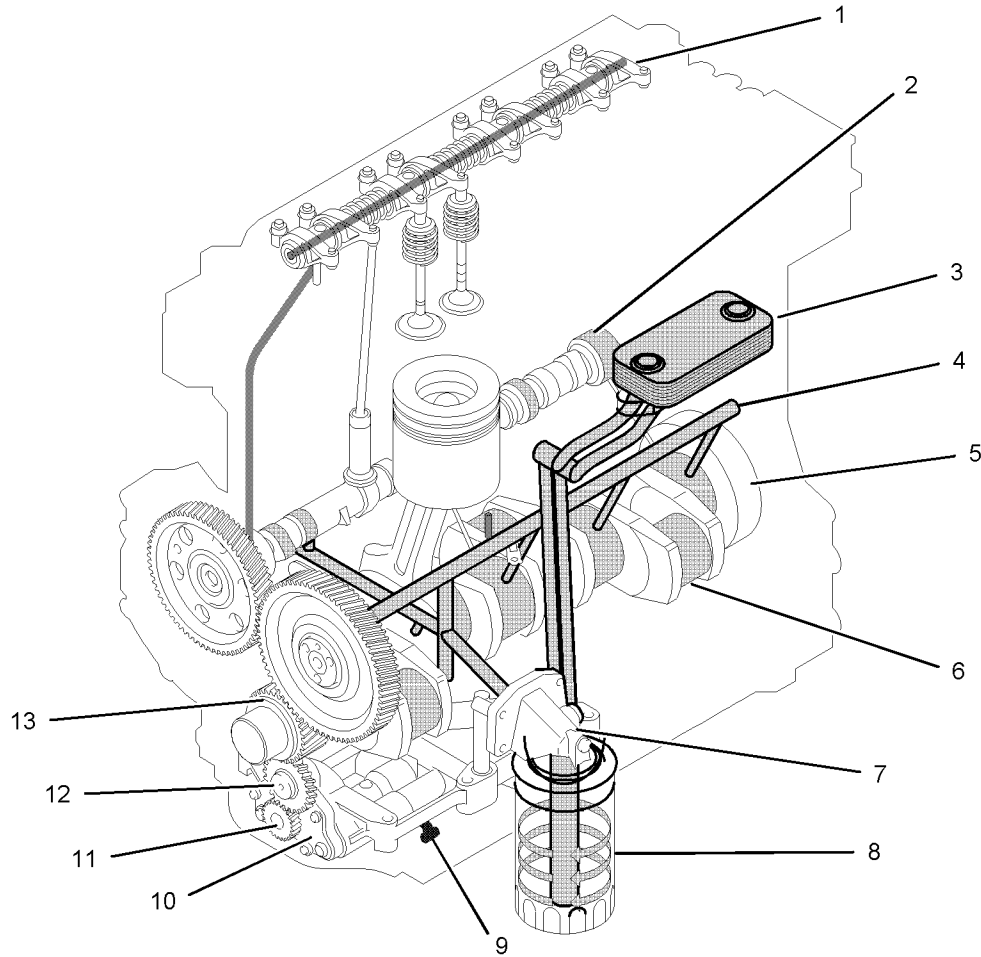


Illustration 7

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Flow diagram of the lubrication system

Lubricating oil from the oil pan flows through a strainer and a pipe (9) to the suction side of the engine oil pump (10). Pressure for the lubrication system is supplied by the oil pump. The crankshaft gear (13) drives a lower idler gear (12). The lower idler gear drives the oil pump gear (11). The 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 an interference fit between the inner rotor and the drive shaft.

The inner rotor has five lobes which mesh with the six lobes of the outer rotor. When the pump 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.

The lubricating oil flows from the outlet side of the oil pump (10) through a passage to the oil filter head (7). The oil then flows from the oil filter head through a passage to a plate type oil cooler. The oil cooler is located on the left side of the cylinder block.

From the oil cooler, the oil returns through a passage to the oil filter head. The oil then flows through a bypass valve that permits the lubrication system to function if the oil filter becomes blocked. Under normal conditions, the oil then flows to the oil filter (8).

The oil flows from the oil filter through a passage that is drilled across the cylinder block to the oil gallery (4). 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 (5). Then, the oil flows through the passages in the crankshaft to the connecting rod bearing journals (6). 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 front journal of the camshaft (2) at a reduced pressure to the cylinder head. The oil then flows through the center of the rocker shaft (1) to the rocker arm levers. The valve stems, the valve springs and the valve lifters are lubricated by the splash and the oil mist.

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

An external line from the cylinder block supplies oil to the turbocharger. The oil then flows through a return line to the oil pan.

Engines have piston cooling jets that are supplied with oil from the oil gallery. The piston cooling jets spray lubricating oil on the underside of the pistons in order to cool the pistons.

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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.

Alternator

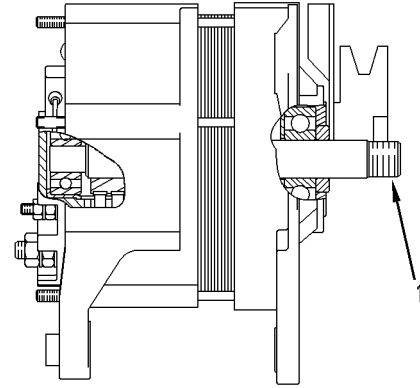


Illustration 8

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(1) Shaft for mounting the pulley

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 drive belt from the crankshaft pulley. The alternator charges the storage battery during the engine operation.

The alternator converts the mechanical energy and the magnetic energy into electrical energy. 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 AC electrical power.

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.

Starting Motor

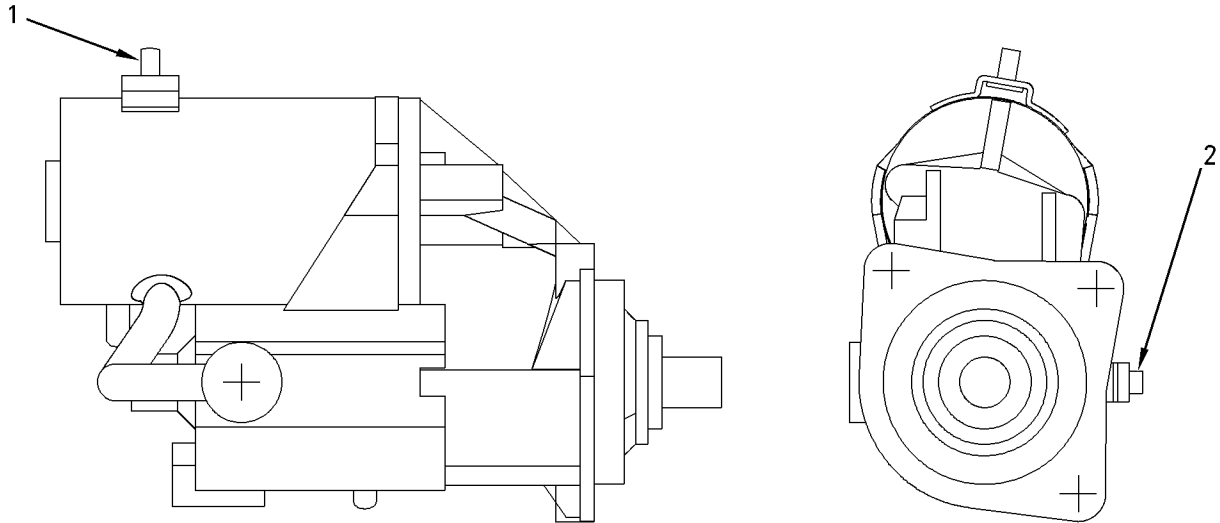


Illustration 9
24 Volt Starting Motor

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(1) Terminal for connection of the ignition switch

(2) Terminal for connection of the battery cable

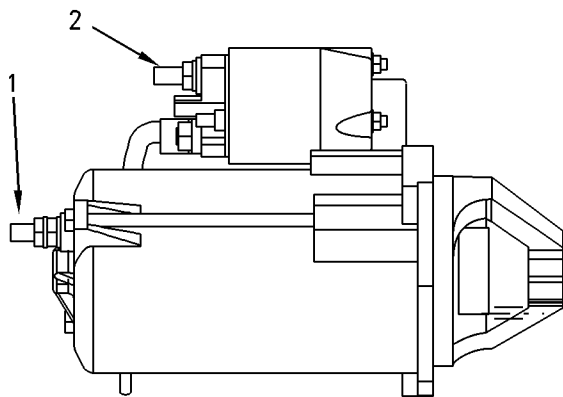


Illustration 10
12 Volt Starting Motor

g00954820

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

The starting motor has a solenoid. When the ignition switch is activated, voltage from the electrical system will cause the solenoid to engage the pinion in the flywheel ring gear of the engine. When the pinion gear is engaged in the flywheel ring gear, the electrical contacts in the solenoid close the circuit between the battery and the starting motor. 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.

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

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Fuel Injection

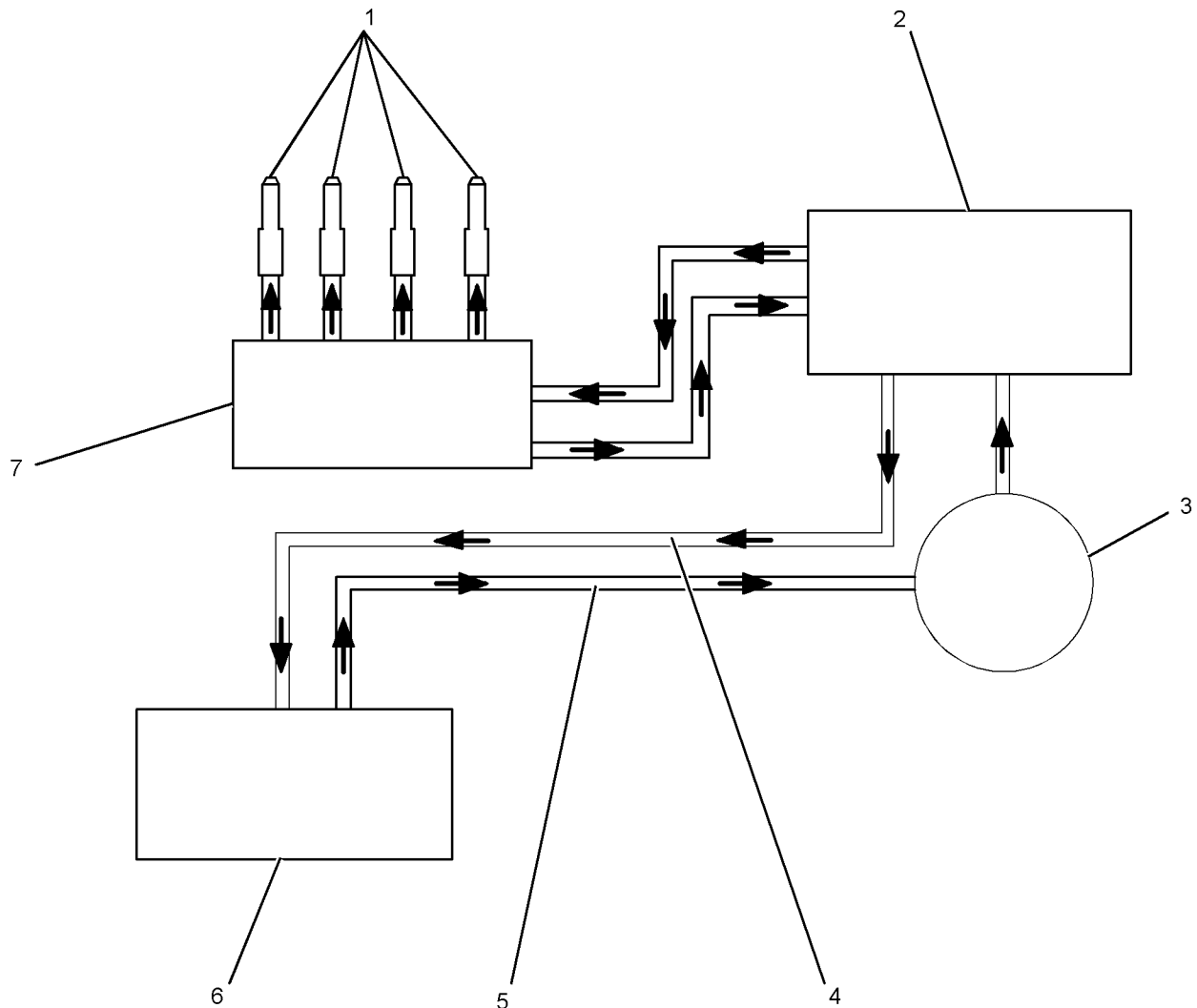


Illustration 11

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Flow diagram of the fuel system

- | | |
|--|-------------------------|
| (1) Fuel injectors | (4) Fuel return lines |
| (2) Fuel transfer pump and secondary fuel filter | (5) Fuel lines |
| (3) Primary fuel filter and water separator | (6) Fuel tank |
| | (7) Fuel injection pump |

The 1104C electronic engine is equipped with a Bosch VP30 fuel injection pump. The fuel injection pump is an axial piston distributor injection pump that is controlled by the Electronic Control Module (ECM).

