SENR9981-01
May 2007

# Systems Operation
# Testing and Adjusting

## 1106D Industrial Engine

**PJ (Engine)**

# Important Safety Information

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

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

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

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

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

**⚠ WARNING**

The meaning of this safety alert symbol is as follows:

**Attention! Become Alert! Your Safety is Involved.**

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

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

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

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

**⚠ WARNING**

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

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

# Table of Contents

## Systems Operation Section



## Testing and Adjusting Section



## Index Section

# Systems Operation Section

# General Information

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## Introduction

The following model views show a typical 1106D engine. Due to individual applications, your engine may appear different from the illustrations.

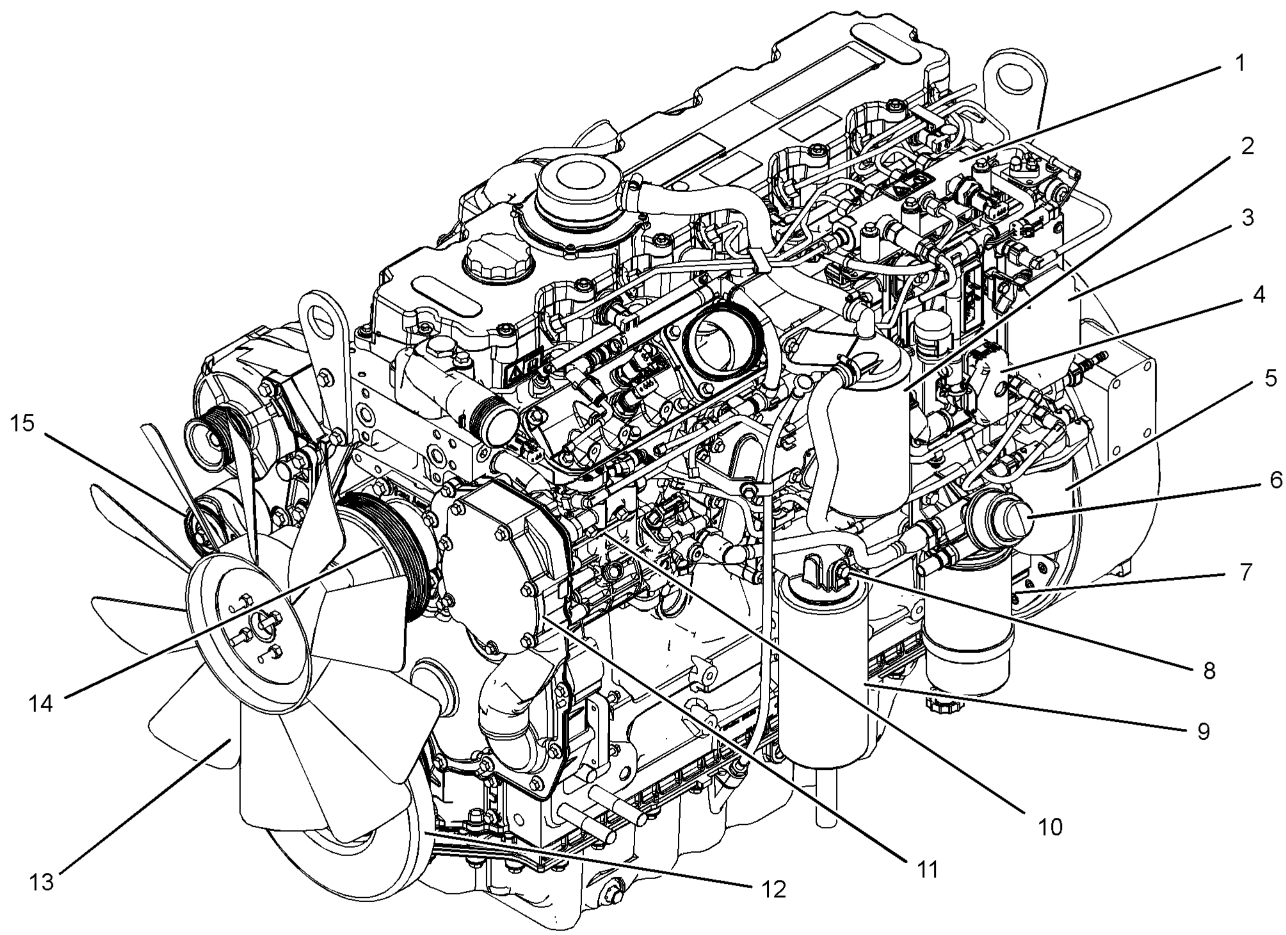


Illustration 1

g01329939

Front left engine view

(1) Fuel manifold (Rail)
(2) Canister for the crankcase breather
(3) Electronic control module
(4) P2 connector
(5) Secondary fuel filter
(6) Hand primer
(7) Primary fuel filter
(8) Oil sampling valve
(9) Oil filter
(10) Fuel pump
(11) Water pump
(12) Damper
(13) Fan
(14) Fan pulley
(15) Belt tensioner

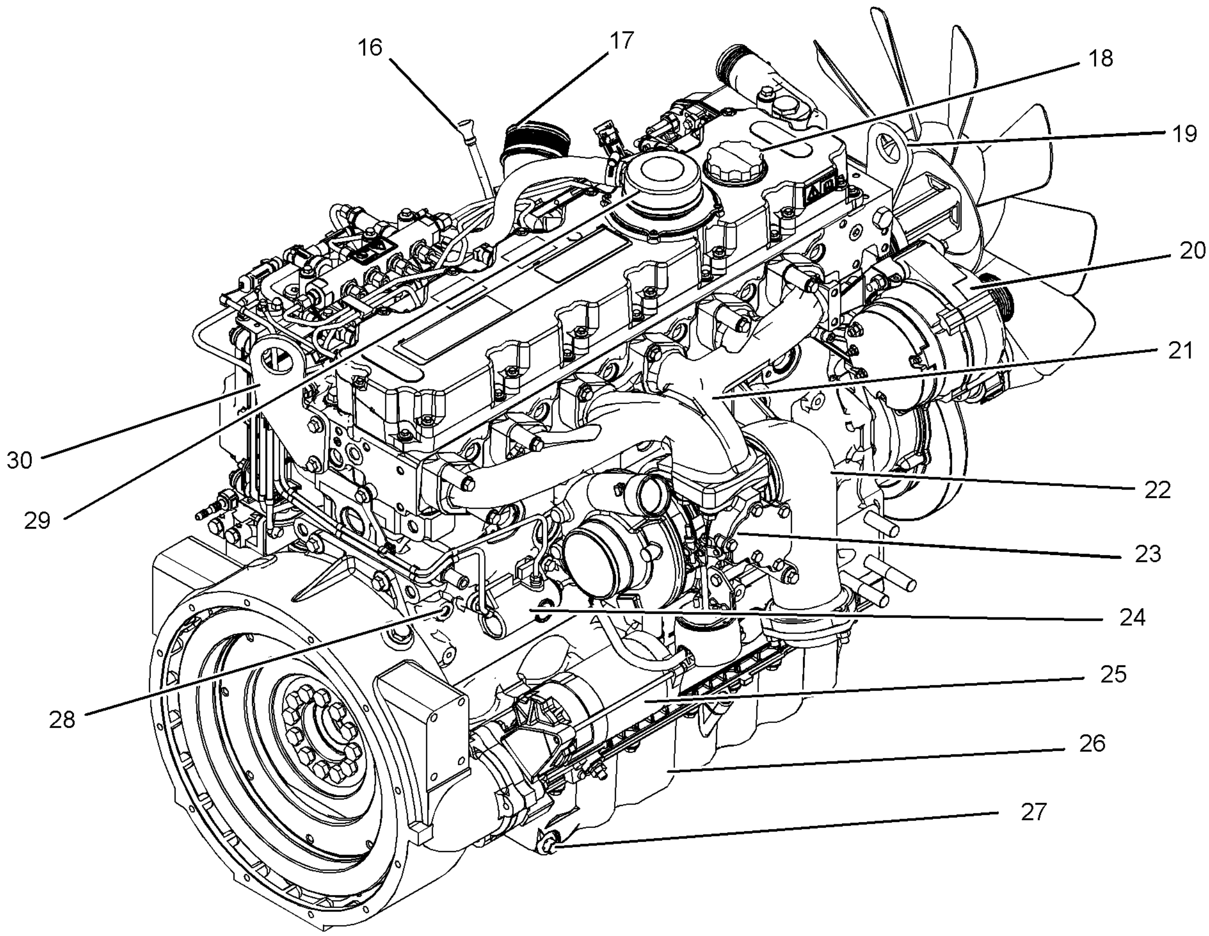


Illustration 2 g01329941

Rear right engine view

(16) Oil gauge
(17) Air intake
(18) Oil filler
(19) Front lifting eye
(20) Alternator
(21) Exhaust manifold
(22) Exhaust elbow
(23) Turbocharger
(24) Wastegate solenoid
(25) Starting motor
(26) Oil pan
(27) Drain plug (oil)
(28) Drain plug or coolant sampling valve
(29) Breather
(30) Rear lifting eye

The 1106D model PJ diesel engine is electronically controlled. The 1106D engine uses an Electronic Control Module (ECM) that receives signals from the fuel injection pump and other sensors in order to control the fuel injectors. The pump supplies fuel to the fuel injectors.

The six cylinders are arranged in-line. The cylinder head assembly has two inlet valves and two exhaust valves for each cylinder. The ports for the exhaust valves are on the right side of the cylinder head. The ports for the inlet valves are on the left 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 Quiescent combustion chamber in the top of the piston in order to achieve clean exhaust emissions. 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 coating of graphite in order to reduce wear when the engine is new. 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 a connecting rod are matched to each cylinder. The piston height is controlled by the distance between the center of the big end bearing and the center of the small end bearing of the connecting rod. Three different lengths of connecting rods are available in order to attain the correct piston height. The three different lengths of connecting rods are made by machining the blank small end bearing of each rod at three fixed distances vertically above the centerline of the big end bearing. .

The crankshaft has seven main bearing journals. End play is controlled by thrust washers which are located on both sides of the number six main bearing.

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

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

- the camshaft gear
- the fuel injection pump

The camshaft and the fuel injection pump run at half the rpm of the crankshaft. The cylinder bores are machined into the cylinder block.

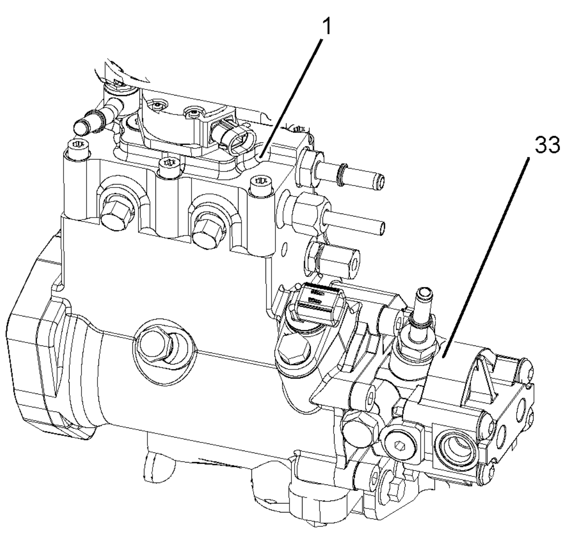


Illustration 3 g01214399

The fuel injection pump (1) that is installed on the left side of the engine is gear-driven from the timing case. The fuel transfer pump (33) is attached to the fuel injection pump (1). The fuel transfer pump draws low pressure fuel from the primary fuel filter. The fuel transfer pump delivers the fuel to the secondary filter at a pressure of 400 kPa (58 psi) to 500 kPa (72.5200 psi). The fuel injection pump draws fuel from the secondary filter. The fuel injection pump increases the fuel to a maximum pressure of 130 MPa (18855 psi). The fuel injection pump delivers the fuel to the fuel manifold. The fuel injection pump is not serviceable. Adjustments to the pump timing should only be made by personnel that have had the correct training. The fuel injection pump uses the engine ECM to control the engine RPM.

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

# Engine Operation

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## Basic Engine

### Introduction (Basic Engine)

The eight major mechanical components of the basic engine are the following parts:

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

## Cylinder Block and Cylinder Head

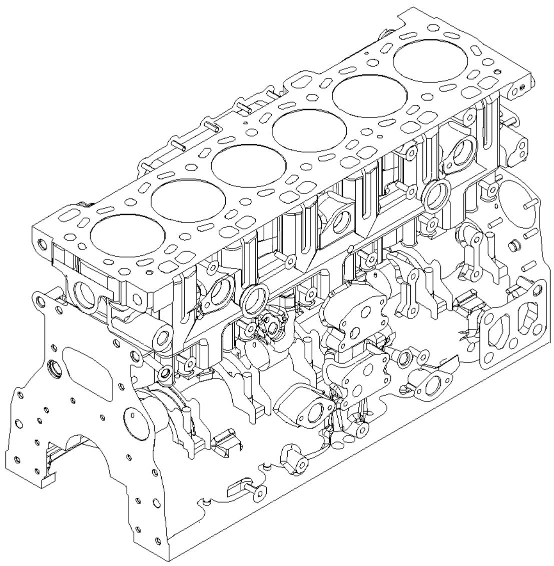

Illustration 4 g01175307

Typical Cylinder Block

The cast iron cylinder block for the 1106D engine has six cylinders which are arranged in-line. The cylinder block is made of cast iron in order to provide support for the full length of the cylinder bores. Worn cylinders may be rebored in order to accommodate oversize pistons and rings.

The cylinder block has seven main bearings which support the crankshaft. Thrust washers are installed on both sides of number six main bearing in order to control the end play of the crankshaft.

Passages supply the lubrication for the crankshaft bearings. These passages are cast into the cylinder block.

The cylinders are honed to a specially controlled finish in order to ensure long life and low oil consumption.

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

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

A multi-layered steel (MLS) cylinder head gasket is used between the engine block and the cylinder head in order to seal combustion gases, water, and oil.

## Cylinder head

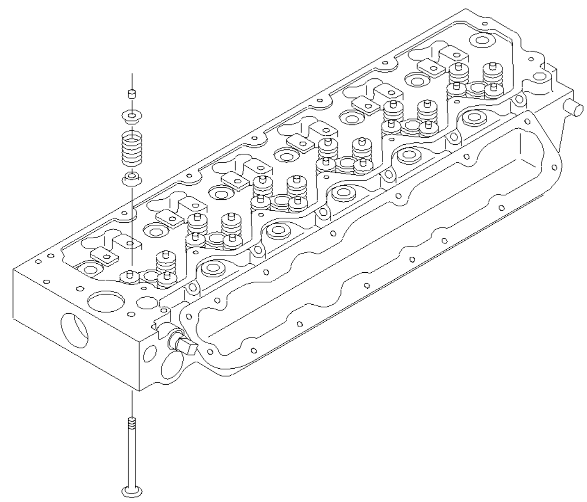

Illustration 5 g01201553

The engine has a cast iron cylinder head. The inlet manifold is integral within the cylinder head. There are two inlet valves and two exhaust valve for each cylinder. Each pair of valves are connected by a valve bridge that is 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. The valve stems move in valve guides that are machined into the cylinder head. There is a renewable valve stem seal that fits over the top of the valve guide.

## Pistons, Rings and Connecting rods

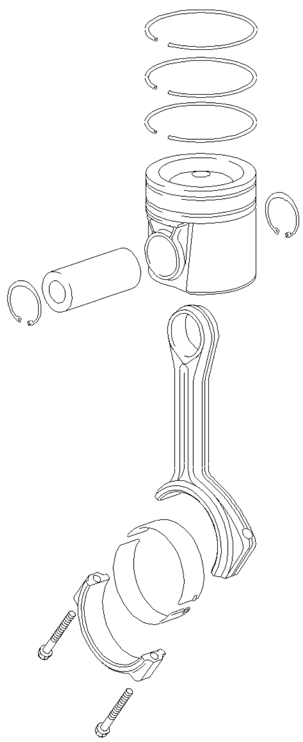

Illustration 6 g01205645

The pistons have a Quiescent 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 piston skirt has a coating of graphite in order to reduce the risk of seizure when the engine is new.

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.

The connecting rods are machined from forged molybdenum steel. The connecting rods 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:

- The splitting produces an accurately matched surface on each side of the fracture for improved strength.

## Crankshaft

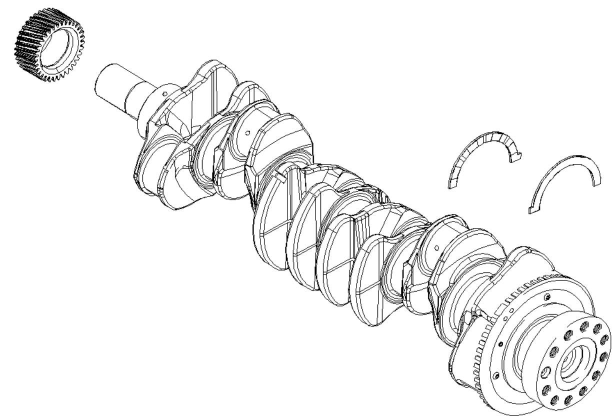

Illustration 7 g01196830

The crankshaft is a chromium molybdenum forging. The crankshaft has seven main journals. Thrust washers are installed on both sides of number six main bearing in order to control the end play of the 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 and fuel transfer 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.

A timing ring is installed to the crankshaft. The timing ring is used by the ECM in order to measure the engine speed and the engine position.

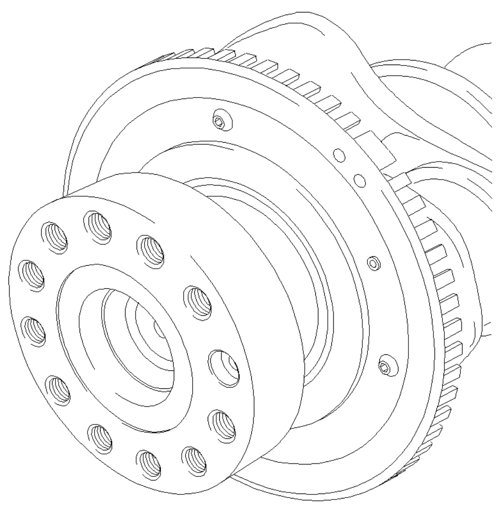

Illustration 8 g01205646

## Vibration Damper

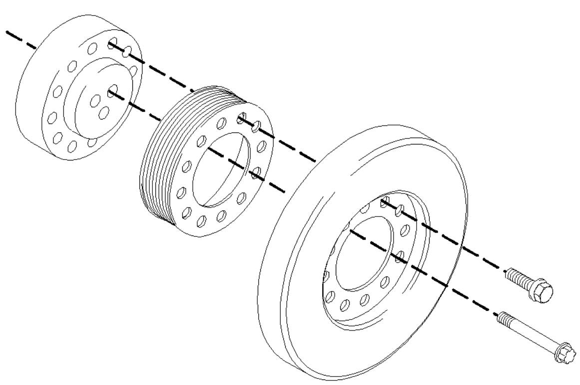

Illustration 9 g01180539

Typical example

The force from combustion in the cylinders will cause the crankshaft to twist. This is called torsional vibration. If the vibration is too great, the crankshaft will be damaged. The vibration damper is filled with viscous fluid in order to limit the torsional vibration.

## Gears and Timing Gear Case

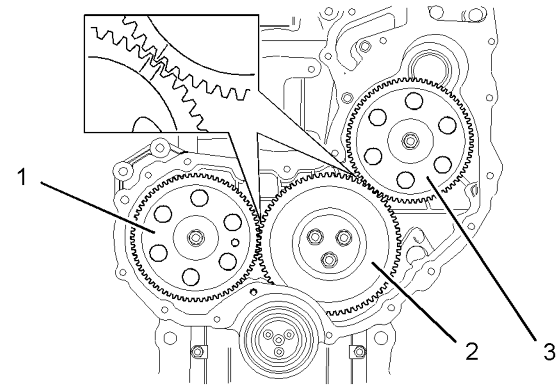


Illustration 10 g01194949

The crankshaft oil seal is mounted in the aluminum timing case. The timing case cover is made from pressed steel.

The timing gears are made of steel.

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

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

## Camshaft

The engine has a single camshaft. The camshaft is made of cast iron. The camshaft lobes arechill hardened.

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

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

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# Air Inlet and Exhaust System

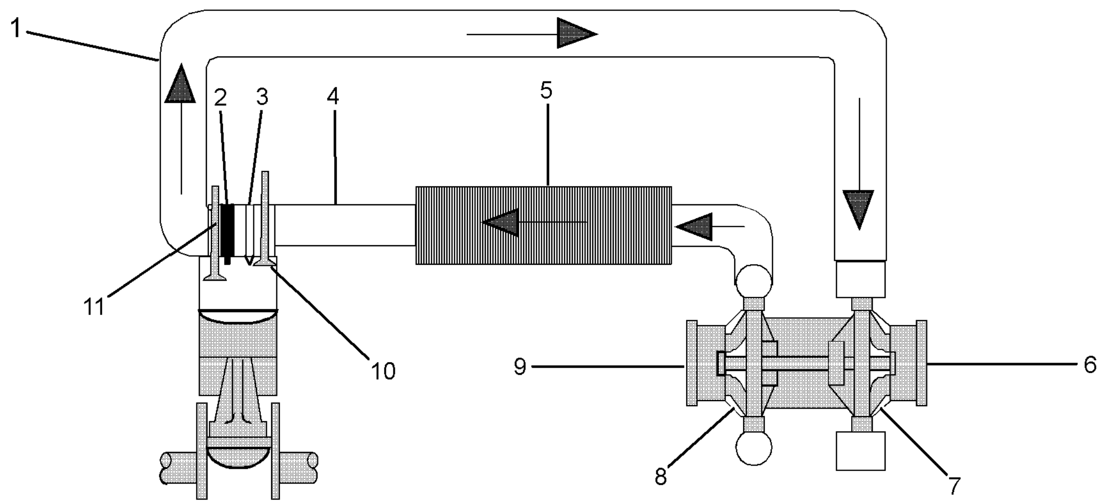


Illustration 11 g01205681

Air inlet and exhaust system

(1) Exhaust manifold
(2) Electronic unit injector
(3) Glow plug
(4) Inlet manifold
(5) Aftercooler core
(6) Exhaust outlet
(7) Turbine side of turbocharger
(8) Compressor side of turbocharger
(9) Air inlet from the air cleaner
(10) Inlet valve
(11) Exhaust valve

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

- Air cleaner
- Turbocharger
- Aftercooler
- Inlet manifold
- Cylinder head, injectors and glow plugs
- Valves and valve system components
- Piston and cylinder
- Exhaust manifold

Air is drawn in through the air cleaner into the air inlet of the turbocharger (9) by the turbocharger compressor wheel (8). The air is compressed and heated to about 150 °C (300 °F) before the air is forced to the aftercooler (5). As the air flows through the aftercooler the temperature of the compressed air lowers to about 50 °C (120 °F). Cooling of the inlet air increases combustion efficiency. Increased combustion efficiency helps achieve the following benefits:

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

From the aftercooler, air is forced into the inlet manifold (4). Air flow from the inlet manifold to the cylinders is controlled by inlet valves (10). There are two inlet valves and two exhaust valves for each cylinder. The inlet valves open when the piston moves down on the intake stroke. When the inlet valves open, cooled compressed air from the inlet port is forced into the cylinder. The complete cycle consists of four strokes:

- Inlet

- Compression
- Power
- Exhaust

On the compression stroke, the piston moves back up the cylinder and the inlet valves (10) close. The cool compressed air is compressed further. This additional compression generates more heat.

**Note:** If the cold starting system is operating, the glow plugs (3) will also heat the air in the cylinder.

Just before the piston reaches the TC position, the ECM operates the electronic unit injector. Fuel is injected into the cylinder. The air/fuel mixture ignites. The ignition of the gases initiates the power stroke. Both the inlet and the exhaust valves are closed and the expanding gases force the piston downward toward the bottom center (BC) position.

From the BC position, the piston moves upward. This initiates the exhaust stroke. The exhaust valves open. The exhaust gases are forced through the open exhaust valves into the exhaust manifold.

Exhaust gases from exhaust manifold (1) enter the turbine side of the turbocharger in order to turn turbocharger turbine wheel (7). The turbine wheel is connected to the shaft that drives the compressor wheel. Exhaust gases from the turbocharger pass through exhaust outlet (6), a silencer and an exhaust pipe.

## Turbocharger

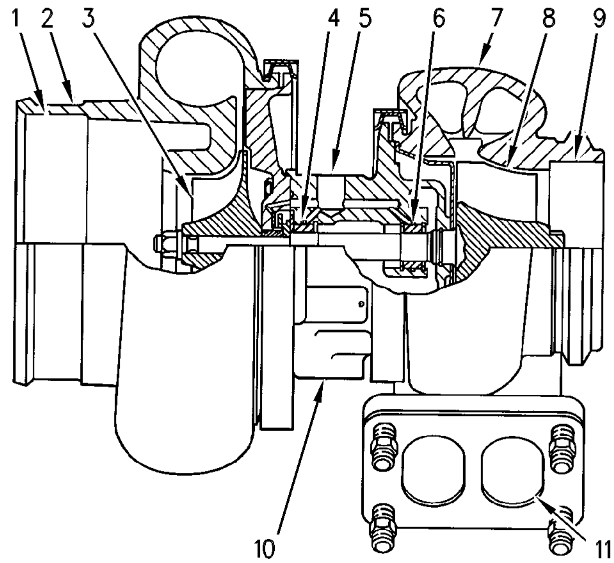


Illustration 12 g00302786

Turbocharger

(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

The turbocharger is mounted on the outlet of the exhaust manifold in one of two positions on the right side of the engine, toward the top of the engine or to the side of the engine. The exhaust gas from the exhaust manifold enters the exhaust inlet (11) and passes through the turbine housing (7) of the turbocharger. Energy from the exhaust gas causes the turbine wheel (8) to rotate. The turbine wheel is connected by a shaft to the compressor wheel (3).

As the turbine wheel rotates, the compressor wheel is rotated. This causes the intake air to be pressurized through the compressor housing (2) of the turbocharger.