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

When the engine is operated, the fuel is pulled from the fuel tank (6) through the primary fuel filter/water separator (3) by the fuel transfer pump (2). When the fuel passes through the water separator, any water in the fuel will go to the bottom of the bowl. The fuel transfer pump is equipped with a secondary fuel filter. From the fuel priming pump, the fuel passes through the fuel supply line to the fuel injection pump (7). The fuel injection pump sends fuel through the high pressure fuel lines to the fuel injectors (1). The fuel injectors spray atomized fuel into the cylinders.

The fuel injection pump needs fuel for lubrication. The precision parts of the pump are easily damaged. The engine must not be operated until the fuel injection pump is full of fuel. The system must be primed when any part of the system is drained of fuel. The fuel system needs priming when a fuel filter is changed, and/or when a fuel line is removed, and/or when the fuel injection pump is replaced.

Fuel Injection Pump

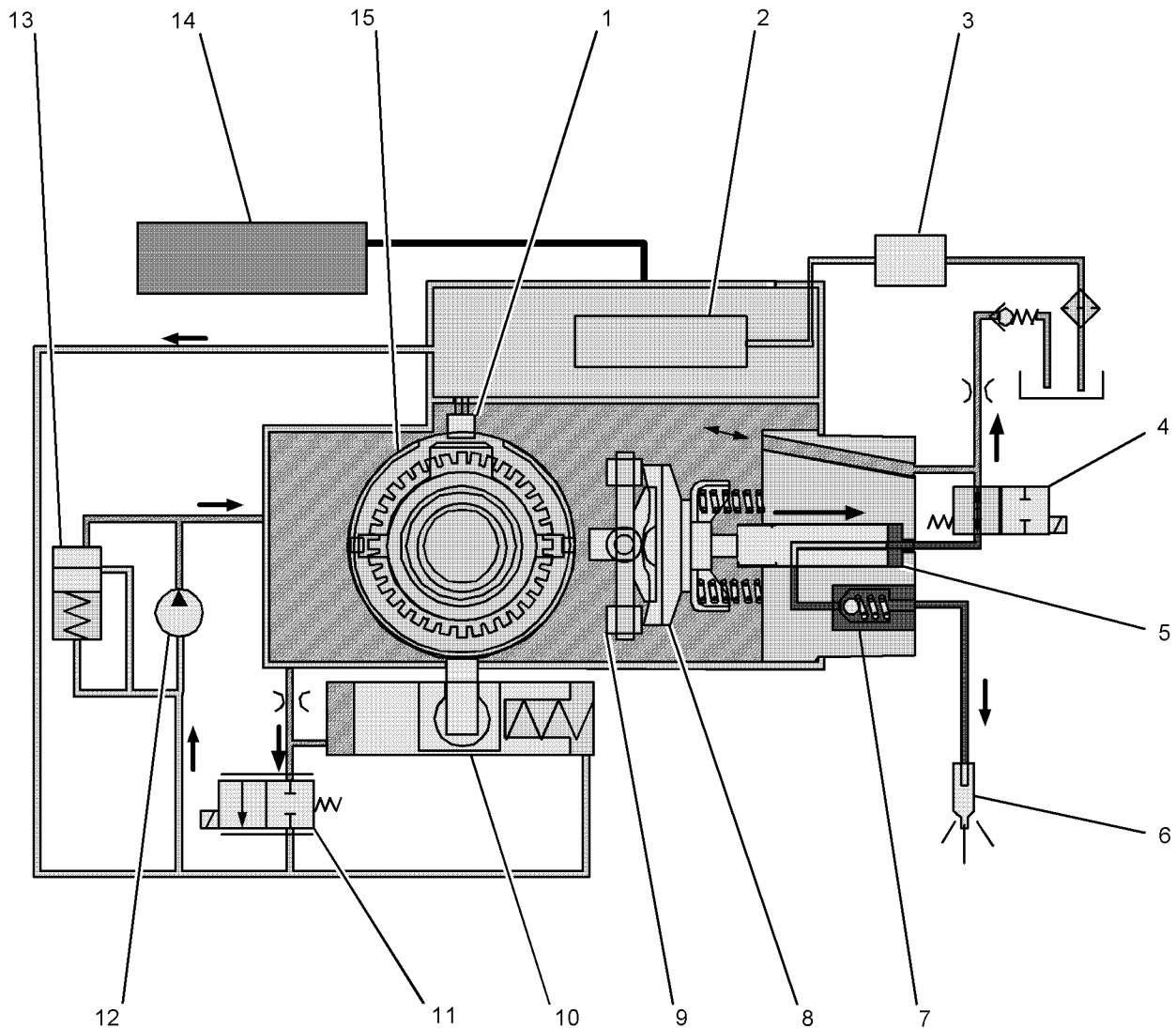


Illustration 12

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Schematic of the Bosch VP30 fuel injection pump

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

The fuel injection pump has the following operations:

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

Delivery

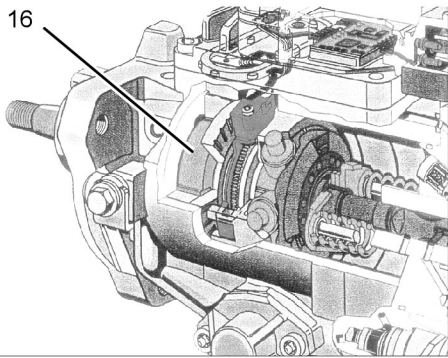


Illustration 13 g01132094
Center view of the Bosch VP30 fuel injection pump
(16) Fuel transfer pump

Fuel is supplied by the head pressure of the priming pump. The fuel enters the fuel transfer pump (16) of the fuel injection pump. The fuel transfer pump is a vane pump. The transfer pump 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.

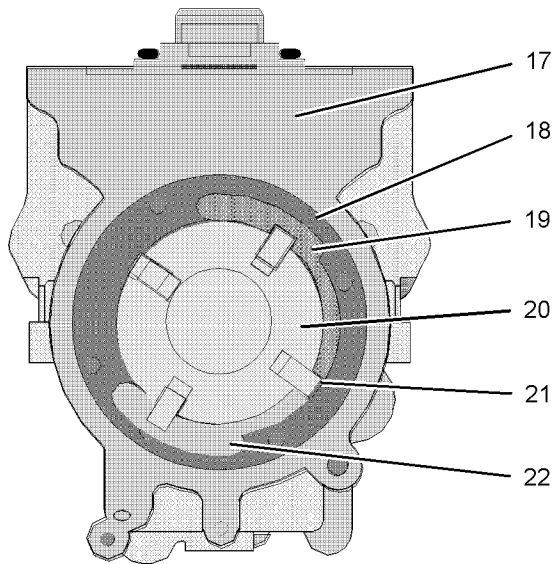


Illustration 14 g01132095
Fuel transfer pump for the Bosch VP30 fuel injection pump
(17) Pump housing
(18) Cam ring
(19) Outlet passage
(20) Rotor
(21) Vane
(22) Inlet passage

The rotor (20) rotates inside the cam ring (18). The ring is firmly attached to the pump housing (17). The vanes (21) are pressed against the ring by centrifugal force. The fuel flows through the inlet passage (22) then into a recess in the pump housing.

The eccentric position of the rotor is relative to the cam ring. A volume is created between the vanes, the rotor, and the cam ring. The fuel is transported by the eccentric position. The eccentric position is relative to the rotor and the outlet passage (19). The fuel is transferred to the outlet passage into the distributor plunger. The volume of the fuel is reduced between the inlet passage and the outlet passage. This creates pressure before the delivery to the distributor plunger.

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 pump is limited by a pressure regulator. The pressure regulator controls the fuel pressure. The fuel forces the valve spring open and the fuel flows back into the inlet passage from the inside of the fuel injection pump.

Generation of High Pressure

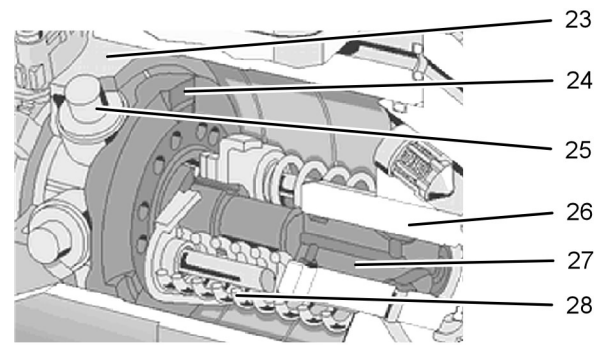


Illustration 15 g01132111
The distributor rotor and the cam plate of the Bosch VP30 fuel injection pump
(23) Cam ring
(24) Cam plate
(25) Roller
(26) Head of the distributor
(27) Distributor plunger
(28) Springs

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

The cam plate moves the distributor plunger toward the head of the distributor (26). The high pressure is created by a decrease in the volume between the distributor plunger and the head of the distributor. The cam plate is pressed to the ring by two springs (28). This brings the distributor plunger back to the original position. The fuel solenoid valve closes the high pressure volume.

Distribution and Injection

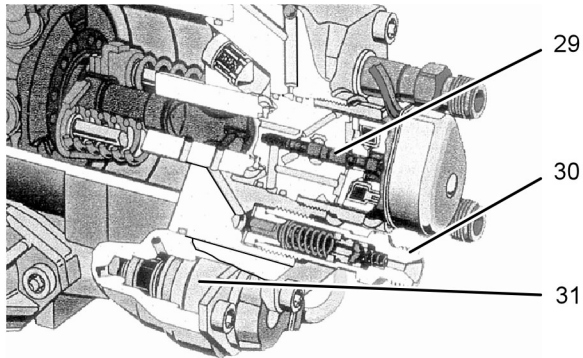


Illustration 16 g01132136
The rear view of the Bosch VP30 fuel injection pump
(29) Fuel solenoid valve
(30) Delivery valve
(31) Timing solenoid valve

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

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

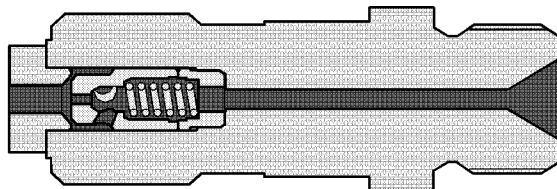


Illustration 17 g01132164
Delivery of fuel from the open delivery valve

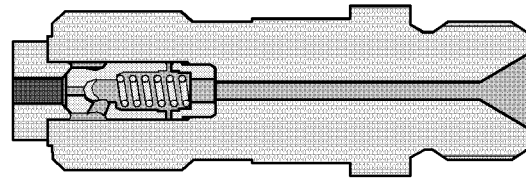


Illustration 18 g01132170
Delivery valve in the closed position

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.

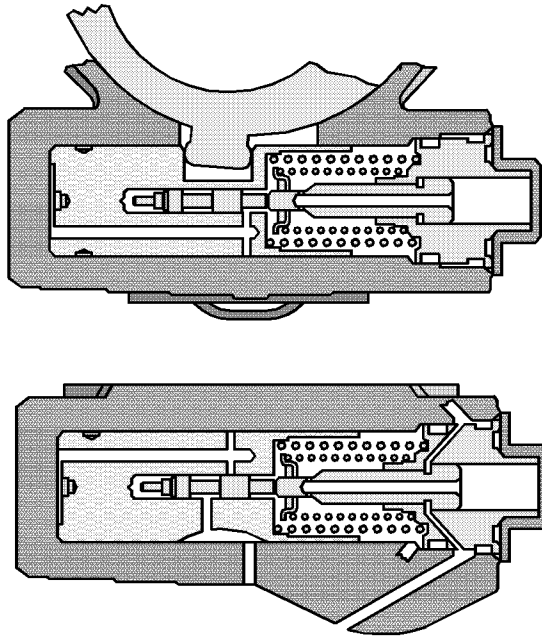


Illustration 19 g01133210
Timing advance for timing mechanism (side view and top view)

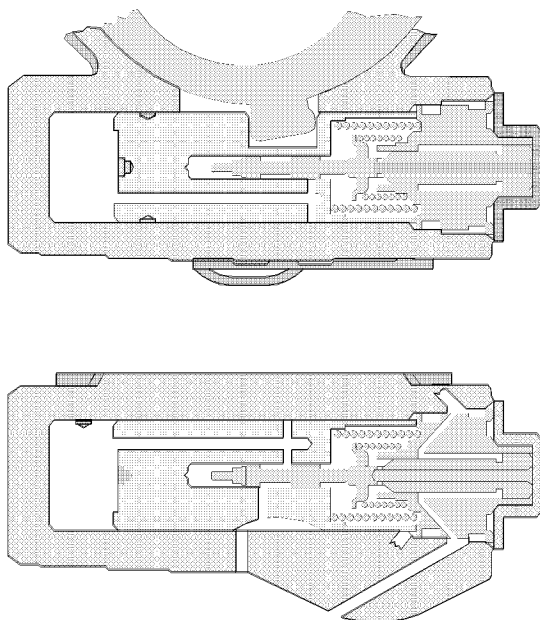


Illustration 20 g01133211
Timing retard for timing mechanism (side view and top view)

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

1. The ECU sends a signal to the timing solenoid valve.
2. The timing mechanism is triggered by the timing solenoid valve.
3. The timing solenoid valve changes the pressure in the timing mechanism.
4. The timing mechanism changes the position of the cam ring.
5. The cam ring changes the position of the rollers.
6. The rollers change the position of the cam plate.
7. The cam plate changes the timing of the fuel delivery.