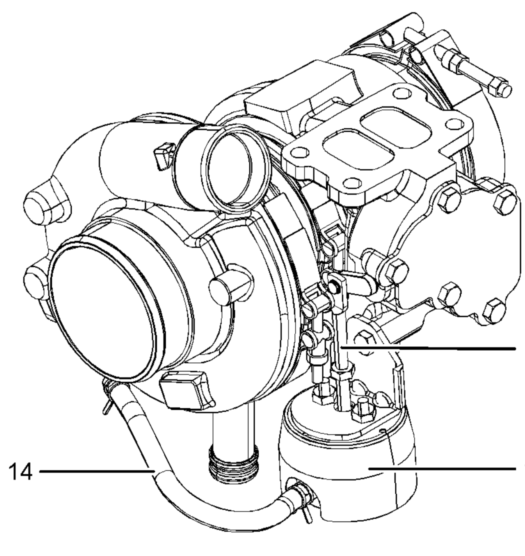


Illustration 13 g01206040

Turbocharger with the wastegate

(12) Actuating lever
(13) Wastegate actuator
(14) Line (boost pressure)

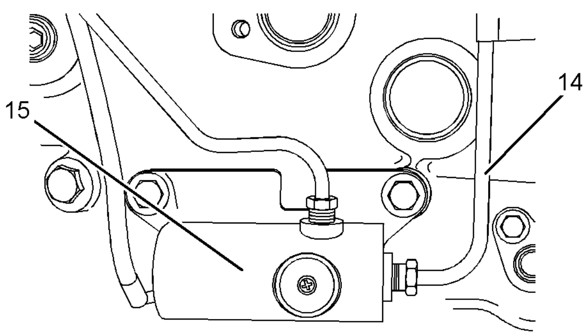


Illustration 14 g01334456

Typical example

(14) Line (boost pressure)
(15) Wastegate solenoid

When the load on the engine increases, more fuel is injected into the cylinders. The combustion of this additional fuel produces more exhaust gases. The additional exhaust gases cause the turbine and the compressor wheels of the turbocharger to turn faster. As the compressor wheel turns faster, air is compressed to a higher pressure and more air is forced into the cylinders. The increased flow of air into the cylinders allows the fuel to be burnt with greater efficiency. This produces more power.

A wastegate is installed on the turbine housing of the turbocharger. The wastegate is a valve that allows exhaust gas to bypass the turbine wheel of the turbocharger. The operation of the wastegate is dependent on the pressurized air (boost pressure) from the turbocharger compressor. The boost pressure acts on a diaphragm that is spring loaded in the wastegate actuator which varies the amount of exhaust gas that flows into the turbine.

If a wastegate solenoid (15) is installed, then the wastegate is controlled by the engine Electronic Control Module (ECM). The ECM uses inputs from a number of engine sensors to determine the optimum boost pressure. This will achieve the best exhaust emissions and fuel consumption at any given engine operating condition. The ECM controls the solenoid valve, which regulates the boost pressure to the wastegate actuator.

When high boost pressure is needed for the engine performance, a signal is sent from the ECM to the wastegate solenoid. This causes low pressure in the air inlet pipe (14) to act on the diaphragm within the wastegate actuator (13). The actuating rod (12) acts upon the actuating lever to close the valve in the wastegate. When the valve in the wastegate is closed, more exhaust gas is able to pass over the turbine wheel. This results in an increase in the speed of the turbocharger.

When low boost pressure is needed for the engine performance, a signal is sent from the ECM to the wastegate solenoid. This causes high pressure in the air inlet pipe (14) to act on the diaphragm within the wastegate actuator (13). The actuating rod (12) acts upon the actuating lever to open the valve in the wastegate. When the valve in the wastegate is opened, more exhaust gas from the engine is able to bypass the turbine wheel, resulting in an decrease in the speed of the turbocharger.

The shaft that connects the turbine to the compressor wheel rotates in bearings (4 and 6). The bearings require oil under pressure for lubrication and cooling. The oil that flows to the lubricating oil inlet port (5) passes through the center of the turbocharger which retains the bearings. The oil exits the turbocharger from the lubricating oil outlet port (10) and returns to the oil pan.

## Valve System Components

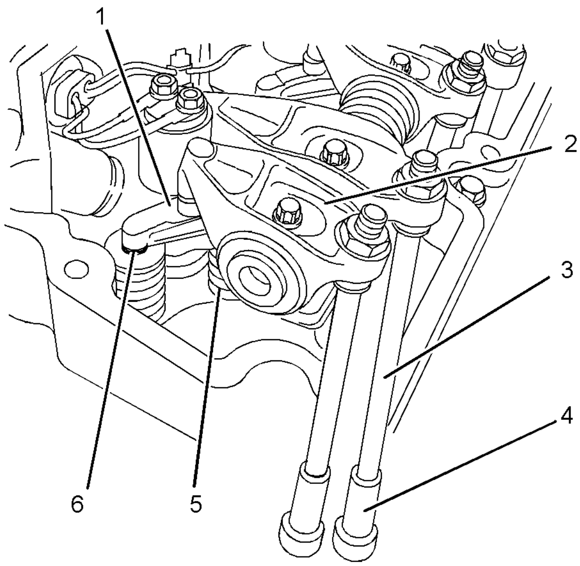


Illustration 15 g01334457

Valve system components

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

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

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

The camshaft has two camshaft lobes for each cylinder. The lobes operate either a pair of inlet valves or a pair of exhaust valves. As the camshaft turns, lobes on the camshaft cause the lifter (4) to move the pushrod (3) up and down. Upward movement of the pushrod against rocker arm (2) results in a downward movement that acts on the valve bridge (1). This action opens a pair of valves (6) which compresses the valve springs (5). When the camshaft has rotated to the peak of the lobe, the valves are fully open. When the camshaft rotates further, the two valve springs (5) under compression start to expand. The valve stems are under tension of the springs. The stems are pushed upward in order to maintain contact with the valve bridge (1). The continued rotation of the camshaft causes the rocker arm (2), the pushrods (3)and the lifters (4) to move downward until the lifter reaches the bottom of the lobe. The valves (6) are now closed. The cycle is repeated for all the valves on each cylinder.

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# Cooling System

## Introduction (Cooling System)

The cooling system has the following components:

- Radiator
- Water pump
- Cylinder block
- Oil cooler
- Cylinder head
- Water temperature regulator (thermostat)

## Coolant Flow

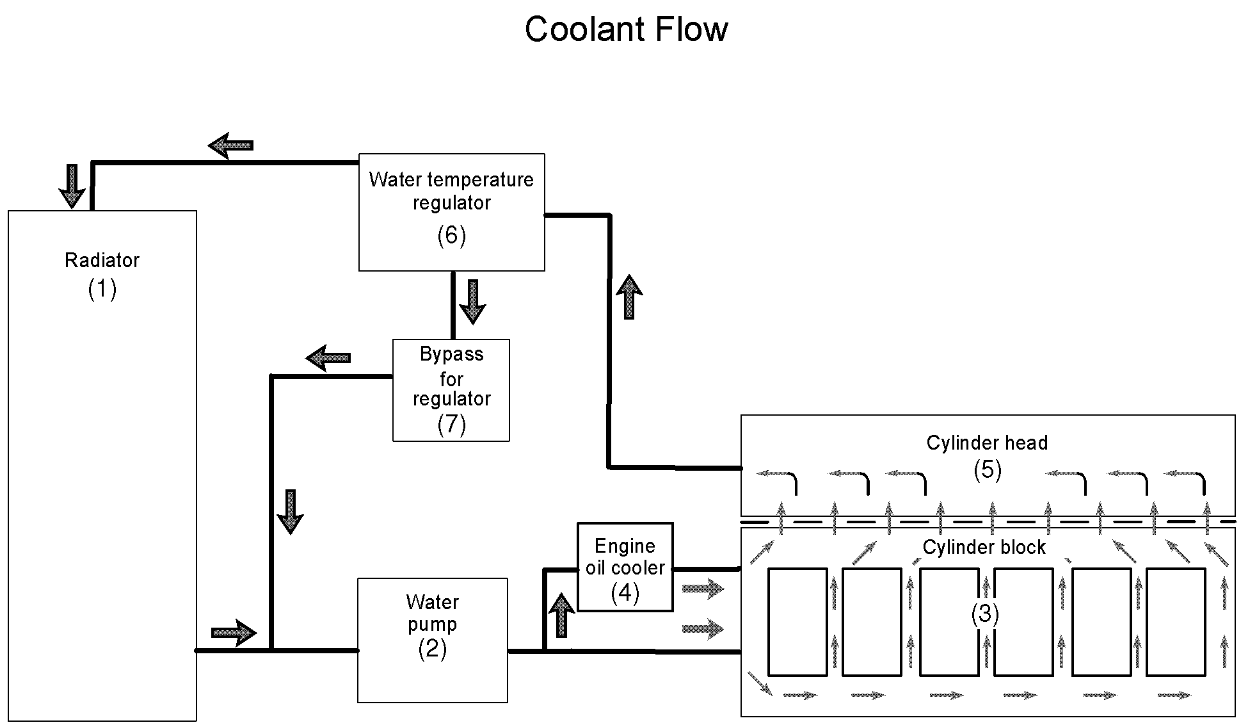


Illustration 16 g01206083

Coolant flow

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

The coolant flows from the bottom of the radiator (1) to the centrifugal water pump (2). The water pump (2) is installed on the front of the timing case. The water pump is driven by a gear. The gear of the fuel injection pump drives the water pump gear. The water pump forces the coolant through a passage in the timing case to the front of the cylinder block (3).

The coolant enters a passage in the left side of the cylinder block (3). Some coolant enters the cylinder block. Some coolant passes over the element of the oil cooler (4). The coolant then enters the block (3). Coolant flows around the outside of the cylinders then flows from the cylinder block into the cylinder head (5).

The coolant flows forward through the cylinder head (5). The coolant then flows into the housing of the water temperature regulator (6). If the water temperature regulator (6) is closed, the coolant goes directly through a bypass (7) to the inlet side of the water pump. If the water temperature regulator is open, and the bypass is closed then the coolant flows to the top of the radiator (1).

i02413834

## Lubrication System

Oil pressure for the engine lubrication system is provided by an engine mounted oil pump. The engine oil pump is located on the bottom of the cylinder block and within the oil pan. Lubricating oil from the oil pan flows through a strainer and a pipe to the inlet side of the engine oil pump. The engine oil pump is driven from the crankshaft through an idler gear.

The engine oil pump has an inner rotor with four lobes. The inner rotor is mounted to a shaft which also carries the drive gear. The engine oil pump also has an outer annulus with five lobes. The axis of rotation of the annulus is offset relative to the rotor. The distance between the lobes of the rotor and the annulus increases on the right hand side when the rotor is rotated. The increasing space between the lobes of the rotor and the annulus causes a reduction in pressure. This reduction in oil pressure causes oil to flow from the oil pan, through the oil strainer and into the oil pump.

The distance between the lobes of the rotor and annulus decreases on the left hand side when the rotor is rotated. The decreasing space between the lobes of the rotor and annulus causes oil to be pressurized. The increase in oil pressure causes oil to flow from the oil pump outlet into the engine lubrication system.

The oil flows from the pump through holes in the cylinder block to a plate type oil cooler. The plate type oil cooler is located on the left hand side of the engine.

From the oil cooler, the oil returns through a drilling in the cylinder block to the filter head.

The oil flows from the oil filter through a passage to the oil gallery. The oil gallery is drilled through the total length of the left side of the cylinder block. If the oil filter is on the right side of the engine, the oil flows through a pipe assembly. The pipe assembly is mounted to the lower face of the cylinder block.

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

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

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

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

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

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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.

## Starting Motor

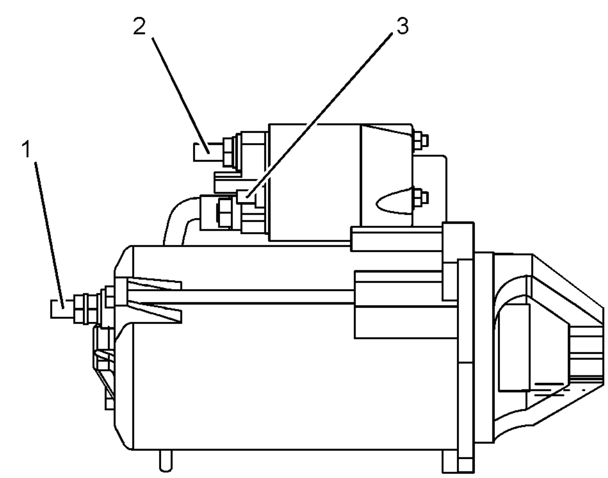


Illustration 17 g01216877

Typical example

12 Volt Starting Motor

(1) Terminal for connection of the ground cable
(2) Terminal 30 for connection of the battery cable
(3) Terminal 50 for connection of the ignition switch

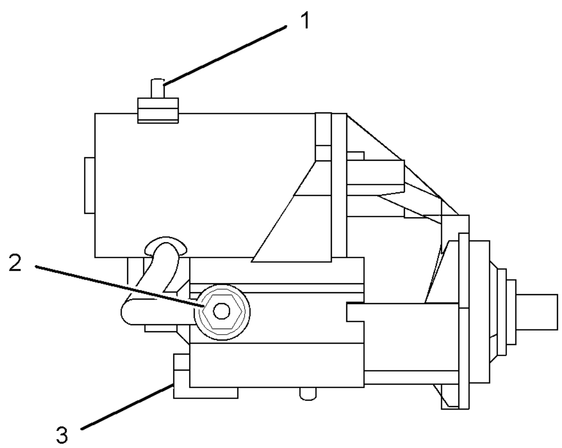


Illustration 18 g01200801

Typical example

24 Volt Starting Motor

(1) Terminal for connection of the ground
(2) Terminal 30 for connection of the battery cable
(3) Terminal 50 for connection of ignition switch

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

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

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

## Alternator

The electrical outputs of the alternator have the following characteristics:

- Three-phase
- Full-wave
- Rectified

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

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

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

The alternating current is changed to direct current by a three-phase, full-wave rectifier. Direct current flows to the output terminal of the alternator. The 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.

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# Cleanliness of Fuel System Components

## Cleanliness of the Engine

NOTICE

It is important to maintain extreme cleanliness when working on the fuel system, since even tiny particles can cause engine or fuel system problems.