Control

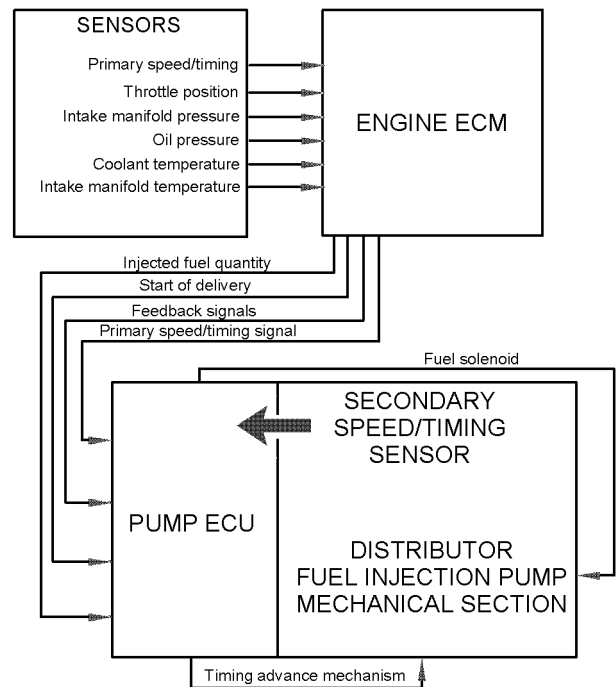


Illustration 21 g01143278
Electronic control for the fuel system (typical example)

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

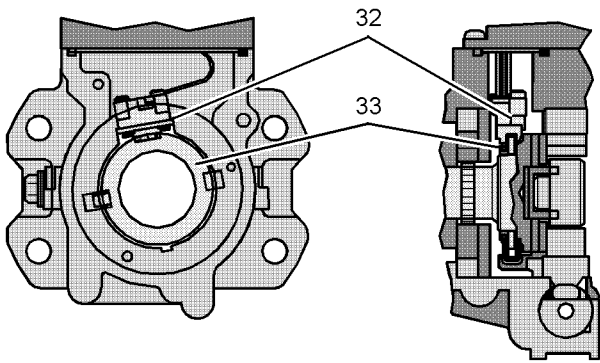


Illustration 22 g01133212

The timing wheel and the secondary speed/timing sensor

- (32) Secondary speed/timing sensor
- (33) Timing wheel

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

The secondary speed/timing sensor 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 secondary speed/timing sensor gets information from the timing wheel. 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.

Note: The engine will not run if the secondary speed/timing sensor fails.

The signal of the speed/timing sensor is constant. Power command signals are routed over the CAN data link from the engine ECM to the ECU on the fuel injection pump.

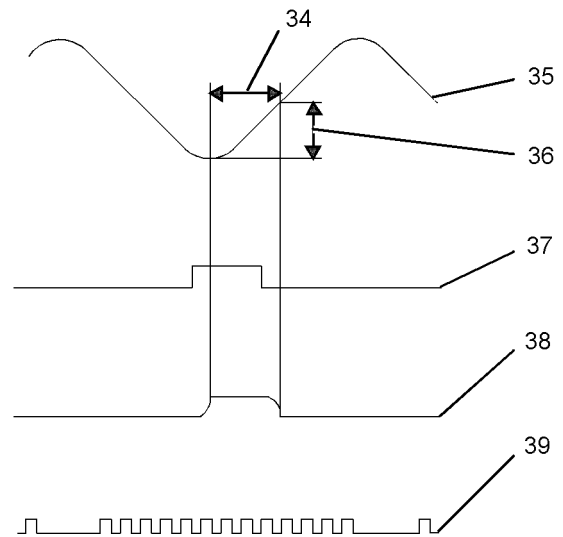


Illustration 23 g01133213

Operating principle

- (34) Angle of fuel delivery
- (35) Lift of the cam
- (36) Stroke
- (37) Pulse for actuating the fuel solenoid
- (38) Valve lift
- (39) 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. The compensation takes place in order to inject the precise amount of fuel.

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 on the fuel injection pump to the zero fuel position.

Fuel Injectors

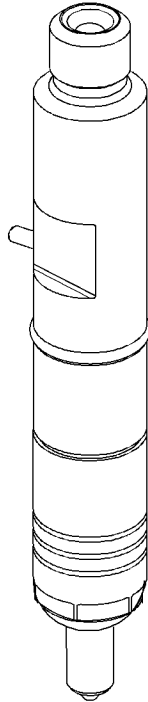


Illustration 24

g01142467

Each fuel injector is held into the cylinder head by a clamp around the fuel injector. The fuel injectors are not serviceable but the nozzles can be removed in order to clean the orifice.

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 nozzle holder which causes the 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 the nozzle orifices into the cylinder. The fuel is injected into the cylinder through the orifices in the nozzle end 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.

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Electronic Control System

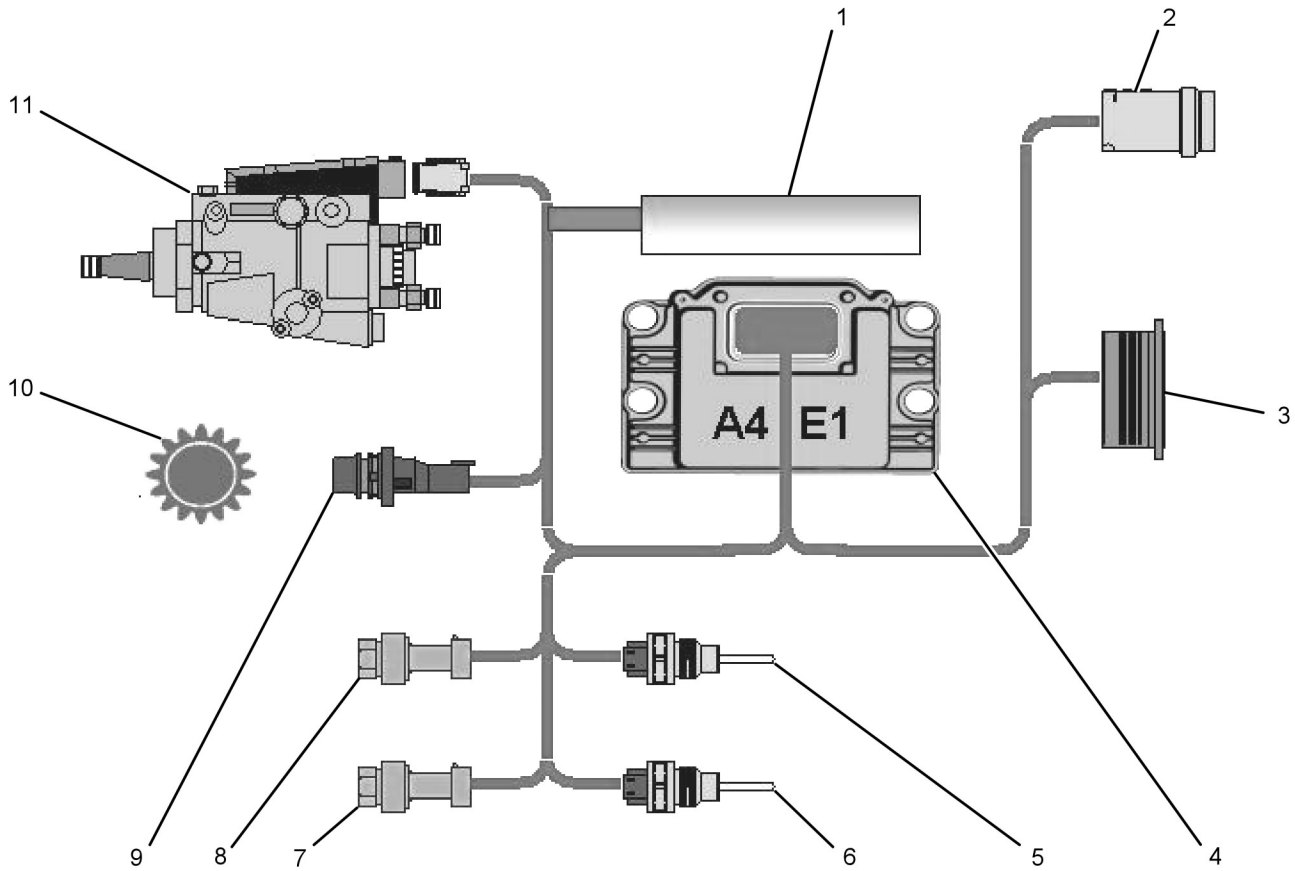


Illustration 25

g01133227

Schematic of the electronic control system

- | | | |
|--|--|-------------------------------------|
| (1) Voltage load-dump protection module (VLPM) | (4) ECM | (8) Intake manifold pressure sensor |
| (2) Service tool connector | (5) Coolant temperature sensor | (9) Primary speed/timing sensor |
| (3) Machine interface connector | (6) Intake manifold temperature sensor | (10) Timing wheel |
| | (7) Engine oil pressure sensor | (11) Fuel injection pump |

The electronic control system for the 1104C electronic engine has the following components:

- Electronic control module (ECM)
- Pressure sensors
- Temperature Sensors
- Primary speed/timing sensor
- Voltage load-dump protection module (VLPM)

Electronic Control Module (ECM)

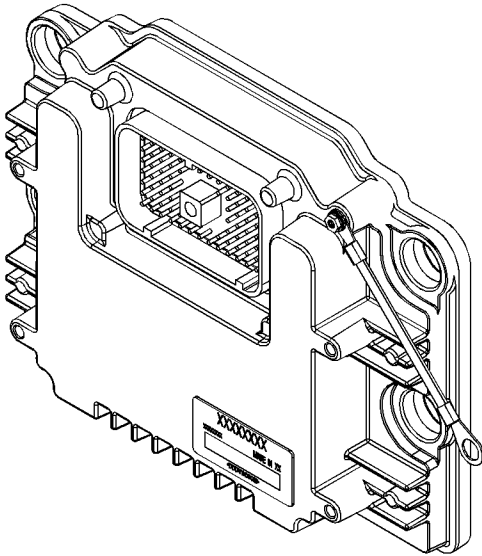


Illustration 26 g01133234
Electronic control module (ECM)

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.

Reprogramming of the ECM requires factory passwords. The reasons for having passwords in an ECM are the following reasons:

- Prevent unauthorized reprogramming.
- Prevent unauthorized erasing of logged events.
- 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 Troubleshooting, RENR2696, "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 Troubleshooting, RENR2696, "Flash 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.

Pressure Sensors

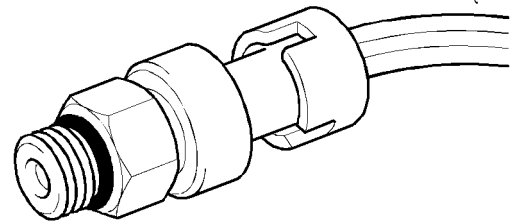


Illustration 27 g00884730
Intake manifold pressure sensor

The intake manifold pressure sensor is a three-wire active sensor that is supplied with power from the ECM. The sensor provides the ECM with a measurement of intake manifold pressure in order to control the air/fuel ratio. This will reduce the engine smoke during transient conditions. The intake manifold pressure sensor is also used for engine monitoring.

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

Required accuracy $\pm 3\%$ of maximum pressure

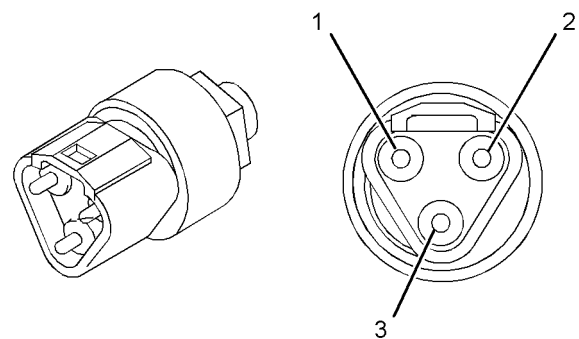


Illustration 28 g01133306
Engine oil pressure sensor

- (1) Sensor common
- (2) 5 volt supply
- (3) Pressure signal

The engine oil pressure sensor is also an active sensor with three wires and a power supply. The 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 a blocked oil filter.