The entire engine should be washed with a high pressure water system in order to remove dirt and loose debris before starting a repair on the fuel system. Ensure that no high pressure water is directed at the seals for the injectors.

## Environment

When possible, the service area should be positively pressurized in order to ensure that the components are not exposed to contamination from airborne dirt and debris. When a component is removed from the system, the exposed fuel connections must be closed off immediately with suitable sealing plugs. The sealing plugs should only be removed when the component is reconnected. The sealing plugs must not be reused. Dispose of the sealing plugs immediately after use. Contact your nearest Perkins dealer or your nearest approved Perkins distributor in order to obtain the correct sealing plugs.

## New Components

High pressure lines are not reusable. New high pressure lines are manufactured for installation in one position only. When a high pressure line is replaced, do not bend or distort the new line. Internal damage to the pipe may cause metallic particles to be introduced to the fuel.

All new fuel filters, high pressure lines, tube assemblies and components are supplied with sealing plugs. These sealing plugs should only be removed in order to install the new part. If the new component is not supplied with sealing plugs then the component should not be used. The technician must wear suitable rubber gloves. The rubber gloves should be disposed of immediately after completion of the repair in order to prevent contamination of the system.

## Refueling

In order to refuel the diesel fuel tank, the refueling pump and the fuel tank cap assembly must be clean and free from dirt and debris. Refueling should take place only when the ambient conditions are free from dust, wind and rain. Only use fuel, free from contamination, that conforms to the specifications in the Operation and Maintenance Manual, “Fluid Recommendations” Fuel Specifications.

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# Fuel Injection

## Introduction (Fuel Injection)

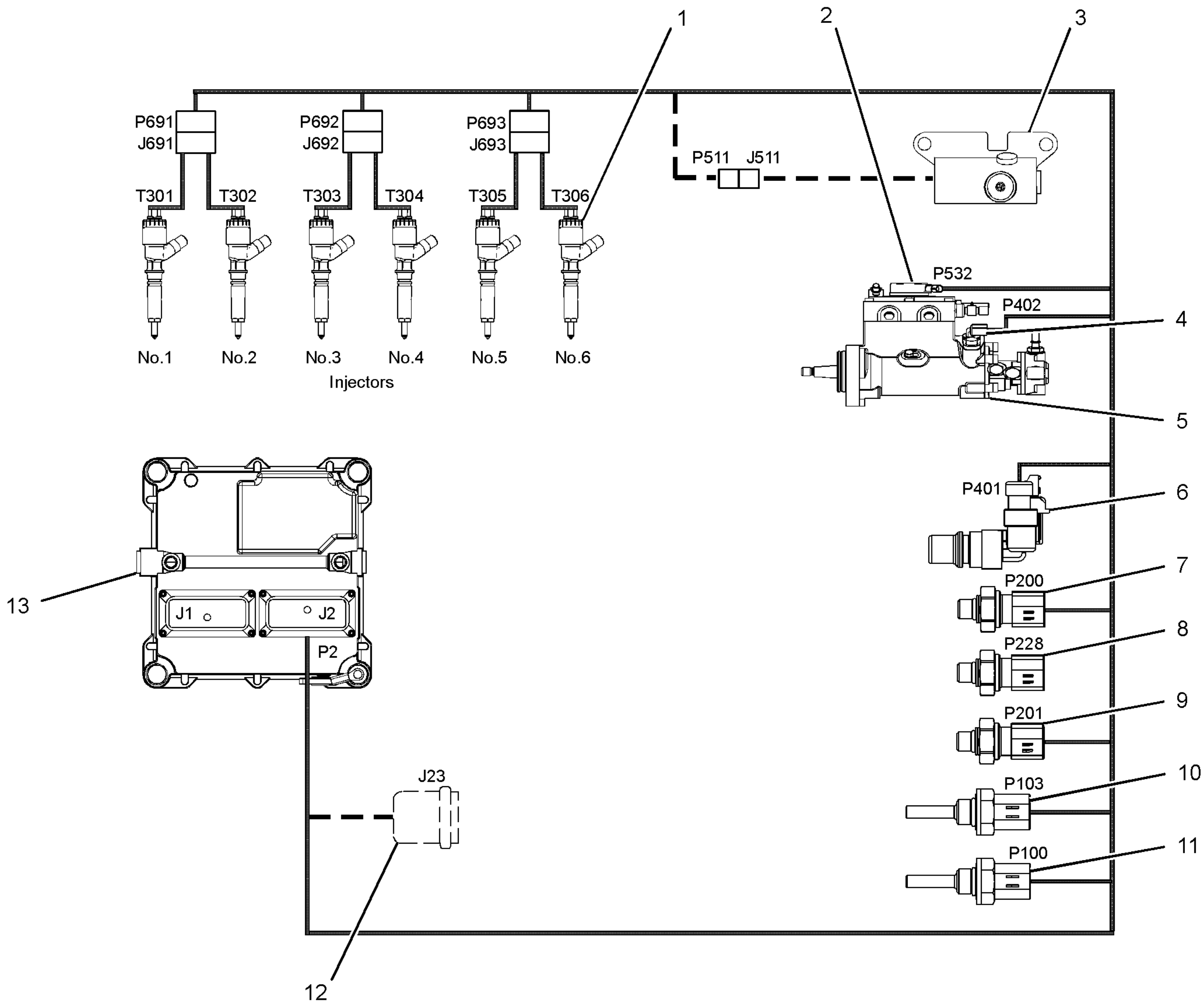


Illustration 19

g01202269

Diagram of the basic fuel system (typical example)

(1) Electronic unit injector
(2) Solenoid for the fuel injection pump
(3) Wastegate solenoid (if equipped)
(4) Position sensor (fuel injection pump)
(5) Fuel injection pump
(6) Crankshaft position sensor
(7) Boost pressure sensor
(8) Fuel pressure sensor
(9) Engine oil pressure sensor
(10) Inlet air temperature sensor
(11) Coolant temperature sensor
(12) Diagnostic connector
(13) Electronic control module (ECM)

## Low Pressure Fuel System

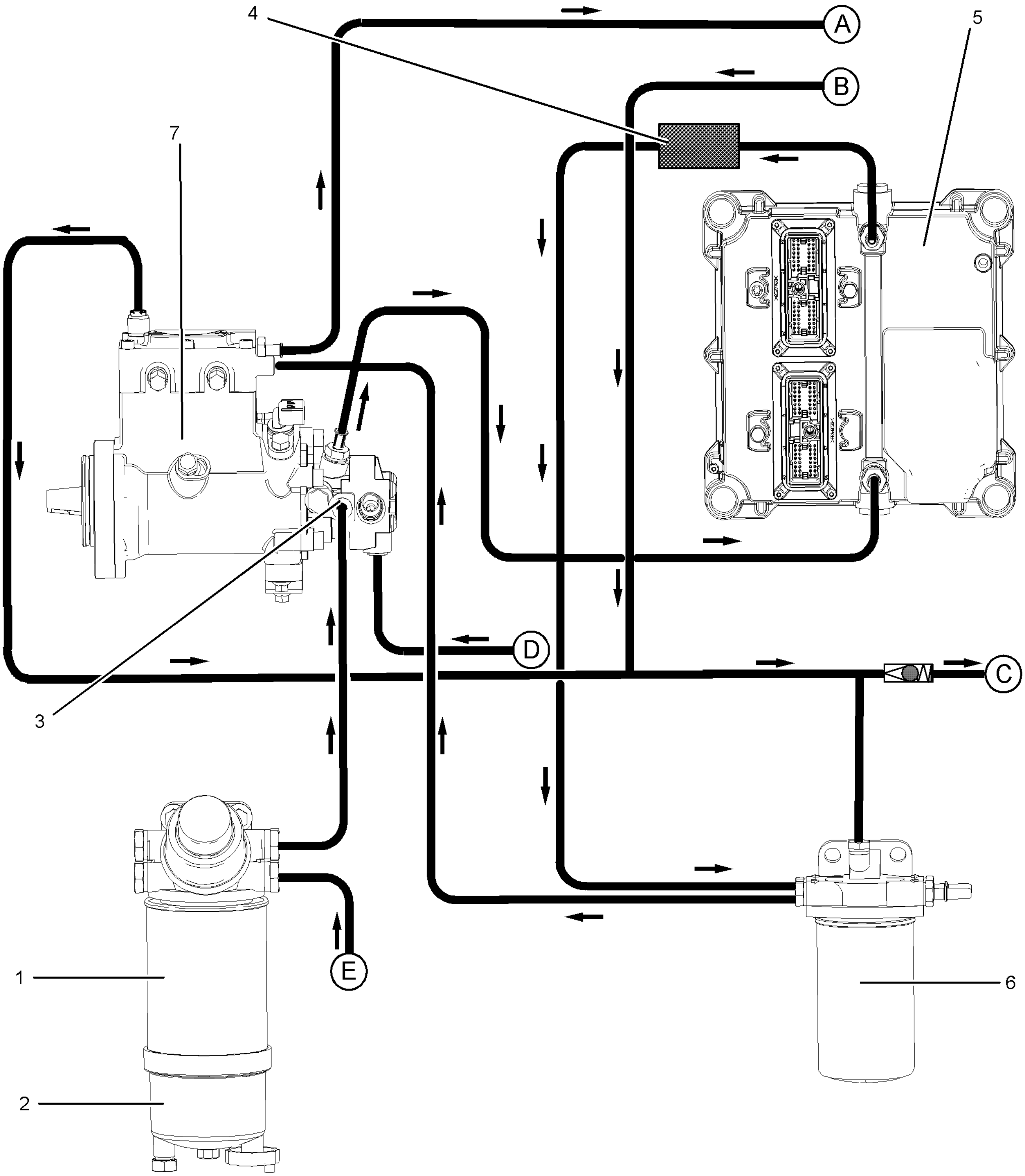


Illustration 20 g01360010

Low pressure fuel system (typical example)

(1) Primary fuel filter
(2) Water separator
(3) Fuel transfer pump
(4) Fuel cooler (if equipped)
(5) ECM
(6) Secondary fuel filter
(7) Fuel injection pump
(A) Outlet for high pressure fuel to the fuel manifold (rail)
(B) Return from the pressure relief valve on the fuel manifold (rail)
(C) Return to fuel tank
(D) Return from the electronic unit injectors
(E) The fuel inlet from the fuel tank

Fuel is drawn from the fuel tank (E) through a 20 micron Primary fuel filter (1) and the Water separator (2) to the Transfer pump (3). The Transfer pump increases the fuel pressure to 400 kPa (58 psi) to 500 kPa (72.52 psi). The fuel is pumped through the optional fuel cooler (4) to the ECM (5). The fuel cools the ECM. The fuel passes from the ECM to a 2 micron fuel filter (6). The fuel filter removes particulates from 20 microns to 2 microns in size in order to prevent contamination of the high pressure components in the fuel system. Fuel passes from the Fuel filter to the Fuel injection pump (7). The fuel is pumped at an increased pressure to the Fuel manifold (rail).

Excess fuel from the Fuel manifold (rail) returns to the tank through a non-return valve. There is a small orifice in the fuel filter base in order to bleed any air back to the tank.

The leak off fuel from the electronic unit injectors returns from a connection in the cylinder head to the pressure side of the transfer pump.

## High Pressure Fuel System

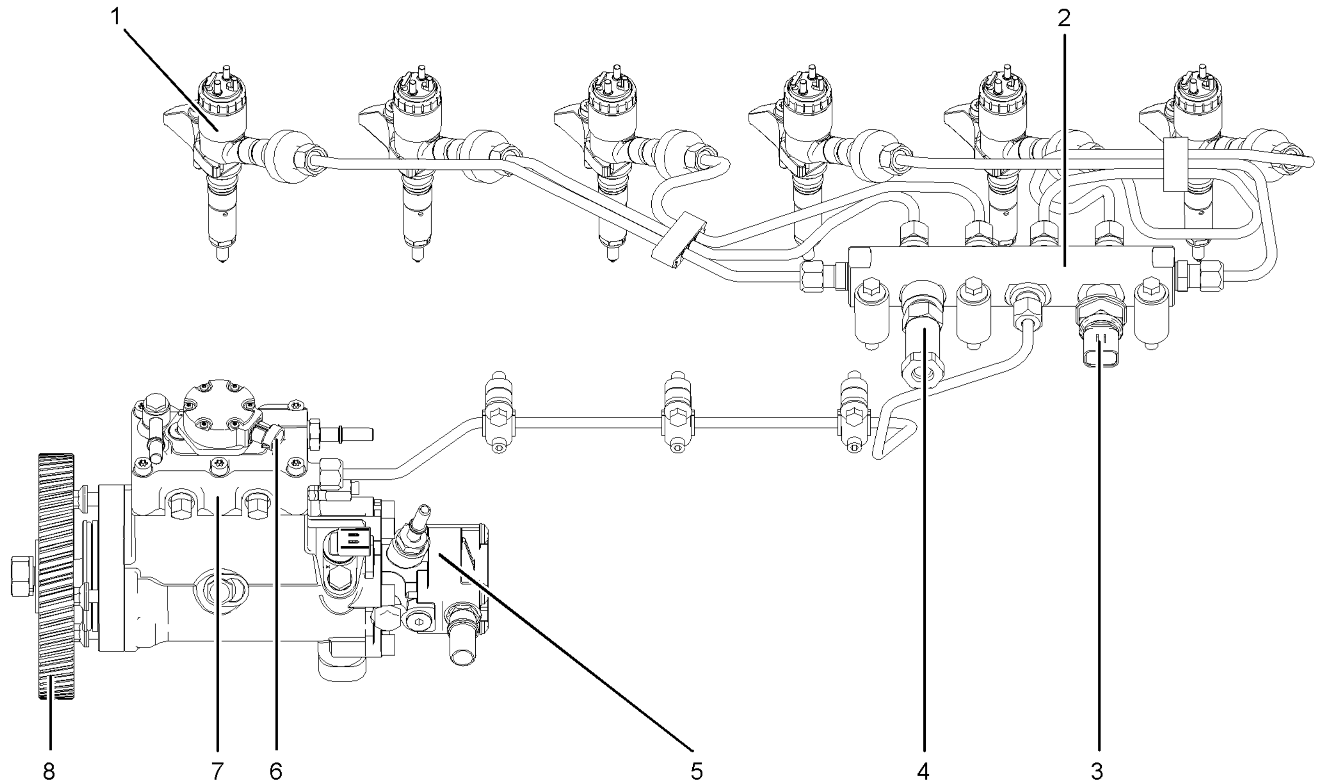


Illustration 21 g01213695

High pressure fuel system (typical example)

(1) Electronic unit injector
(2) Fuel manifold (rail)
(3) Fuel pressure sensor
(4) Fuel pressure relief valve
(5) Fuel transfer pump
(6) Solenoid for the fuel injection pump
(7) Fuel injection pump
(8) Fuel pump gear

The fuel injection pump (7) feeds fuel to the high pressure fuel manifold (2). The fuel is at a pressure of 70 MPa (10152.7 psi) to 130 MPa (18855 psi). A pressure sensor (3) in the high pressure fuel manifold (2) monitors the fuel pressure in the high pressure fuel manifold (2). The ECM controls a solenoid (6) in the fuel injection pump (7) in order to maintain the actual pressure in the high pressure fuel manifold (2) at the desired level. The high pressure fuel is continuously available at each injector. The ECM determines the correct time for activation of the correct electronic unit injector (1) which allows fuel to be injected into the cylinder. The leakoff fuel from each injector passes into a drilling which runs along the inside of the cylinder head. A pipe is connected to the rear of the cylinder head in order to return the leakoff fuel to the pressure side of the fuel transfer pump.

## Components of the Fuel Injection System

**The fuel injection system has the following mechanical components:**

- Primary filter/water separator
- Fuel priming pump
- Fuel transfer pump
- Secondary fuel filter
- Fuel injection pump
- Fuel injectors
- Fuel manifold
- Pressure relief valve
- Fuel pressure sensor

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

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

## Primary Filter/water Separator

The primary filter/water separator is located between the fuel tank and the priming pump.

## Fuel Priming Pump

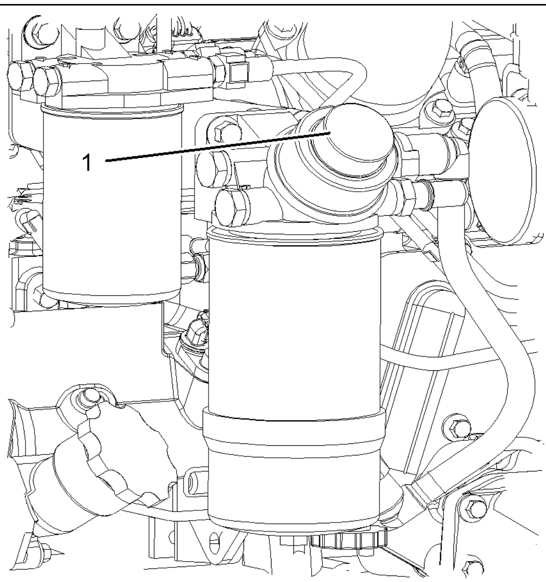


Illustration 22 g01154164

Hand fuel priming pump

The pump has a plunger (1) which is manually operated in order to prime the fuel system. Air is removed from the fuel system to the fuel return line to the tank. The fuel transfer pump is located in the fuel injection pump.

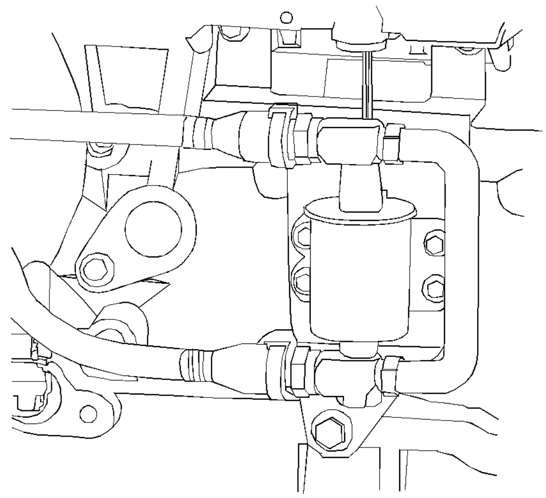

Illustration 23 g01201623

Electric fuel priming pump

The electric fuel priming pump can be installed on some engines.

## Secondary Fuel Filter

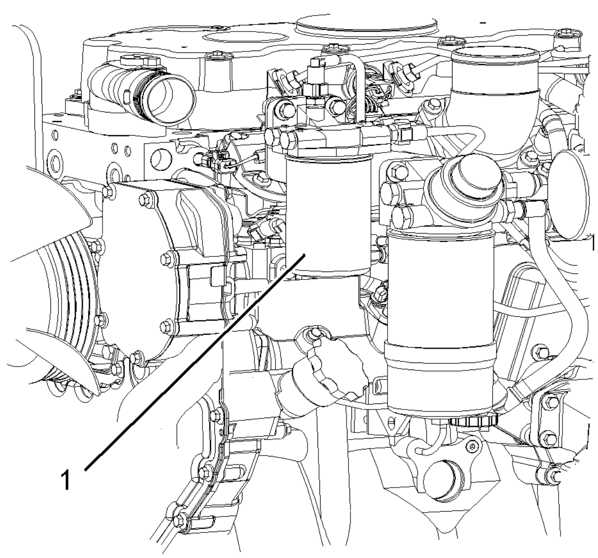


Illustration 24 g01153855

Typical example

The secondary fuel filter (1) is located after the priming pump. The filter is always before the fuel injection pump.

## Fuel Pump Assembly

The fuel pump assembly consists of a low pressure transfer pump and a high pressure fuel injection pump. The pump assembly is driven from a gear in the front timing case at half engine speed. The fuel injection pump has two pistons that are driven by a camshaft. There is a cam for each piston and each cam has three lobes. The fuel injection pump delivers a volume of fuel six times for each revolution. The stroke of the pistons is fixed. The injector will use only part of the fuel that is delivered by each stroke of the pistons in the pump. The solenoid for the fuel injection pump is controlled by the ECM in order to maintain the fuel manifold pressure at the correct level. The solenoid allows excess fuel to be diverted away from the fuel manifold and back to the tank. A feature of the fuel injection pump allows fuel to return to the tank continuously.

## Fuel Injection Pump

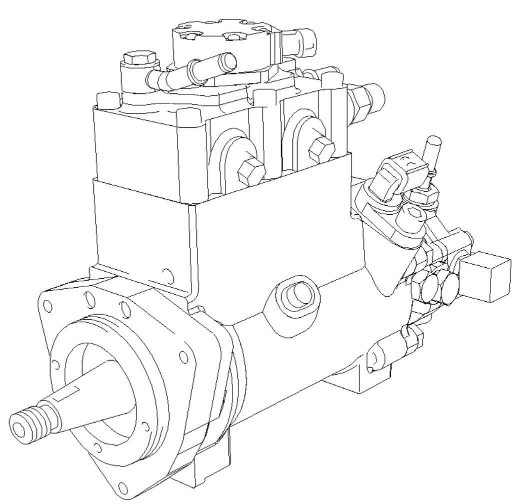

Illustration 25 g01201251

**The fuel injection pump has the following operation:**

- Generation of high pressure fuel

The fuel output of the fuel injection pump is controlled by the ECM in response to changes in fuel pressure.

### Fuel Transfer Pump

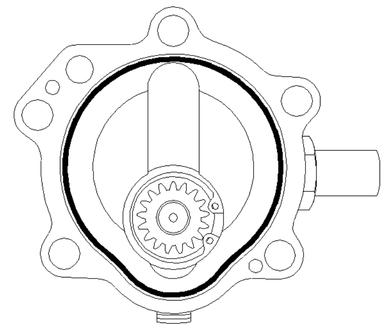

Illustration 26 g01201254

The fuel transfer pump is a serviceable component.

The fuel transfer pump provides a relatively low fuel pressure to the fuel injection pump. The fuel transfer pump has a regulating valve in order to control the low pressure. The fuel transfer pump circulates fuel through the primary fuel filter and the secondary fuel filter. The fuel transfer pump has a fuel bypass valve in order to allow the low pressure fuel system to be primed.

### Shutoff

The engine shuts off by interrupting the fuel supply. The engine electronic control module (ECM) specifies the amount of fuel. The quantity of the fuel that is required by the ECM is set to zero.

## Control

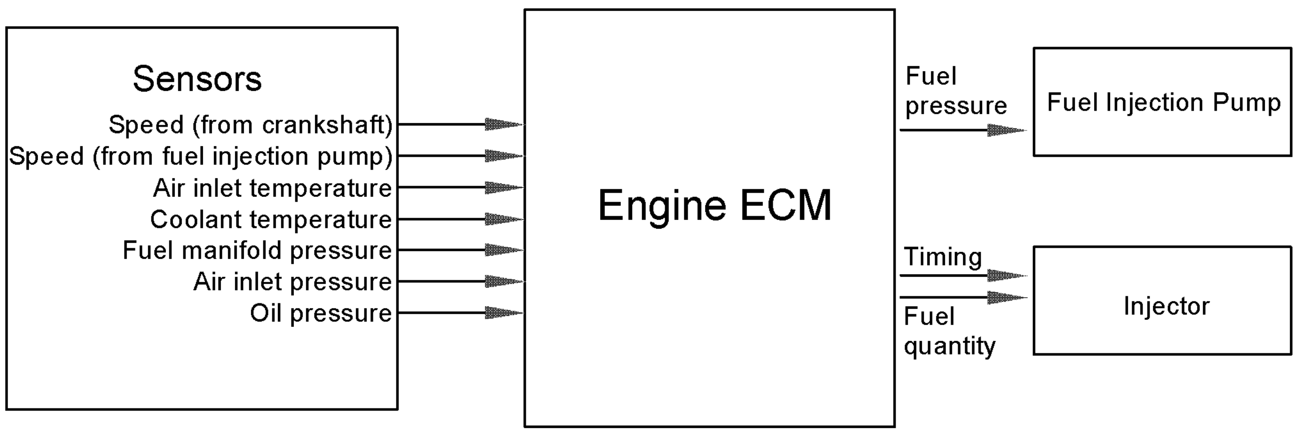


Illustration 27 g01216984

Electronic control for the fuel system (typical example)

The ECM determines the quantity, timing and pressure of the fuel in order to be injected into the fuel injector.

The ECM uses input from the sensors on the engine. These sensors include the speed/timing sensors and the pressure sensors.

The ECM controls the fuel pressure by increasing or decreasing the flow of fuel from the fuel injection pump. The ECM controls the timing and the flow of fuel by actuating the injector solenoid.

The amount of fuel is proportional to the duration of the signal to the injector solenoid.

## Fuel Injectors

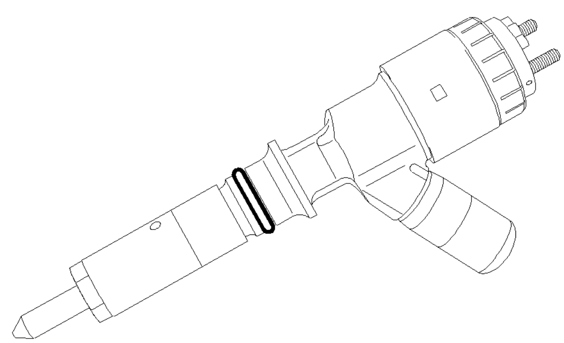

Illustration 28 g01201611

The fuel injectors are not serviceable.

When the ECM sends a signal to the injector solenoid, a valve inside the injector opens. The valve allows the high pressure fuel from the fuel manifold to enter the injector. 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.

The timing and duration of injection is controlled by a solenoid valve in the injector. The valve has two positions. In the closed position, the valve closes the inlet to the injector. In this position, fuel above the injector needle is allowed to vent through the leakoff port.

In the open position, the valve opens the inlet to the injector. Simultaneously, the valve closes the leakoff port in order to allow high pressure fuel to flow to the needle. When the solenoid valve is closed, some fuel escapes past the valve in order to vent through the leakoff port. A certain volume of fuel always flows from the leakoff port. If the volume of fuel increases beyond a critical level, the high pressure fuel pump will not be able to maintain pressure in the fuel manifold. The faulty electronic unit injector must be identified and replaced.

When the signal to the injector ends, the valve closes. The fuel in the injector changes to a low pressure. When the pressure drops the needle valve will close and the injection cycle stops. When the needle valve opens, fuel under high pressure will flow through nozzle orifices into the cylinder. The fuel is injected into the cylinder through the orifices in the nozzle as a very fine spray.