The operating range for the engine oil pressure sensor 110 to 882 kPa (16 to 128 psi)

Required accuracy ±3% of maximum pressure

Temperature Sensors

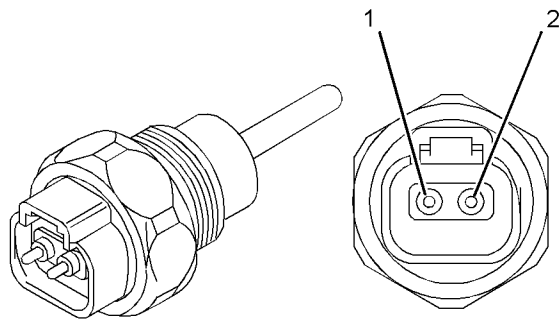


Illustration 29 g01133312
Temperature sensor
(1) Negative terminal
(2) Positive terminal

The intake manifold temperature sensor and the coolant temperature sensor are two-wire passive sensors. The intake manifold temperature sensor provides the ECM with intake manifold air temperature so that the ECM can control the fuel for starting and injection timing. The coolant temperature sensor provides the ECM with coolant temperature so that the ECM can control injection timing. The temperature sensors are also used for engine monitoring.

The operating range for the temperature sensors -40° to 150°C (-40° to 302°F)

Required accuracy for sensor ±1 °C (±1.8 °F)

Primary Speed/Timing Sensor

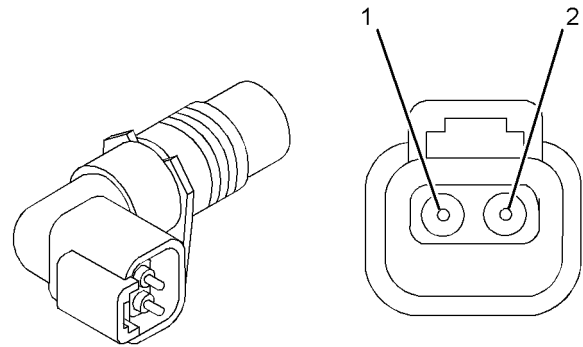


Illustration 30 g01133334
Primary speed/timing sensor
(1) Negative terminal
(2) Positive terminal

The primary speed/timing sensor is also a two-wire passive sensor. The sensor provides the ECM with the speed and the position of the engine from a timing wheel that is mounted on the crankshaft so that the ECM can request fuel and timing from the fuel injection pump. The timing wheel has one missing tooth that is located 70 degrees after top center.

The operating range for the primary speed/timing sensor 142 to 3333 RPM

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

Note: If the primary speed/timing sensor fails, the engine will be derated and the engine will continue to operate on the secondary speed/timing sensor. Refer to Troubleshooting, RENR2696 for more information.

Voltage Load-dump Protection Module (VLPM)

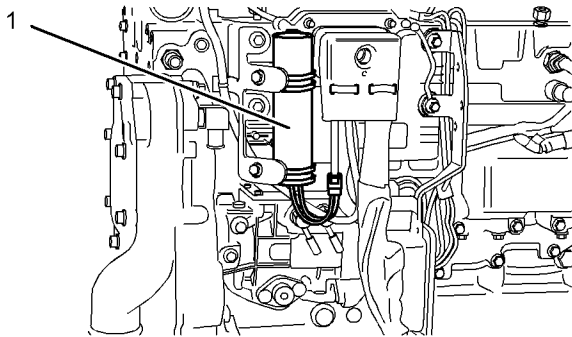


Illustration 31

g01133354

(1) VLPM

The VLPM monitors the voltage of the system and the VLPM will protect the ECU on the fuel injection pump against voltage spikes and reverse polarity. The fuel injection pump will be shutdown if there is high voltage on the system.

i02251435

Power Sources

Introduction (Power Supplies)

The 1104C electronic engine has four supplies to the following components:

- ECM
- Fuel Injection Pump
- Pressure sensors
- Throttle position sensor

ECM Power Supply

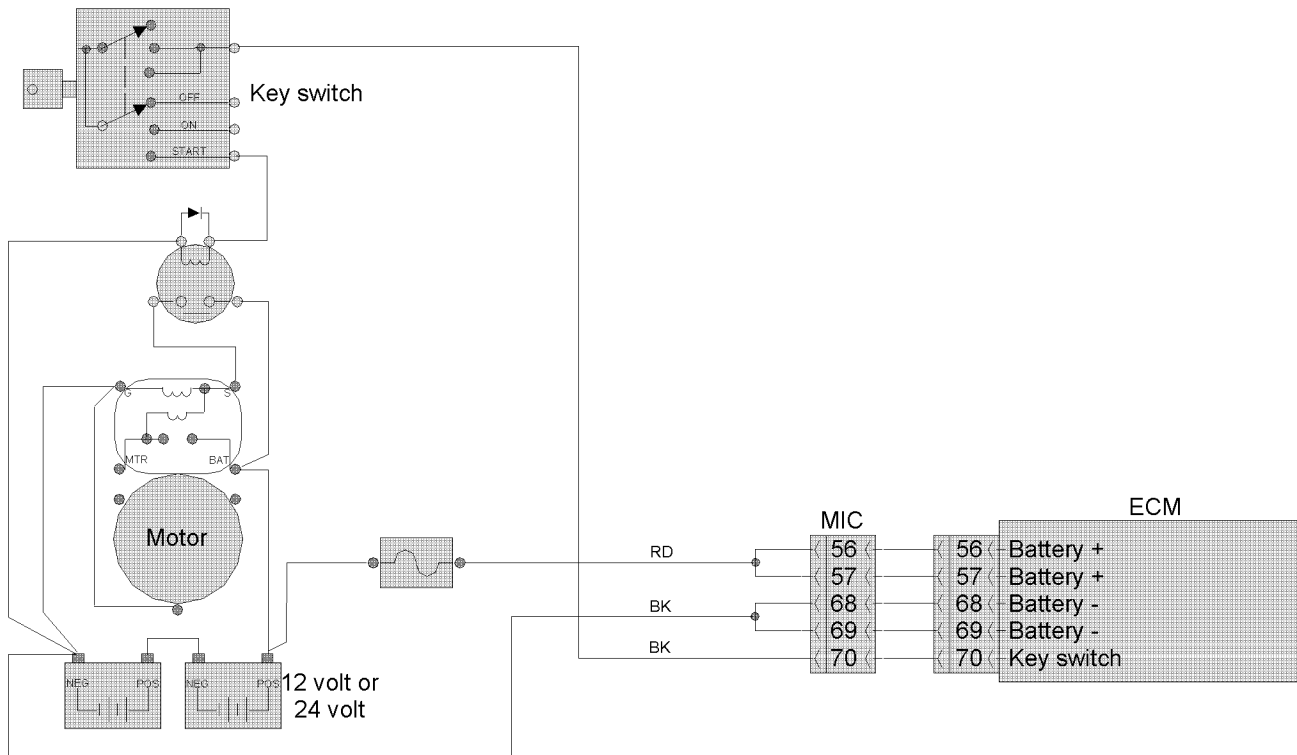


Illustration 32
Power Supply for the ECM

g01141374

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

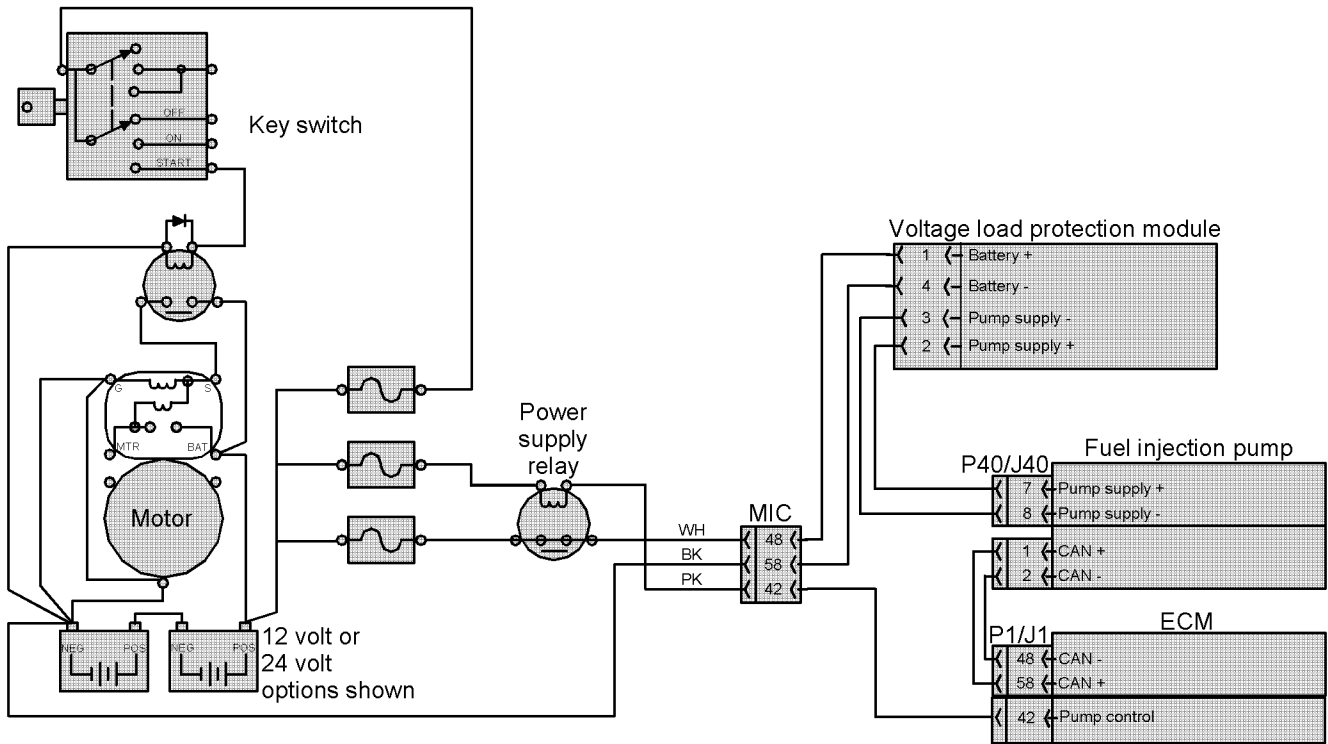


Illustration 33
Power supply for the fuel injection pump

g01141661

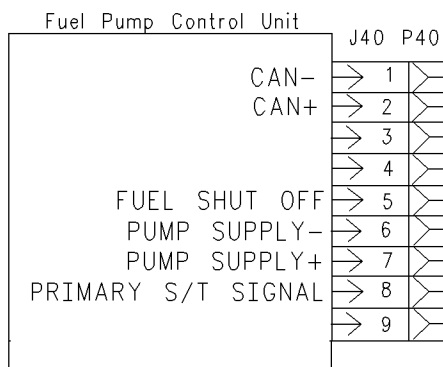


Illustration 34
Connection for the fuel injection pump (J40/P40)

g00931447

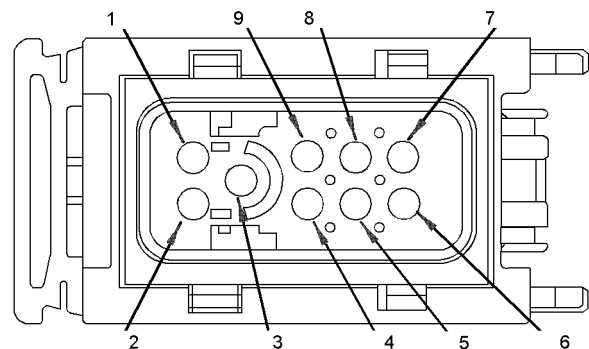


Illustration 35
Connector for the fuel injection pump (J40)

g01143327

- (1) Can -
- (2) Can +
- (3) Unused
- (4) Unused
- (5) Fuel shutoff
- (6) Battery -
- (7) Battery +
- (8) Signal for primary speed/timing sensor
- (9) Unused

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

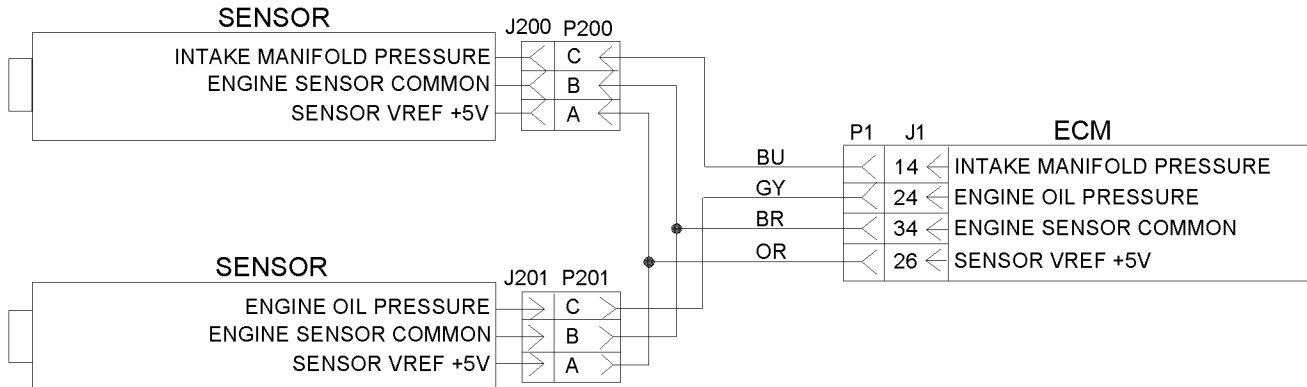


Illustration 36

g01143335

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 for the Throttle Position Sensor

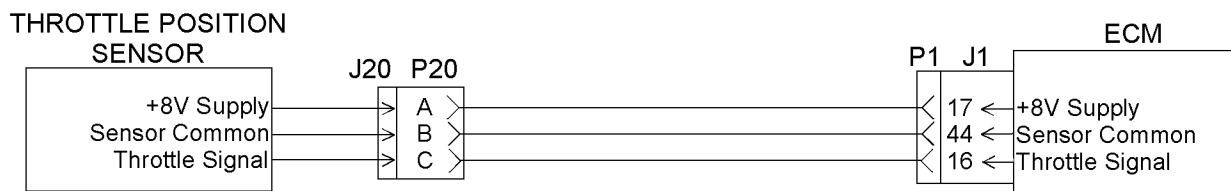


Illustration 37

g01134572

Schematic for the throttle position sensor

The ECM supplies 8.0 ± 0.4 DC volts through the ECM connector to the 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.

i02285310

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.