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

## Fuel Manifold

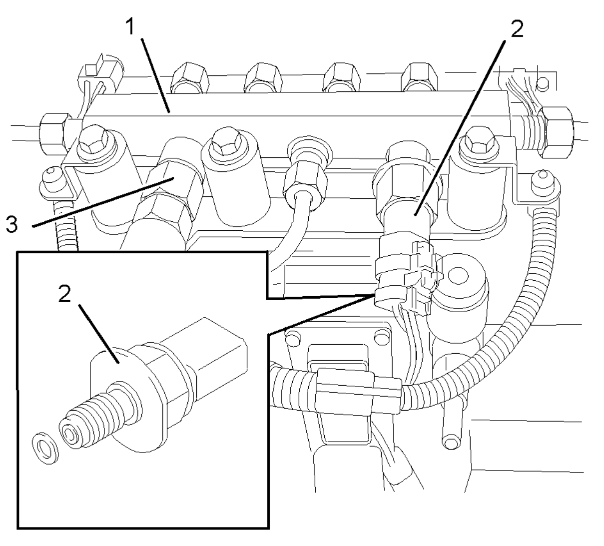


Illustration 29 g01203653

The fuel manifold (1) stores high pressure fuel from the fuel injection pump. The high pressure fuel will flow to the injectors.

The fuel pressure sensor (2) measures the fuel pressure in the fuel manifold (1).

The relief valve (3) will prevent the fuel pressure from getting too high.

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# Electronic Control System

## Introduction (Electronic Control System)

The ECM and the sensors are located on the left side of the engine. Refer to illustration 30.

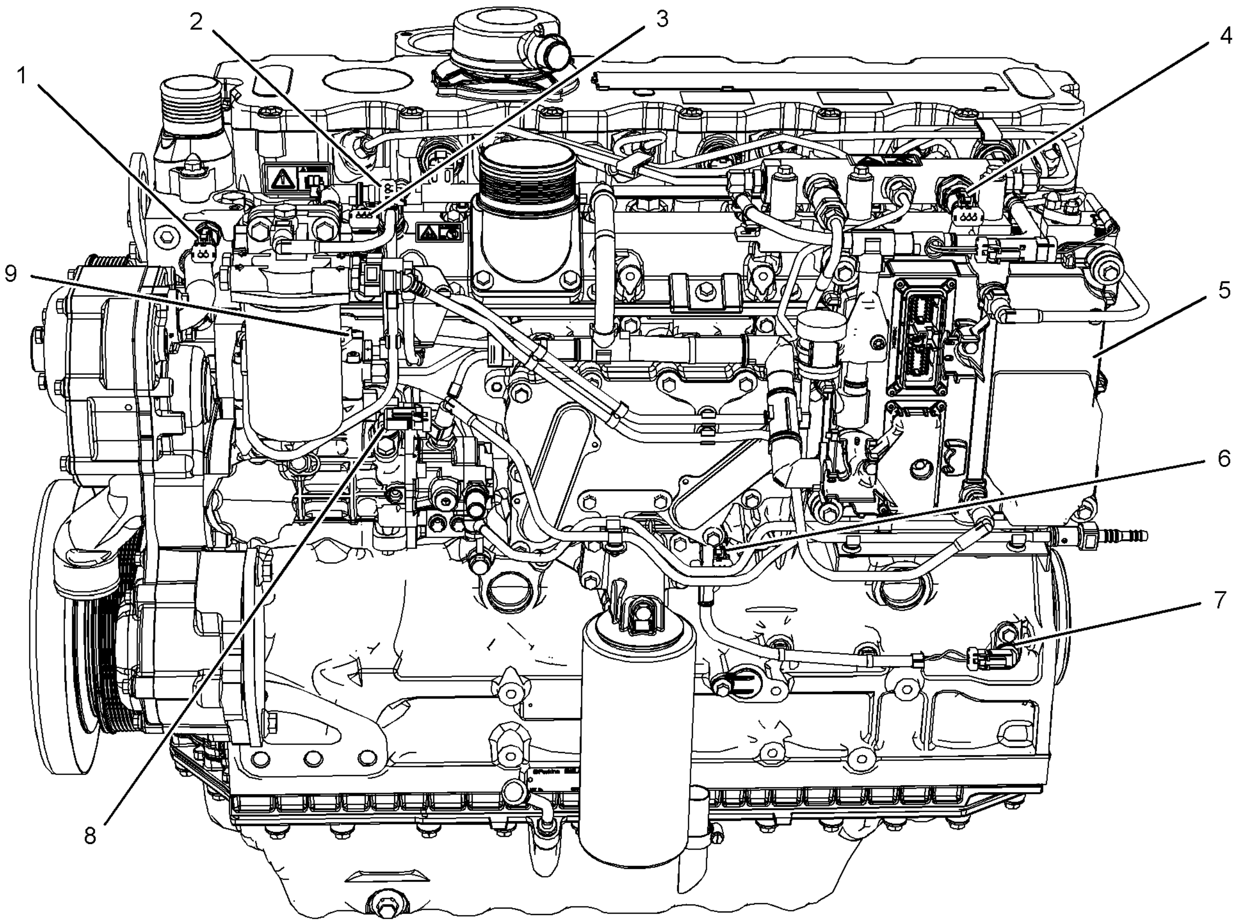


Illustration 30

g01360052

A typical example of an electronic control system

(1) Coolant Temperature Sensor
(2) Inlet Manifold Temperature Sensor
(3) Inlet Manifold Pressure Sensor
(4) Fuel Pressure Sensor
(5) Electronic Control Module (ECM)
(6) Oil Pressure Sensor
(7) Primary Speed/Timing Sensor
(8) Secondary Speed/Timing Sensor
(9) Solenoid for the Fuel Injection Pump

**Note:** If equipped, the wastegate solenoid is installed on the right side of the engine.

Table 1

| Connector | Function |
|---|---|
| P1 | Machine Harness to ECM Connector (64 Pin Connector) |
| P2 | Engine Harness to ECM Connector (64 Pin Connector) |
| P532 | Fuel Rail Pump Solenoid Connector (2 Pin Connector) |
| P402 | Secondary Speed/Timing Sensor (2 Pin Connector) |
| P401 | Primary Speed/Timing Sensor (2 Pin Connector) |
| P201 | Engine Oil Pressure Sensor (3 Pin Connector) |
| P228 | Fuel Rail Pressure Sensor (3 Pin Connector) |
| P200 | Intake Manifold Pressure Sensor (3 Pin Connector) |
| P103 | Intake Manifold Temperature Sensor (2 Pin Connector) |
| P100 | Coolant Temperature Sensor (2 Pin Connector) |
| J23 | Diagnostic Connector |
| P691/J691 | Electronic Unit Injectors for No. 1 and No. 2 Cylinders (4 Pin Connector) |
| P692/J692 | Electronic Unit Injectors for No. 3 and No. 4 Cylinders (4 Pin Connector) |
| P693/J693 | Electronic Unit Injectors for No. 5 and No. 6 Cylinders (4 Pin Connector) |
| P511 | Wastegate Valve (if equipped) (2 Pin Connector) |

The 1106D engine was designed for electronic control. The engine has an Electronic Control Module (ECM), a fuel injection pump and electronic unit injectors. All of these items are electronically controlled. There are also a number of engine sensors. Turbocharged engines can be equipped with an electronically controlled wastegate for the turbocharger. The ECM controls the engine operating parameters through the software within the ECM and the inputs from the various sensors. The software contains parameters that control the engine operation. The parameters include all of the operating maps and customer selected parameters.

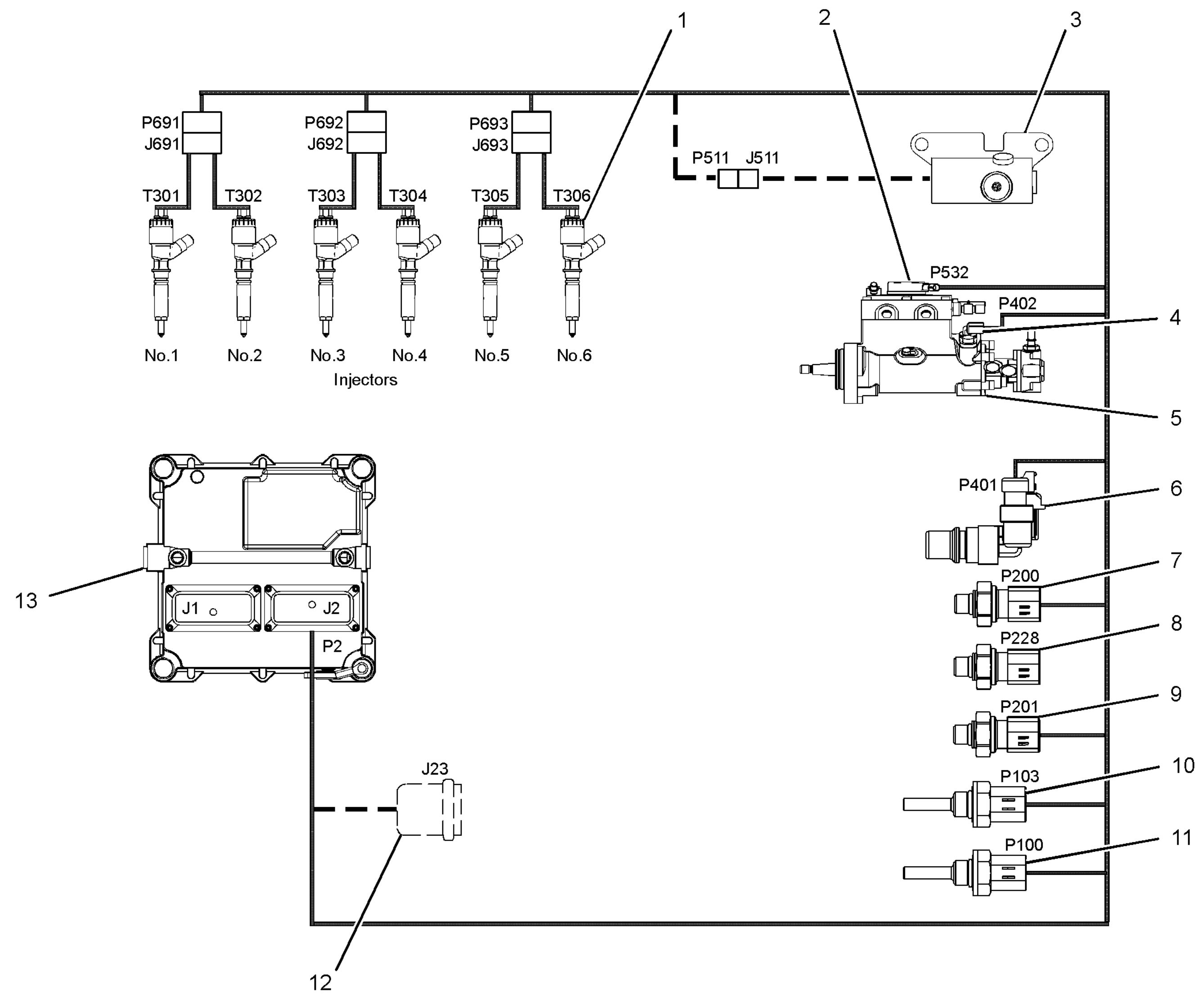


Illustration 31 g01178531

The electronic control system has the following components:

- ECM
- Pressure sensors
- Temperature Sensors
- Crankshaft position sensor
- Secondary position sensor
- The solenoid for the fuel injection pump
- Wastegate solenoid
- Electronic unit injectors

## ECM

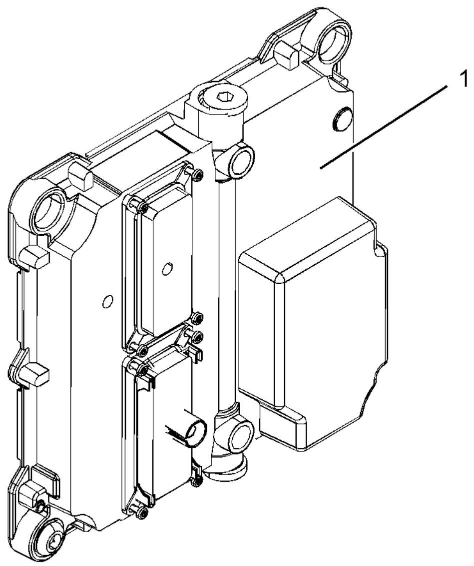


Illustration 32 g01199973

Typical example

The Electronic Control Module (ECM) (1) functions as a governor and a computer for the fuel system. The ECM receives signals from the sensors in order to control the timing and the engine speed.

The electronic system consists of the ECM, the engine sensors and inputs from the parent machine. The ECM is the computer. The flash file is the software for the computer. The flash file defines the following characteristics of the engine:

- Engine power
- Torque curves
- Engine speed (rpm)
- Engine Noise
- Smoke and Emissions

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

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

The flash file contains the software with all the fuel setting information. The information determines the engine performance.

Flash programming is the method of programming or updating the flash file. Refer to the following Troubleshooting, “Flashing Programming ” for the instructions on the flash programming of the flash file.

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

### Engine Speed Governor

The electronic controls determine the injection timing, the amount of fuel that is delivered to the cylinders and the intake manifold pressure if an electronically controlled wastegate is installed on the turbocharger. These decisions are based on the actual conditions and the desired conditions at any given time.

The governor has software that compares the desired engine speed to the actual engine speed. The actual engine speed is determined through the primary speed/timing sensor and the secondary speed/timing sensor. If the desired engine speed is greater than the actual engine speed, the governor injects more fuel in order to increase engine speed.

### Timing Considerations

Fuel injection timing is determined by the ECM after considering input from the following components:

- Engine coolant temperature sensor
- The sensor for the intake manifold air temperature
- The sensor for the intake manifold pressure
- Speed/timing sensors

At start-up, the ECM determines the top center position of the number 1 cylinder from the secondary speed/timing sensor in the fuel injection pump. The ECM decides when fuel injection should occur relative to the top center position. The ECM optimizes engine performance by control of each of the electronic unit injectors so that the required amount of fuel is injected at the precise point of the engine’s cycle. The electronic unit injectors are supplied high pressure fuel from the fuel injection pump. The ECM also provides the signal to the solenoid in the fuel injection pump. The solenoid in the fuel injection pump controls a valve in the fuel injection pump. This valve controls the pressure in the fuel injection pump. Fuel that is not required for the engine is diverted away from the fuel injection pump back to the fuel tank.

The ECM adjusts injection timing and fuel pressure for the best engine performance, the best fuel economy and the best control of exhaust emissions. The actual timing can be viewed with an electronic service tool. Also, the desired timing can be viewed with an electronic service tool.

### Fuel Injection

The flash file inside the ECM sets certain limits on the amount of fuel that can be injected.

The FRC Limit is a limit that is based on intake manifold air pressure and engine rpm. The FRC Limit is used to control the air/fuel ratio in order to control the engine's exhaust emissions. When the ECM senses a higher intake manifold air pressure, the ECM increases the FRC Limit. A higher intake manifold air pressure indicates that there is more air in the cylinder. When the ECM increases the FRC Limit, the ECM allows more fuel into the cylinder.

The Rated Fuel Limit is a limit that is based on the power rating of the engine and on the engine rpm. The Rated Fuel Limit enables the engine power and torque outputs to conform to the power and torque curves of a specific engine model.

These limits are in the flash file and these limits cannot be changed.

## Diagnostic Codes

When the ECM detects an electronic system problem, the ECM generates a diagnostic code. Also, the ECM logs the diagnostic code in order to indicate the time of the problem's occurrence. The ECM also logs the number of occurrences of the problem. Diagnostic codes are provided in order to indicate that the ECM has detected an electrical problem or an electronic problem with the engine control system. In some cases, the engine performance can be affected when the condition that is causing the code exists.

If the operator indicates that a performance problem occurs, the diagnostic code may indicate the cause of the problem. Use a laptop computer to access the diagnostic codes. The problem should then be corrected.

### Event Codes

Event Codes are used to indicate that the ECM has detected an abnormal engine operating condition. The ECM will log the occurrence of the event code. This does not indicate an electrical malfunction or an electronic malfunction. If the temperature of the coolant in the engine is higher than the permitted limit, then the ECM will detect the condition. The ECM will then log an event code for the condition.

## Passwords

System Configuration Parameters are protected by factory passwords. This will prevent unauthorized reprogramming of the system and the unauthorized removal of logged events. Factory passwords are calculated on a computer system that is available only to Perkins distributors. Since factory passwords contain alphabetic characters, only an electronic service tool may change System Configuration Parameters. System Configuration Parameters affect the power rating or the emissions. Passwords also allow the customer to control certain programmable engine parameters.

Refer to Troubleshooting, "Programming Parameters" and Troubleshooting, "Factory Passwords".

## Speed/Timing Sensor

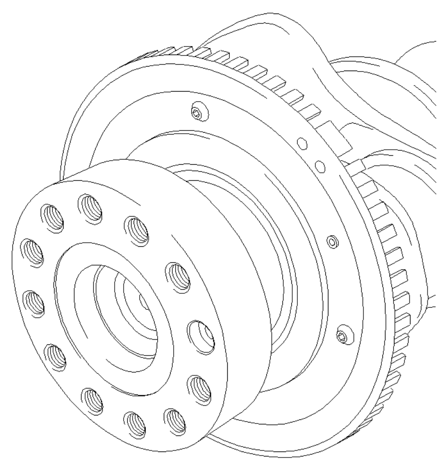

Illustration 33 g01208972

Timing wheel on the crankshaft

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

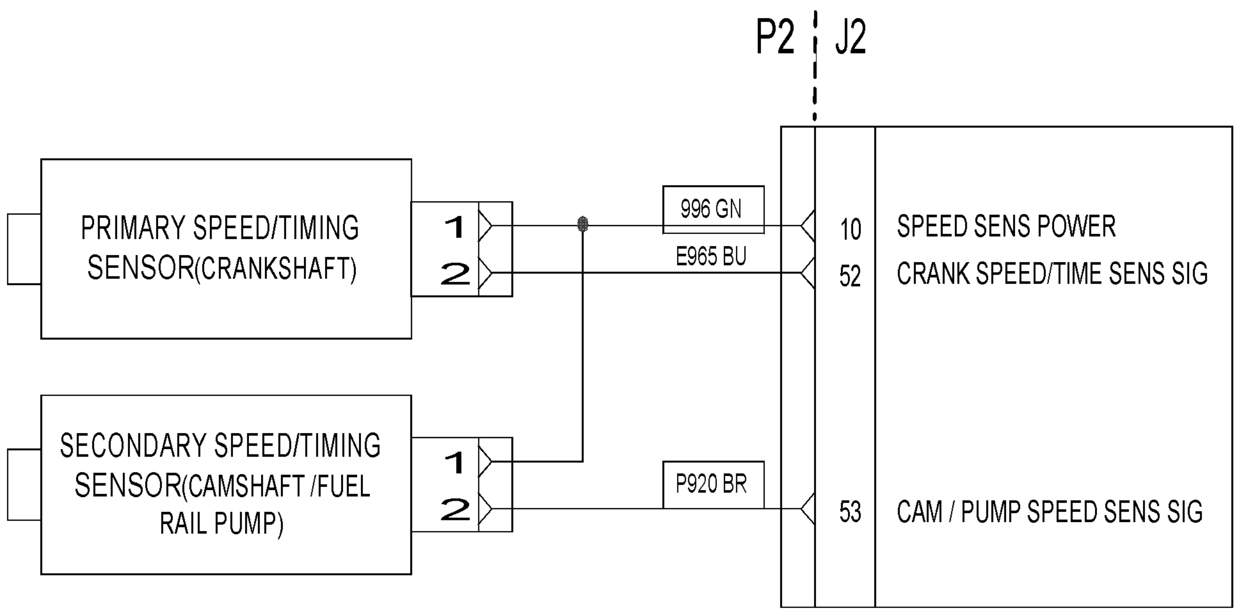


Illustration 34 g01321764

Schematic for speed/timing sensor

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

## Pressure Sensors

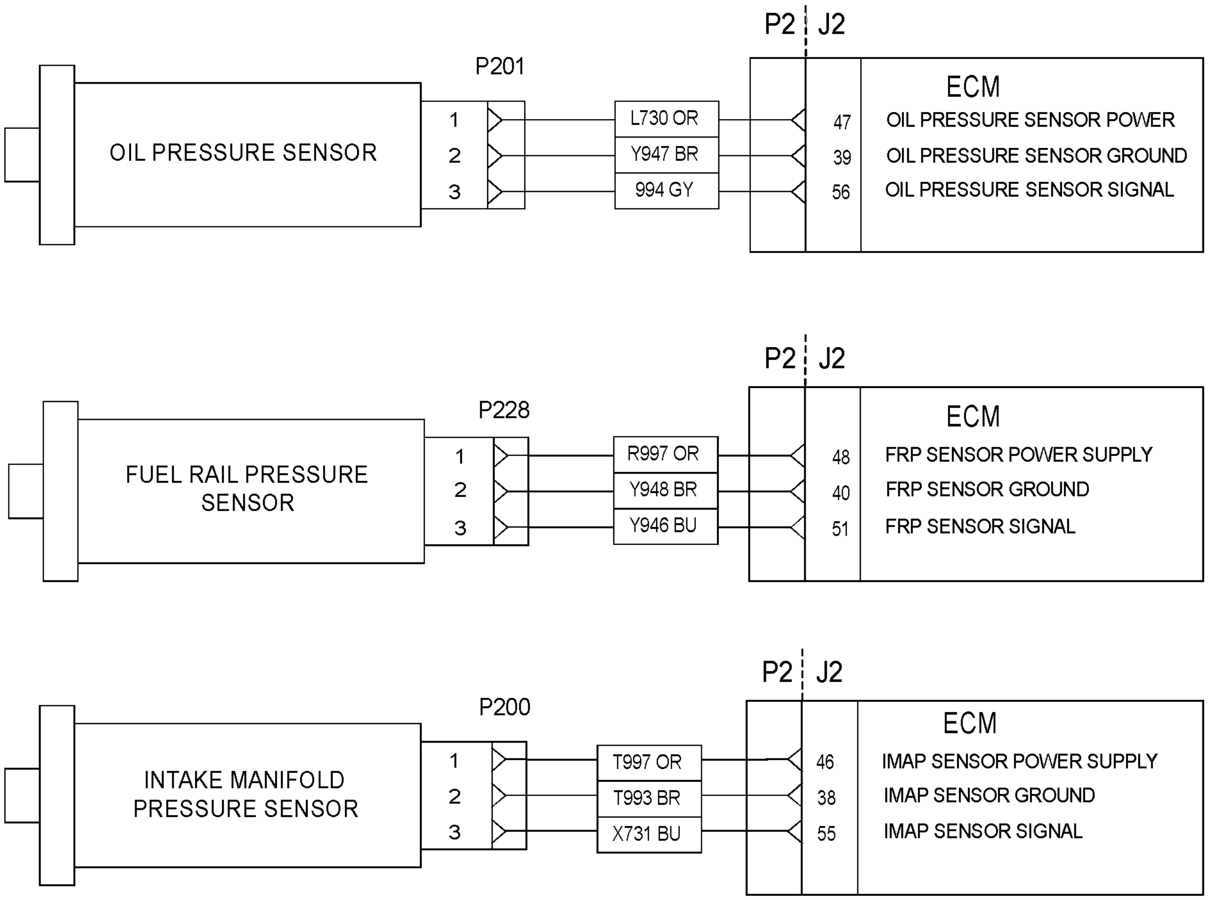


Illustration 35 g01321773

Schematic for pressure sensors

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

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

The operating range of the boost pressure sensors

For standard power engines,
the range is up to the following. .................. 339 kPa (49.169 psi)

For all high power engine,
the range is up to the following. .................. 440 kPa (63.818 psi)

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

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

## Temperature Sensors

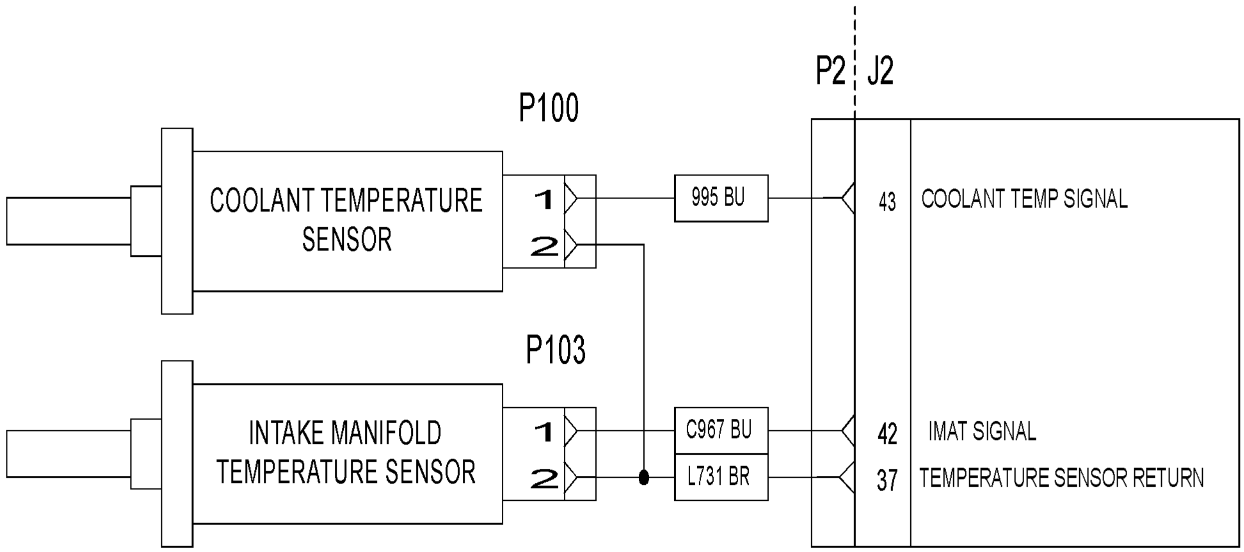


Illustration 36 g01321776

Schematic for the temperature sensors

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

- Fuel delivery
- Injection timing

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

The sensors are also used for engine monitoring.

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# Power Sources

## Introduction (Power Supplies)

The 1106D Engine supplies power to the ECM. The ECM powers the following components:

- All sensors on the engine
- The solenoid for the fuel Injection Pump
- The solenoid for the Wastegate (optional)
- Diagnostic connector
- Electronic unit injectors

The glow plugs are powered directly from the battery.