Intake manifold temperature sensor – The intake manifold temperature sensor is a sensor that measures the intake 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.

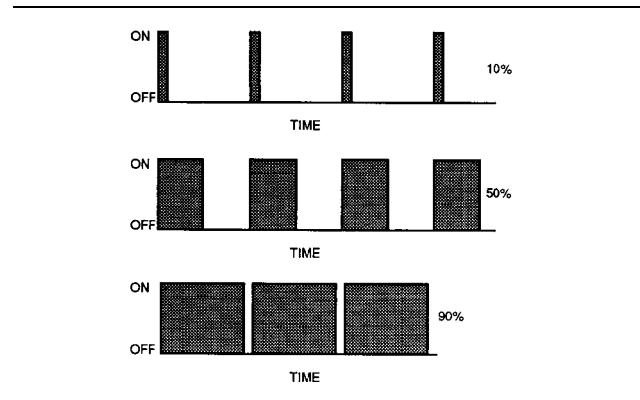


Illustration 38
Example Of Pulse Width Modulation

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

i02242712

Fuel System - Inspect

A number of 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. Inspect the fuel filter for excess contamination. If necessary, install a new fuel filter. Determine the source of the contamination. Make the necessary repairs.
4. Service the primary fuel filter (if equipped).
5. 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.

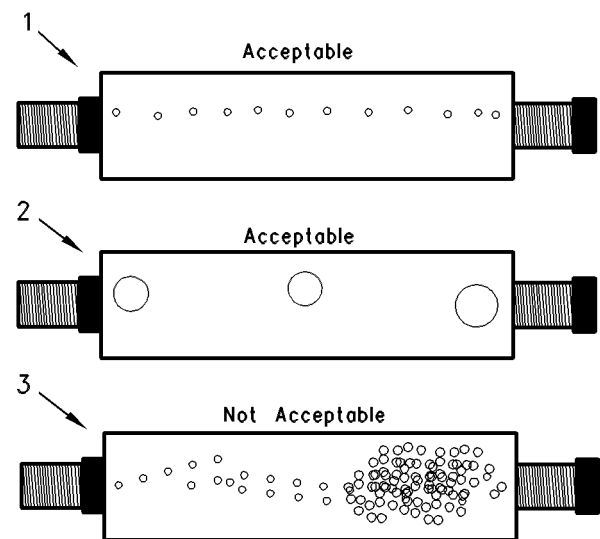


Illustration 39

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.

i02242740

Finding Top Center Position for No. 1 Piston

Table 1

Required Tools		
Part Number	Part Description	Qty
27610211	Crankshaft timing pin	1
27610212	Camshaft timing pin	1

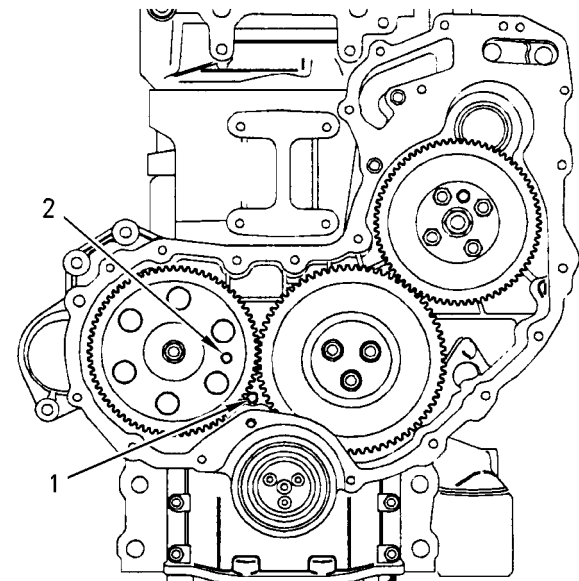


Illustration 40

g00923080

- (1) Hole for crankshaft pin
- (2) Hole for camshaft pin

1. Remove the valve mechanism cover, the glow plugs, and the cover for the front housing.

Note: The crankshaft timing pin can be inserted with the crankshaft pulley still on the engine.

2. Rotate the crankshaft in the normal direction of the engine until the inlet valve of the No. 4 cylinder has just opened and the exhaust valve of the No. 4 cylinder has not completely closed.

3. Carefully rotate the crankshaft in the normal direction of the engine in order to align the hole in the crankshaft with the hole in the cylinder block and the timing case. Insert the 27610211 Crankshaft Timing Pin fully into the hole in the crankshaft web.

4. Insert the 27610212 Camshaft Timing Pin through the hole in the camshaft gear and into the body of the timing case. The engine is set at the top center position for No. 1 piston.

Note: The camshaft gear can rotate a small amount when the pin is installed.

5. Remove the timing pins from the camshaft gear and the crankshaft web.

i02285307

Fuel Injection Timing - Adjust

Table 2

Required Tools		
Part Number	Part Description	Qty
27610032	Timing Pin	1

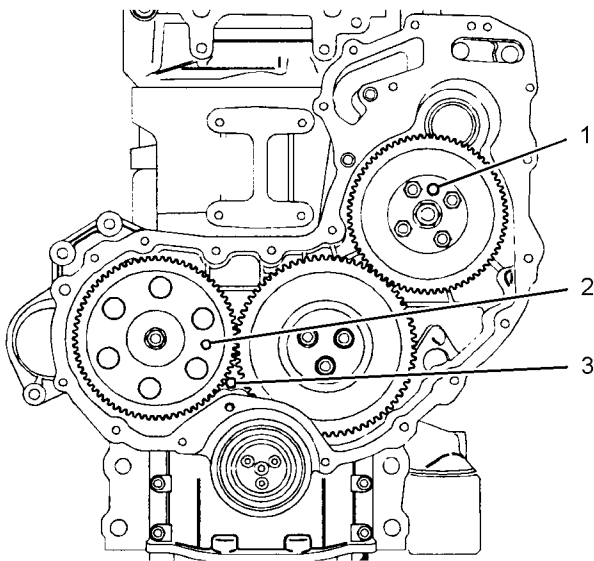


Illustration 41

g01134728

- (1) Hole for timing pin for the fuel pump
- (2) Hole for camshaft pin
- (3) Hole for crankshaft pin

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

Note: Do not remove the timing pins after finding top center on the compression stroke.

2. Remove the four setscrews and the four washers and then remove the fuel pump gear from the hub on the fuel injection pump.
3. Remove the idler gear. Refer to Disassembly and Assembly, "Idler Gear (Front) - Remove".
4. Install the fuel pump gear on the hub of the fuel injection pump shaft and install the four setscrews and the four washers.
5. Turn the fuel pump gear until the slot in the hub is aligned with the hole in the fuel injection pump body.

6. Insert the 27610032 Timing Pin through the hole in the fuel pump gear and through the slot in the hub. Push the timing pin fully into the hole in the body of the fuel injection pump.

Note: The 27610032 Timing Pin must be a sliding fit in the hole in the body of the fuel injection pump.

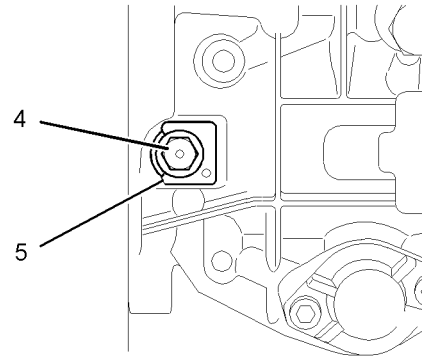


Illustration 42

g01143217

7. Release the locking screw (4). Remove the spacer (5). Tighten the locking screw (4) to 31 N·m (23 lb ft).
8. Remove the four setscrews and the four washers and then remove the fuel pump gear from the hub on the fuel injection pump.
9. Install the idler gear. Refer to Disassembly and Assembly, "Idler Gear (Front) - Install".
10. Install the fuel pump gear over the 27610032 Timing Pin and engage with the idler gear.
11. Loosely install the four washers and the four setscrews.
12. Rotate the fuel pump gear counterclockwise in order to take up the backlash in the gear train and then tighten the four setscrews to 28 N·m (20.7 lb ft).
13. Release the locking screw (4). Install the spacer (5) under the head of the locking screw. Tighten the locking screw (4) to 12 N·m (9 lb ft).
14. Remove all three timing pins and install the removed components.
15. Check the fuel injection timing again. Refer to Testing and Adjusting, "Fuel Injection Timing - Check".

i02253244

Fuel Injection Timing - Check

Table 3

Required Tools		
Part Number	Part Description	Qty
27610032	Timing Pin	1

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

Note: Do not remove the timing pins after finding top center on the compression stroke.

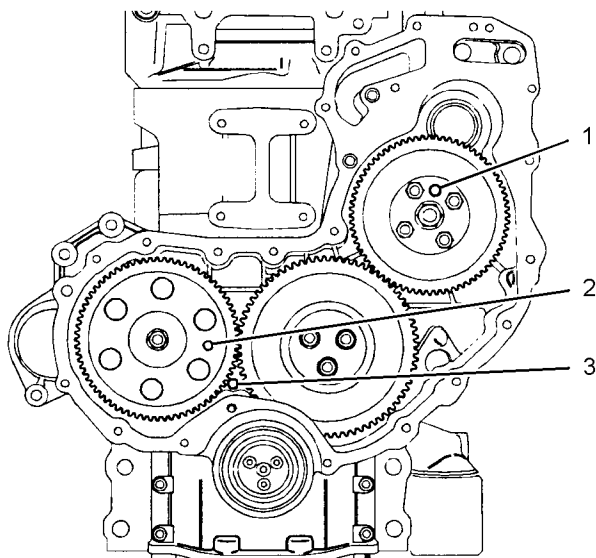


Illustration 43

g01134728

- (1) Hole for timing pin for the fuel pump
- (2) Hole for camshaft pin
- (3) Hole for crankshaft pin

2. Insert the 27610032 Timing Pin through the hole in the fuel pump gear and through the slot in the hub. Push the timing pin fully into the hole in the body of the fuel injection pump.

Note: The 27610032 Timing Pin must be a sliding fit in the hole in the body of the fuel injection pump.

3. The timing of the fuel pump is correct when all three of the timing pins are in the position.

Note: If the 27610032 Timing Pin cannot be pushed into the body of the fuel injection pump, then the fuel pump gear must be realigned on the hub on the fuel injection pump shaft. Refer to Testing and Adjusting, "Fuel Injection Timing - Adjust".

4. Remove all three timing pins and install the removed components.

i02243111

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, "Refill Capacities and 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

i02253606

i02253617

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 during normal operation.
- The low pressure fuel lines are disconnected.
- A leak exists in the low pressure fuel system during engine operation.
- The fuel filter or the fuel pump is replaced.
- The high pressure fuel lines are disconnected.

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

1. Remove the cover for the fuel injectors.
2. Turn the key to the RUN position for three minutes in order to energize the fuel priming pump. Do not start the engine. Then turn the key to the OFF position.

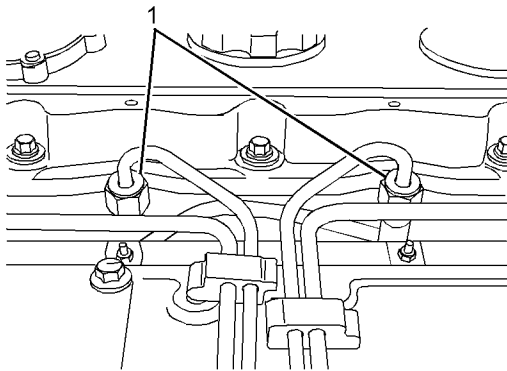


Illustration 44

g01135020

(1) Connections for the high pressure fuel lines

3. Loosen the connections for the high pressure fuel lines (1).
4. Operate the electric starter motor until fuel that is free of air comes from the connections.
5. Tighten the connections for the high pressure fuel lines to a torque of 30 N·m (22 lb ft).
6. Start the engine and check for leaks.
7. Install the cover for the fuel injectors.

Fuel System Pressure - Test

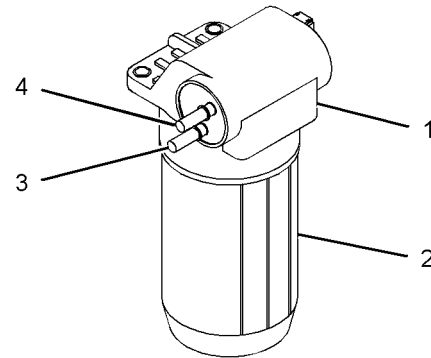


Illustration 45

g01135042

- (1) Fuel transfer pump
- (2) Fuel filter housing
- (3) Outlet for the supply for the fuel injection pump
- (4) Outlet for the return to the fuel tank

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

Check the Function of the Fuel Transfer Pump

1. Make a note of the location of the fuel lines from the fuel transfer pump. Remove the two lines from the outlets (3) and (4).
2. Connect two lengths of 5/16 inch rubber hose to outlets (3) and (4). Place the hoses into a suitable container that is capable of holding 3.0 L (0.66 Imp gal) of fuel.
3. Energize the fuel transfer pump until a constant flow of fuel is running from the outlet for the supply for the fuel injection pump.

Note: The flow from the outlet for the return for the fuel tank will have a slower flow rate.

4. Measure the combined flow of both outlets with a stopwatch. Fuel flow should be a minimum of 2.0 L (0.44 Imp gal) per minute.
5. If the combined flow is less than 2.0 L (0.44 Imp gal) per minute, replace the fuel transfer pump.
6. Reconnect the outlet lines in the correct positions.

7. Start the engine and check for any leakage of fuel or air from the fuel lines.

Check the Function of the Pressure Regulator

1. Remove the fuel line from the outlet for the supply for the fuel injection pump (3).
2. Install a pipe with a tap for a pressure gauge. Connect a 0 to 80 kPa (0 to 12 psi) pressure gauge.
3. Start the engine and run the engine at idle for two minutes in order to remove any trapped air.
4. Record the pressure reading at idle and at rated speed. The minimum pressure reading should be the following values:

Bosch VP30

Idle 27.5 kPa (3.98 psi)

Rated speed 24 kPa (3.48 psi)

Note: The maximum pressure reading at the inlet to the fuel injection pump is 80 kPa (12 psi).

5. Reconnect the fuel line. Run the engine at idle for two minutes in order to remove any trapped air.

Check for the following issues if the pressures are outside of the above specifications.

- All electrical connections are installed correctly.
- There are no leaks in the fuel lines or connections.
- The O-ring on fuel filter housing (2) does not leak.

Air Inlet and Exhaust System

i02254115

Air Inlet and Exhaust System - Inspect

i02253770

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 element with a clean element.
3. Check for evidence of dirt on the clean side of the engine air cleaner element. If dirt is observed, contaminants are flowing past the element.

Wastegate - Test

! 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.

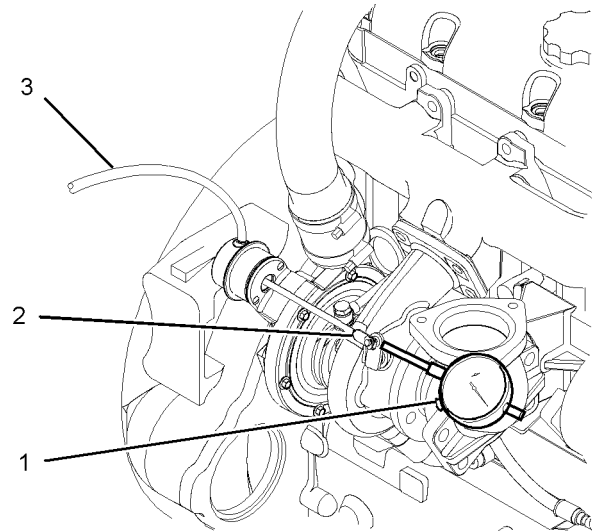


Illustration 46

g01135413

Note: The turbocharger is a nonserviceable item. The pressure for the wastegate can be checked, but not adjusted.

1. Use a suitable dial indicator (1). Align the dial gauge to the actuator rod (2).
2. Remove the air hose to the actuator . Install an air line (3) that can be adjusted in order to give the correct pressure.

i02254773

3. 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.
4. For more information on installing a new turbocharger, contact your Perkins dealer or your Perkins distributor.

i01888954

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 injectors are removed.
 - The fuel supply is disconnected.
1. Install a gauge for measuring the cylinder compression in the hole for a fuel injector.
 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.

Engine Valve Lash - Inspect/Adjust

WARNING

To prevent possible injury, do not use the starter to turn the flywheel.

Hot engine components can cause burns. Allow additional time for the engine to cool before measuring valve clearance.

Valve Lash Setting

Valve lash setting

Inlet valve	0.2 mm (0.008 inch)
Exhaust valve	0.45 mm (0.018 inch)

Refer to Systems Operation, "Engine Design" for the location of the cylinder valves.

Valve Lash Adjustment

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

The valve lash is measured between the top of the valve stem and the rocker arm lever.

Note: An adjustment is not necessary if the measurement of the valve lash is in the acceptable range. Inspect the valve lash while the engine is stopped. The temperature of the engine does not change the valve lash setting.

Note: When the following procedures are performed, the front housing must be installed.

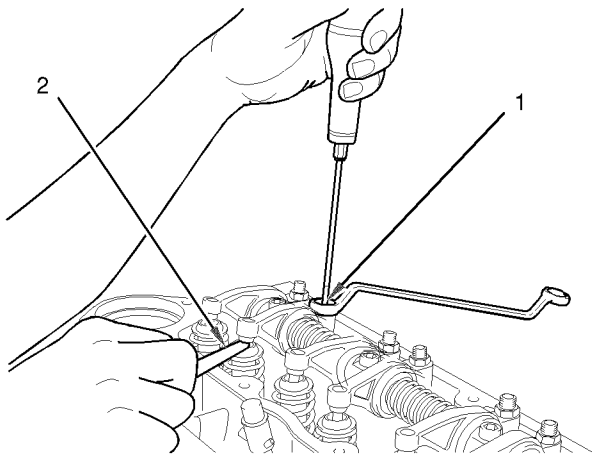


Illustration 47

g01016764

Setting the valve lash

- (1) Adjustment screw
(2) Feeler gauge

1. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install".
2. Rotate the crankshaft in a clockwise direction that is viewed from the front of the engine. When the inlet valve of the No. 4 cylinder has opened and the exhaust valve of the No. 4 cylinder has not completely closed measure the valve lash of the inlet valve and the exhaust valve of the No. 1 cylinder. If necessary, make adjustment.
 - a. Loosen the valve adjustment screw locknut that is on adjustment screw (1).

- b. Place the appropriate feeler gauge (2) between the rocker arm and the valve. Turn 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 adjustment screw (1) is being held from turning.

3. Rotate the crankshaft in a clockwise direction that is viewed from the front of the engine. When the inlet valve of the No. 2 cylinder has opened and the exhaust valve of the No. 2 cylinder has not completely closed measure the valve lash of the inlet valve and the exhaust valve of the No. 3 cylinder.

If adjustment is necessary, refer to Steps 2.a, 2.b, and 2.c above.

4. Rotate the crankshaft in a clockwise direction that is viewed from the front of the engine. When the inlet valve of the No. 1 cylinder has opened and the exhaust valve of the No. 1 cylinder has not completely closed measure the valve lash of the inlet valve and the exhaust valve of the No. 4 cylinder.

If adjustment is necessary, refer to Steps 2.a, 2.b, and 2.c above.

5. Rotate the crankshaft in a clockwise direction that is viewed from the front of the engine. When the inlet valve of the No. 3 cylinder has opened and the exhaust valve of the No. 3 cylinder has not completely closed measure the valve lash of the inlet valve and the exhaust valve of the No. 2 cylinder.

If adjustment is necessary, refer to Steps 2.a, 2.b, and 2.c above.

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

i01889422

Valve Depth - Inspect

Table 4

Required Tools		
Part Number	Part Description	Qty
21825617	Dial gauge	1
21825496	Dial gauge holder	1

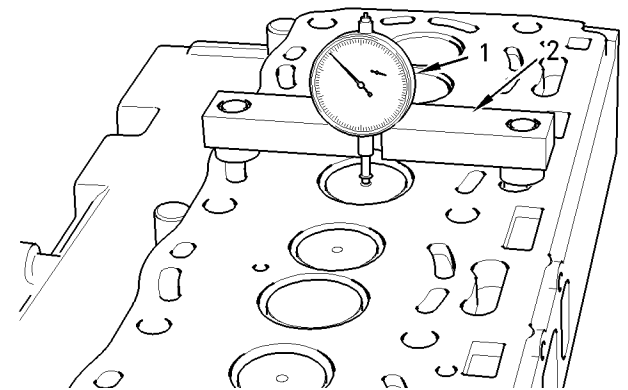


Illustration 48 g00983531

Measurement of the valve depth

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

1. Use the dial gauge (1) with the dial gauge holder (2) to check the depths of the inlet valves and the exhaust valves below the face of the cylinder head. Use the cylinder head face (3) to zero the dial gauge (1).
2. Position the dial gauge holder (2) and the dial gauge (1) in order to measure the valve depth. Measure the depth of the inlet valve and the exhaust valve before the valve springs are removed.

Refer to Specifications, "Cylinder Head Valves" for the minimum, the maximum, and the service wear limits for the valve depth below the cylinder head face.

If the valve depth below the cylinder head face exceeds the service limit, use a new valve to check the valve depth. If the valve depth still exceeds the service limit, renew the cylinder head or renew the valve seat inserts (if equipped). If the valve depth is within the service limit with a new valve, renew the valves.

3. Inspect the valves for cracks and other damage. Check the valve stems for wear. Check that the valve springs are the correct length under the test force. Refer to Specifications, "Cylinder Head Valves" for the dimensions and tolerances of the valves and the valve springs.

i01938952

Valve Guide - Inspect

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

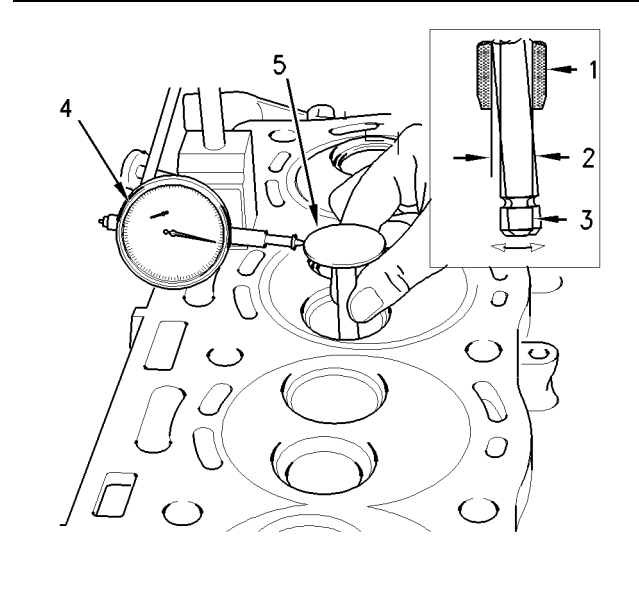


Illustration 49 g00986821

- (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 suitable dial indicator with the 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.

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 Specifications, "Cylinder Head Valves" for the maximum clearance of the valve in the valve guide.

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.

i01893791

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 for clearances and torques.

Refer to the Specifications Module, "Engine Oil Pump".

1. Remove the oil pump from the engine. Refer to the Disassembly and Assembly, "Engine Oil Pump - Remove". 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.

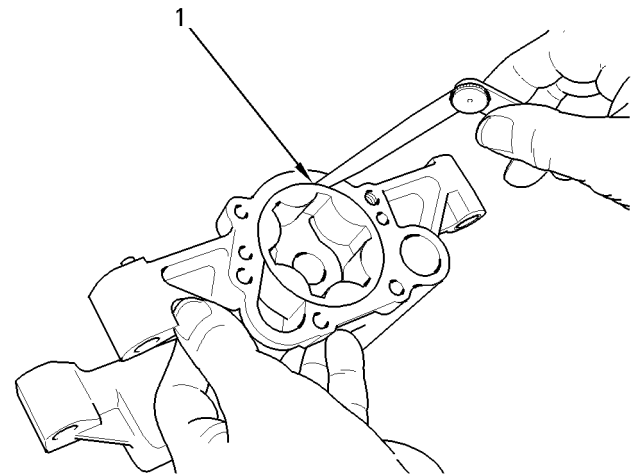


Illustration 50

g00985779

Clearance for the outer rotor body

(1) 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 (1).

i01126690

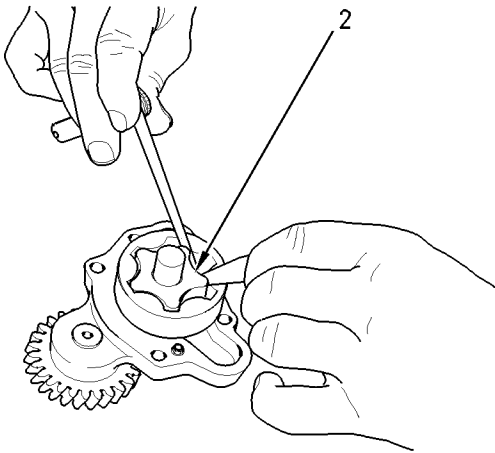


Illustration 51 g00985780

Clearance for the inner rotor

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

4. Measure the clearance of the inner rotor to the outer rotor (2).

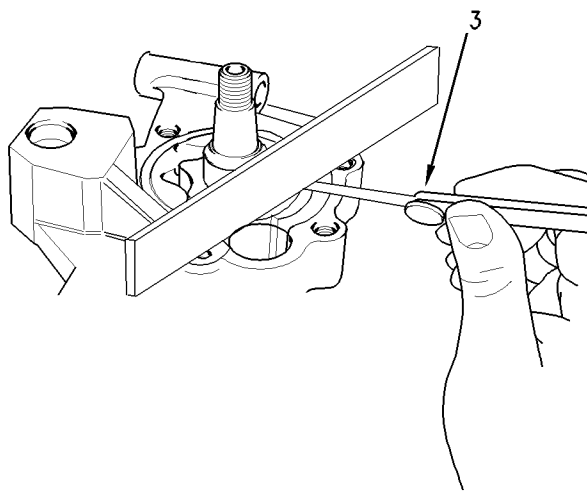


Illustration 52 g00989217

5. Measure the end play of the rotor with a straight edge and a feeler gauge (3).
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. Refer to Disassembly and Assembly, "Engine Oil Pump - Install".

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.

i01945015

Increased Engine Oil Temperature - Inspect

Look for a restriction in the oil passages of the oil cooler (if equipped). 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.

Cooling System

i02274237

Cooling System - Check (Overheating)

Above normal coolant temperatures can be caused by many conditions. Use the following procedure to determine the cause of above normal coolant temperatures:

1. Check the coolant level in the cooling system. If the coolant level is too low, air will get into the cooling system. Air in the cooling system will cause a reduction in coolant flow and bubbles in the coolant. Air bubbles will keep the coolant away from the engine parts, which will prevent the transfer of heat to the coolant. Low coolant level is caused by leaks or incorrectly filling the expansion tank.
2. Check that the exterior of the radiator is not blocked with debris.
3. Check that the drive belts are not loose. Refer to Testing and Adjusting, "V-Belt - Test".
4. Check that the fan is correctly installed and that the fan is not damaged.
5. Check for air in the cooling system. Air can enter the cooling system in different ways. The most common causes of air in the cooling system are not filling the cooling system correctly and combustion gas leakage into the cooling system. Combustion gas can get into the system through inside cracks, a damaged cylinder head, or a damaged cylinder head gasket. Air in the cooling system causes a reduction in coolant flow and bubbles in the coolant. Air bubbles keep the coolant away from the engine parts, which prevents the transfer of heat to the coolant.
6. Check the sending unit. In some conditions, the temperature sensor in the engine sends signals to a sending unit. The sending unit converts these signals to an electrical impulse which is used by a mounted gauge. If the sending unit malfunctions, the gauge can show an incorrect reading. Also if the electric wire breaks or if the electric wire shorts out, the gauge can show an incorrect reading.
7. Check the radiator for a restriction to coolant flow. Check the radiator for debris, dirt, or deposits on the inside of the core. Debris, dirt, or deposits will restrict the flow of coolant through the radiator.
8. Check the filler cap. A pressure drop in the cooling system can cause the boiling point to be lower. This can cause the cooling system to boil. Refer to Testing and Adjusting, "Cooling System - Test".
9. Check the cooling system hoses and clamps. Damaged hoses with leaks can normally be seen. Hoses that have no visual leaks can soften during operation. The soft areas of the hose can become kinked or crushed during operation. These areas of the hose can cause a restriction in the coolant flow. Hoses become soft and/or get cracks after a period of time. The inside of a hose can deteriorate, and the loose particles of the hose can cause a restriction of the coolant flow.
10. Check for a restriction in the air inlet system. A restriction of the air that is coming into the engine can cause high cylinder temperatures. High cylinder temperatures require higher than normal temperatures in the cooling system.
11. Check for a restriction in the exhaust system. A restriction of the air that is coming out of the engine can cause high cylinder temperatures.
 - a. Make a visual inspection of the exhaust system.
 - b. Check for damage to exhaust piping. Check for damage to the exhaust elbow. If no damage is found, check the exhaust system for a restriction.
12. Check the water temperature regulator. A water temperature regulator that does not open, or a water temperature regulator that only opens part of the way can cause overheating. Refer to Testing and Adjusting, "Water Temperature Regulator - Test".
13. Check the water pump. A water pump with a damaged impeller does not pump enough coolant for correct engine cooling. Remove the water pump and check for damage to the impeller.
14. Consider high outside temperatures. When outside temperatures are too high for the rating of the cooling system, there is not enough of a temperature difference between the outside air and coolant temperatures. The maximum temperature of the ambient air that enters the engine should not exceed 50 °C (120 °F).
15. When a load that is applied to the engine is too large, the engine rpm does not increase with an increase of fuel. This lower engine rpm causes a reduction in coolant flow through the system. This combination of less air and less coolant flow during high input of fuel will cause above normal heating.

i01889427

i01964006

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.
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.

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 53. 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.

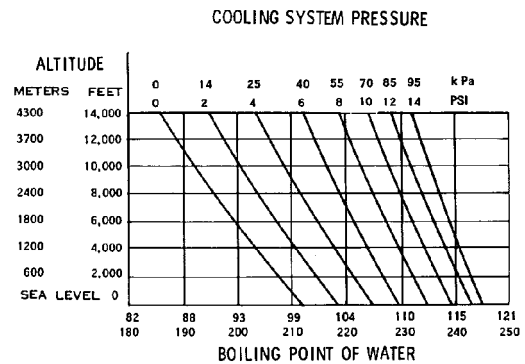


Illustration 53

g00286266

Cooling system pressure at specific altitudes and boiling points of water



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.

Checking the Filler Cap

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

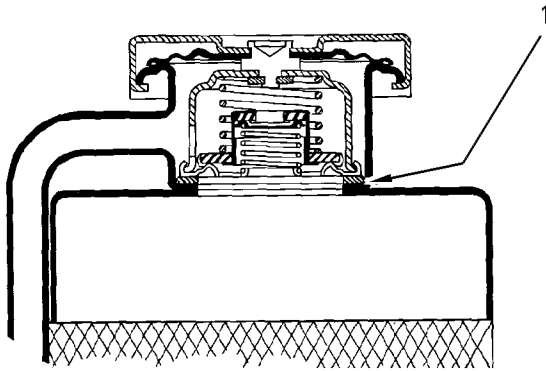


Illustration 54 g00296067
Typical schematic of filler cap

(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.

i02265391

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.

Perform the following procedure in order to inspect the engine oil cooler (if equipped):

1. Place a container under the oil cooler in order to collect any engine oil or coolant that drains from the oil cooler.
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 plates for cracks and dents. Replace the cooling plates if cracks or dents exist.

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

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 and the oil system of the engine are filled to the correct level. Operate the engine. Check for oil or coolant leakage.

i01889428

Water Temperature Regulator - Test

Note: Do not remove the water temperature regulator from the water temperature regulator housing in order to perform the test.

1. Remove the water temperature regulator housing which contains the water temperature regulator from the engine. Refer to Disassembly and Assembly, "Water Temperature Regulator - Remove and Install".
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 housing in the pan of water. The water temperature regulator housing must be below the surface of the water. The water temperature regulator housing 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 housing. 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. Refer to Disassembly and Assembly, "Water Temperature Regulator - Remove and Install".

Install the water temperature regulator. Refer to Disassembly and Assembly, "Water Temperature Regulator - Remove and Install".

Basic Engine

i01889476

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.

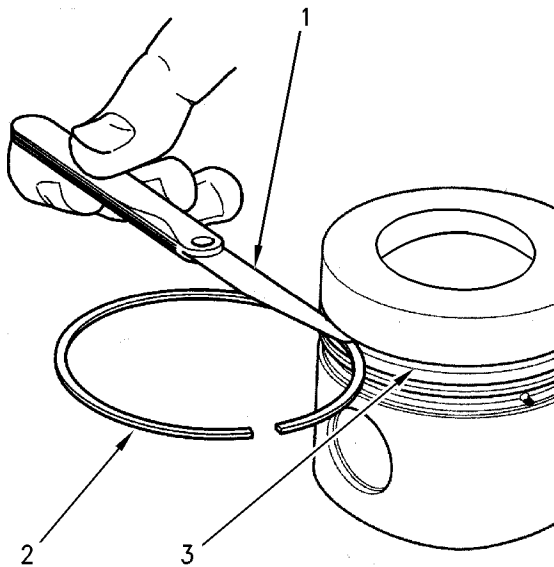


Illustration 55

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 the 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

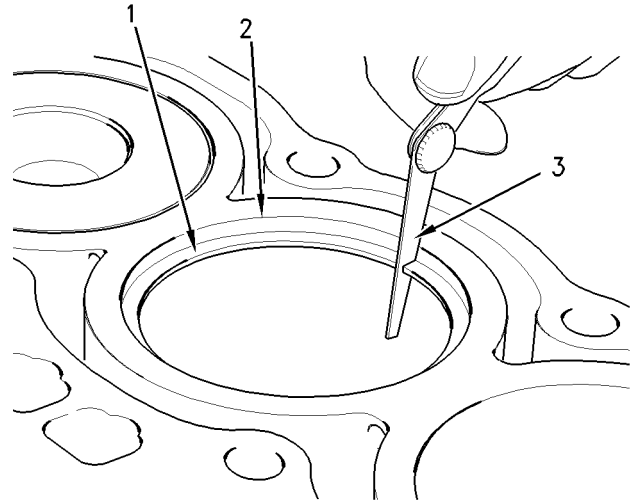


Illustration 56

g00983549

- (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 the 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.

i01946425

Connecting Rod - Inspect

This procedure determines the following characteristics of the connecting rod:

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

i01748770

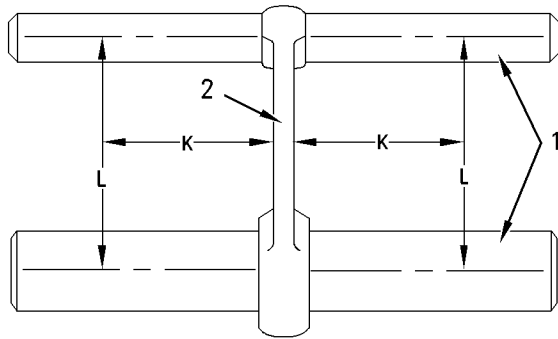


Illustration 57

g00927038

Inspection of the connecting rod parallel alignment.

- (1) Measuring pins
- (2) Connecting rod
- (L) Measure the distance between the center of the bore for the piston pin bearing and the center of the connecting rod bearing.
- (K) Measure the distance 127 mm (5.0 inch) from the connecting rod.

1. Use the appropriate tools in order to measure the distances for the connecting rod (2).
 - Appropriate gauges for measuring distance
 - Measuring pins (1)

Note: The connecting rod bearings should be removed before taking the measurements.

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

The measurements must be taken at distance (K). Distance (K) has a value of 127 mm (5.0 inch) from both sides of the connecting rod.

Measure length (L).

The total difference in measurements of length (L) from each side should not vary more than ± 0.25 mm (± 0.010 inch).

If the piston pin bearing is not removed, the limits are reduced to ± 0.06 mm (± 0.0025 inch).

3. Inspect the piston pin bearing and the piston pin for wear and other damage.
4. Measure the clearance of the piston pin in the piston pin bearing. Refer to Specifications, "Connecting Rod" for clearance dimensions.

Connecting Rod Bearings - Inspect

Check the connecting rod bearings and the connecting rod bearing journal for wear or other damage.

Connecting rod bearings are available with a smaller inside diameter than the original size bearings. These bearings are for crankshafts that have been ground.

i01748792

Main Bearings - Inspect

Check the main bearings for wear or other damage. Replace both halves of the bearings and check the condition of the other bearings if a main bearing is worn or damaged.

Main bearings are available with a smaller inside diameter than the original size bearings. These bearings are for main bearing journals that have been ground.

i01946424

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 piston height above the cylinder block.
4. Check the camshaft bearing 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. Refer to Disassembly and Assembly, "Camshaft Bearings - Remove and Install".

i01905914

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

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

Remachining 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 117.20 mm (4.614 inch) after the cylinder head has been machined.

If the bottom face of the cylinder head has been remachined, 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.

i01889496

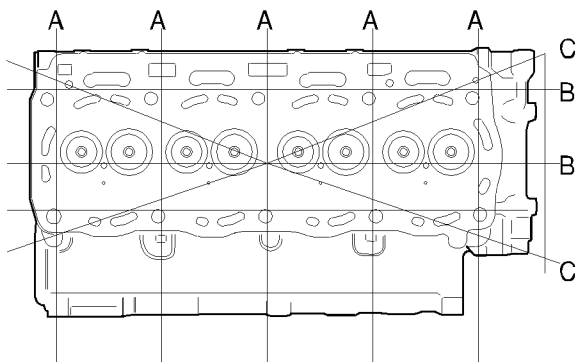


Illustration 58

g01012606

Flatness of the cylinder head (typical example)

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

8. Measure the cylinder head for flatness. Measure the flatness of the cylinder head with a straight edge and with a feeler gauge.
 - 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).

Piston Height - Inspect

Table 5

Required Tools		
Part Number	Part Description	Qty
21825617	Dial gauge	1
21825496	Dial gauge holder	1

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

i01897548

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.

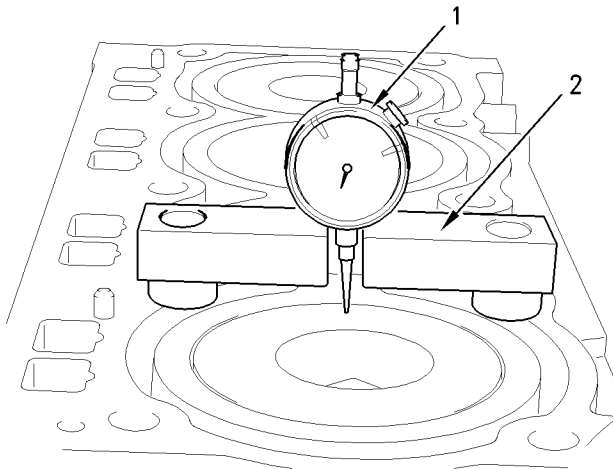


Illustration 59

g00983585

- (1) Dial gauge
(2) 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.
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".

Flywheel - Inspect

Alignment of the Flywheel Face

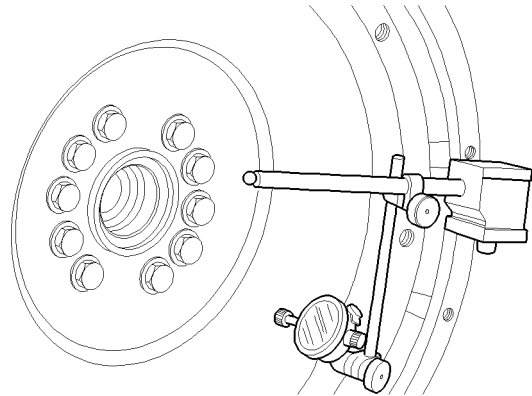


Illustration 60

g00987751

1. Install the dial indicator. Refer to Illustration 60.
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

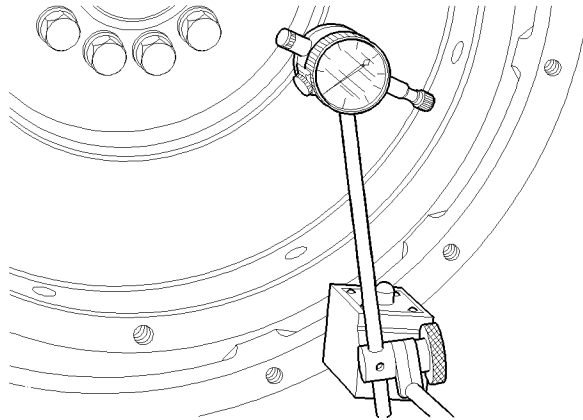


Illustration 61

g00987752

1. Install the dial indicator. Refer to Illustration 61.
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).

i02270535

Flywheel Housing - Inspect

Concentricity of the Flywheel Housing

Table 6

Required Tools		
Part Number	Part Description	Qty
21825617	Dial gauge	1

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

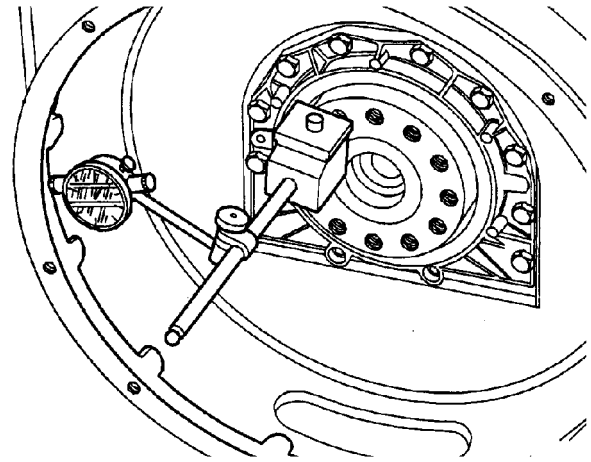


Illustration 62

g00913387

1. Install the 21825617 dial gauge. See Illustration 62.
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 7.

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.

i02270822

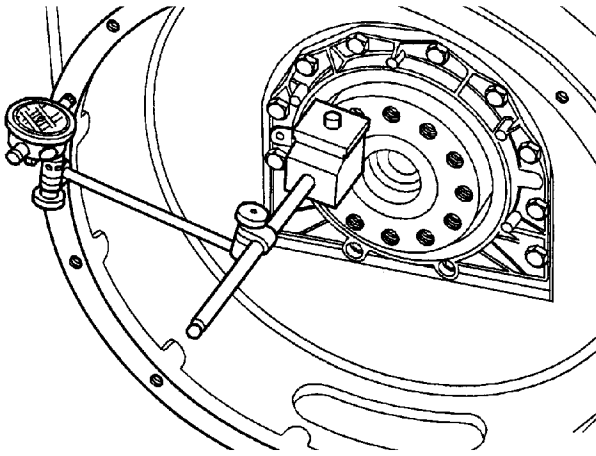


Illustration 63

g00913389

1. Install the 21825617 dial gauge. See Illustration 63.
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 7.

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

Table 7

Limits for Flywheel Housing Runout and Alignment (Total Indicator Reading)	
Bore of the Housing Flange	Maximum Limit (Total Indicator Reading)
362 mm (14.25 inch)	0.23 mm (0.009 inch)
410 mm (16.14 inch)	0.25 mm (0.010 inch)
448 mm (17.63 inch)	0.28 mm (0.011 inch)
511 mm (20.11 inch)	0.30 mm (0.012 inch)
584 mm (22.99 inch)	0.36 mm (0.014 inch)
648 mm (25.51 inch)	0.41 mm (0.016 inch)
787 mm (30.98 inch)	0.48 mm (0.019 inch)

Gear Group - Inspect

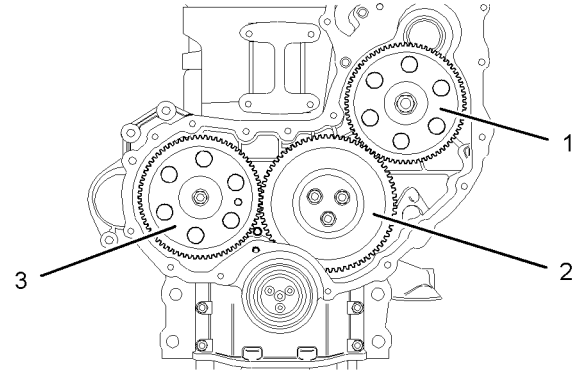


Illustration 64

g01137592

- (1) Fuel pump drive gear
- (2) Idler gear
- (3) Camshaft drive gear

Remove the front timing cover and inspect the gears. The timing marks on the gears indicate the front side of the gears. Inspect the gears for broken teeth or worn teeth.

Electrical System

i01899123

Alternator - Test

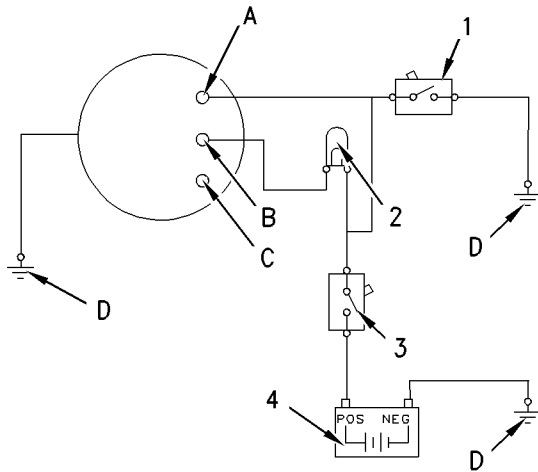


Illustration 65

g00931045

Typical wiring schematic for an alternator

- (A) Terminal "B+"
- (B) Terminal "D+"
- (C) Terminal "W"
- (D) Ground
- (1) Electrical switch
- (2) Dash light
- (3) Ignition switch
- (4) Battery

Warning Lamp Does Not Illuminate

The warning lamp for the charging system should illuminate when the ignition switch is in the ON position. Follow the steps below in order to test the system.

1. Check the light bulb. Replace the light bulb if the element is broken.
2. Use a suitable Multimeter to check the battery voltage. Check the battery voltage with the ignition switch OFF.
3. Check the voltage between the terminal (A) and ground. The measured voltage should equal the battery voltage.

4. Turn the ignition switch to the ON position. Check the voltage between terminal (B) and ground. If the voltage is more than 2 Volts the alternator needs to be replaced.

Warning Light is On When the Engine is Running

1. Start the engine and run the engine at fast idle.
2. Measure the voltage between terminal (A) and ground.
3. Measure the voltage between terminal (B) and ground.
4. The measured voltage for terminal (A) and terminal (B) should be 13 to 15 volts for a 12 volt system. The measured voltage for terminal (A) and terminal (B) should be 26 to 30 volts for a 24 volt system.
5. If the voltages do not match replace the alternator.
6. Increase the engine to high idle. Turn an electrical load ON.
7. Measure the voltage between terminal (A) and ground.
8. Measure the voltage between terminal (B) and ground.
9. The measured voltage for terminal (A) and terminal (B) should be 13 to 15 volts for a 12 volt system. The measured voltage for terminal (A) and terminal (B) should be 26 to 30 volts for a 24 volt system.
10. Replace the alternator if the voltage does not match.

i01899136

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.

The correct procedures to test the battery can be found in the manual that is supplied by the OEM.

i01955101

V-Belt - Test

Table 8

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 the 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".

i02270879

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".

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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 9

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 10

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 10 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.

Note: Do not crank the engine for more than 30 seconds. Allow the starter to cool for two minutes before cranking the engine again.

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 9, then go to Step 2.
- b. The battery voltage is less than the voltage in Table 9.

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 9.
- 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 9, 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 9. 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 10.
- b. Voltage drops are equal to the voltage drops that are given in Table 10 or the voltage drops are less than the voltage drops that are given in Table 10. 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 10. 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.

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Glow Plugs - Test

Continuity Check of the Glow Plugs

The following test will check the continuity of the glow plugs.

1. Disconnect the power supply and the bus bar.
2. Use a suitable digital multimeter to check continuity (resistance). Turn the audible signal on the digital multimeter ON.
3. Place one probe on the connection for the glow plug and the other probe to a suitable ground. The digital multimeter should make an audible sound. Replace the glow plug if there is no continuity.
4. Check the continuity on all the glow plugs.

Checking The Operation of The Glow Plug

The following test will check the operation of the glow plugs.

1. Disconnect the power supply and the bus bar.
2. Connect the power supply to only one glow plug.

3. Place a suitable ammeter on the power supply wire.
4. Connect a suitable digital multimeter to the terminal on the glow plug and to a suitable ground.
5. Turn the switch to the ON position in order to activate the glow plugs.

Table 11

12 Volt System	
Amp	Time (sec)
30	Initial
21	4
14	8
10	20
9	60

Table 12

24 Volt System	
Amp	Time (sec)
12	Initial
8.5	8
7	20
6	60

6. Check the reading on all of the glow plugs.
7. If there is no reading on the ammeter check the electrical connections. If the readings on the ammeter are low replace the glow plugs. If there is still no reading replace the glow plugs.

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