# ECM Power Supply

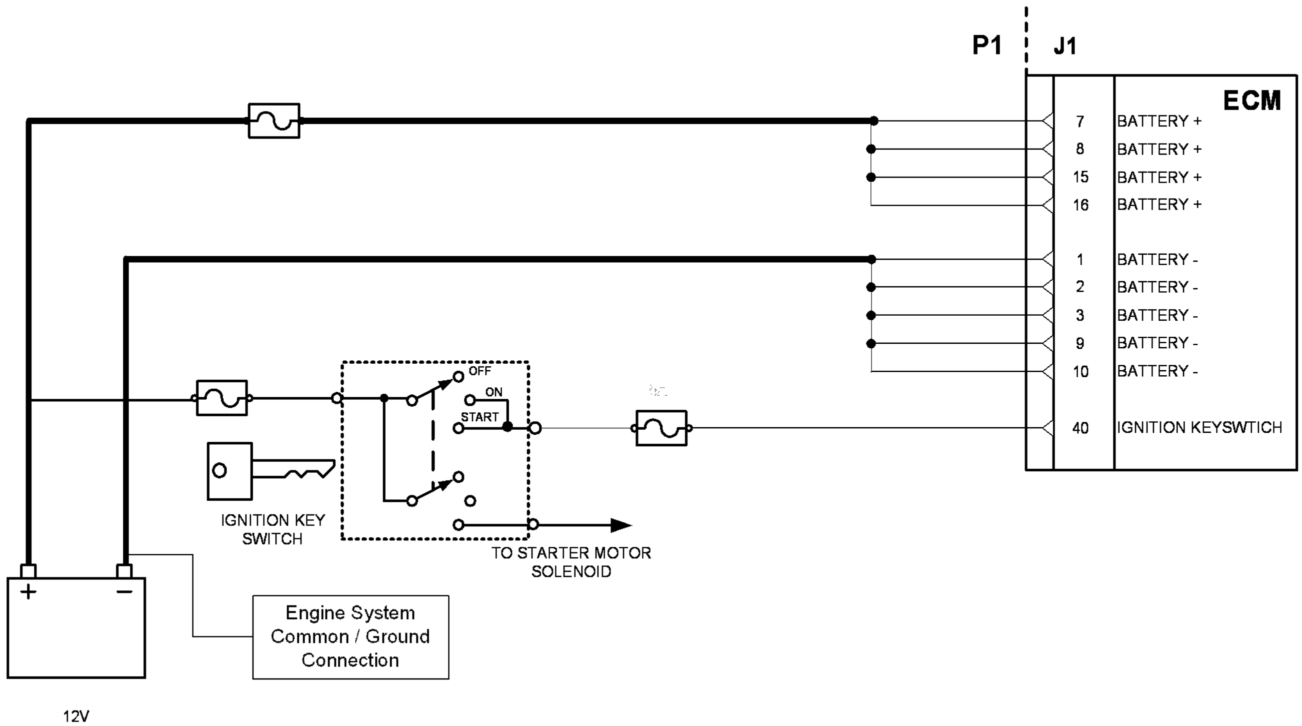


Illustration 37 g01321781

Schematic for ECM

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

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

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.

## Power Supply for the Pressure Sensors

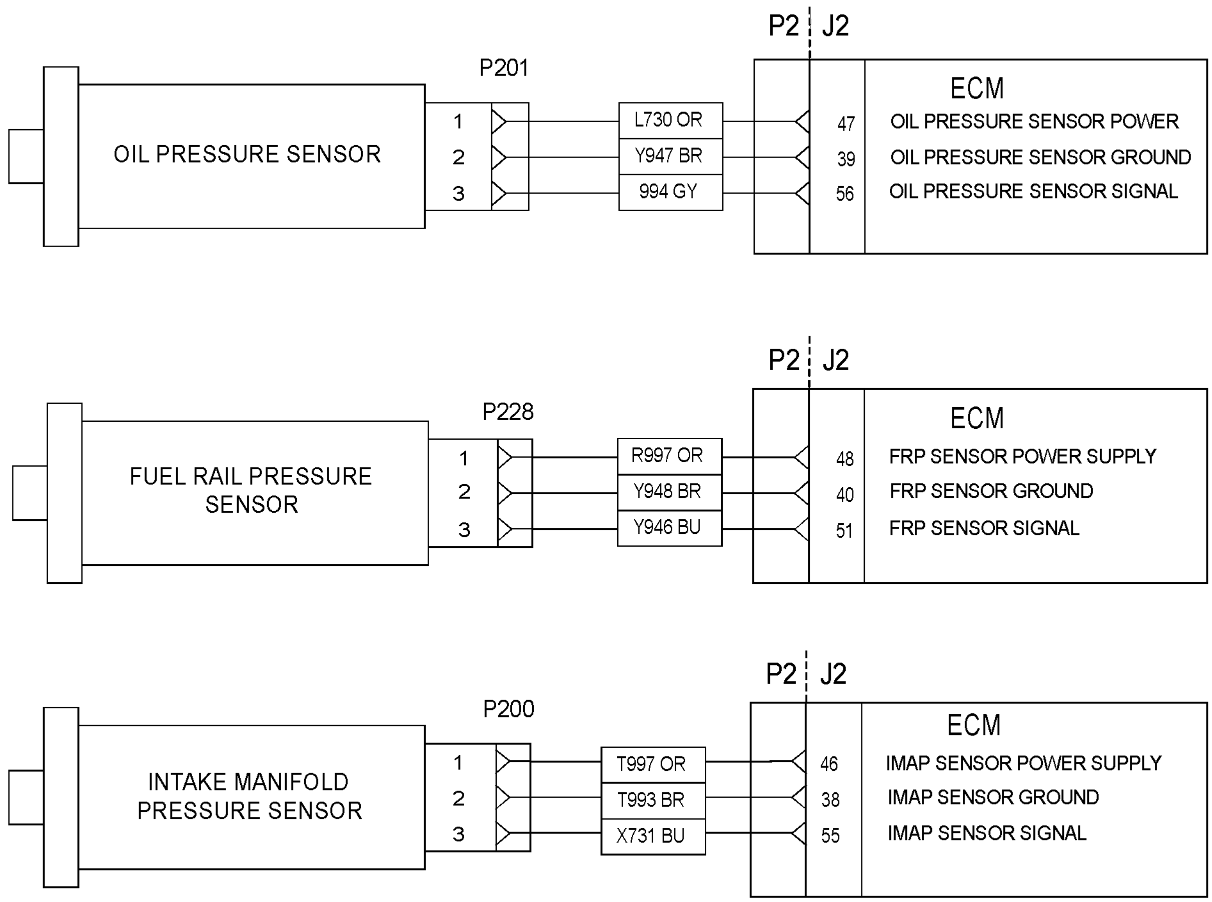


Illustration 38 g01321773

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 Glow plugs

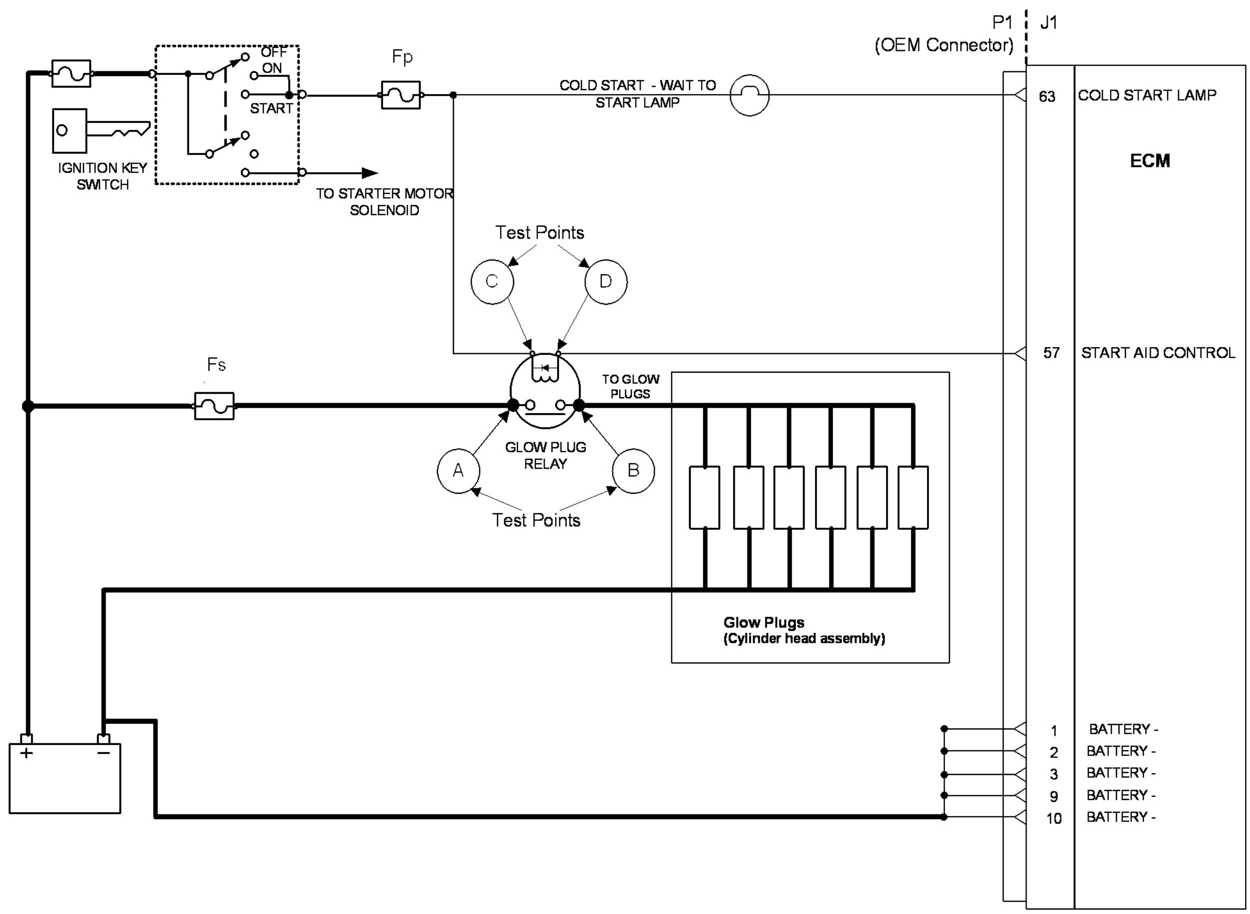


Illustration 39 g01201233

Schematic for the glow plugs

i02636374

# Glossary of Electronic Control Terms

**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.

**Adaptive Trim** – This is a software process that is performed in the ECM that optimizes engine performance by automatically compensating for degradation of injector components.

**Alternating Current (AC)** – Alternating current is an electric current that reverses direction at a regular interval that is reoccurring.

**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.

**Inlet Manifold Pressure (Engines that are turbocharged) –** The difference between the turbocharger outlet pressure and atmospheric pressure is commonly referred to as inlet manifold pressure. The sensor for the inlet manifold air pressure measures the amount of boost.

**Breakout Harness –** The breakout harness is a test harness that is designed to connect into the engine harness. This connection allows a normal circuit operation and the connection simultaneously provides a Breakout T in order to measure the signals.

**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.

**CAN Data Link –** The CAN Data Link is a serial communications port that is used for communication with other microprocessor based devices.

**Code –** Refer to “Diagnostic Code” or “Event Code”.

**Cold Mode –** Cold mode is a mode for cold starting and for cold engine operation. This mode is used for engine protection, reduced smoke emissions and faster warm up time.

**Communication Adapter Tool –** The communication adapter provides a communication link between the ECM and the Electronic Service Tool.

**Component Identifier (CID) –** The CID is a number that identifies the specific component of the electronic control system that has experienced a diagnostic code.

**Coolant Temperature Sensor –** The coolant temperature sensor detects the engine coolant temperature for all normal operating conditions and for engine monitoring.

**Customer Specified Parameters –** A customer specified parameter is a parameter that can be changed in the ECM with the Electronic Service Tool. A customer specified parameter’s value is set by the customer. These parameters are protected by customer passwords.

**Data Link –** The Data Link is a serial communication port that is used for communication with other microprocessor based devices.

**Derate –** Certain engine conditions will generate event codes. Also, engine derates may be applied. The map for the engine derate is programmed into the ECM software. The derate can be one or more of 3 types: reduction of rated power, reduction of rated engine speed, and reduction of rated machine speed for OEM products.

**Desired Engine Speed –** The desired engine speed is input to the electronic governor within the ECM. The electronic governor uses the signal from the throttle position sensor, the engine speed/timing sensor, and other sensors in order to determine the desired engine speed.

**Diagnostic Code –** A diagnostic code is sometimes referred to as a fault code. These codes indicate an electronic system malfunction.

**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. The diagnostic lamps are red and orange. The lamp may not be included in all applications.

**Digital Sensor Return –** The common line (ground) from the ECM is used as ground for the digital sensors.

**Digital Sensors –** Digital sensors produce a pulse width modulated signal. Digital sensors are supplied with power from the ECM.

**Digital Sensor Supply –** The power supply for the digital sensors is provided by the ECM.

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

**DT, DT Connector, or Deutsch DT –** This is a type of connector that is used on Perkins engines. The connectors are manufactured by Deutsch.

**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 control computer of the engine. The ECM provides power to the electronics. The ECM monitors data that is input from the sensors of the engine. The ECM acts as a governor in order to control the speed and the power of the engine.

**Engine Monitoring –** Engine Monitoring is the part of the electronic engine control that monitors the sensors. This also warns the operator of detected problems.

**Engine Oil Pressure Sensor –** The engine oil pressure sensor measures engine oil pressure. The sensor sends an electronic signal to the ECM that is dependent on the engine oil pressure.

**Engine Speed/Timing Sensor** – An engine speed/timing sensor is a Hall effect sensor. The ECM interprets this signal as the crankshaft position and the engine speed. Two sensors are used to provide the speed and timing signals to the ECM. The primary sensor is associated with the crankshaft and the secondary sensor is associated with the fuel injection pump camshaft.

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

**Ether Relay** – The ether relay is used to actuate the ether injection system. The ECM controls the relay.

**Failure Mode Identifier (FMI)** – This identifier indicates the type of failure that is associated with the component. The FMI has been adopted from the SAE practice of J1587 diagnostics. The FMI follows the parameter identifier (PID) in the descriptions of the fault code. The descriptions of the FMIs are in the following list.

**0** – The data is valid but the data is above the normal operational range.

**1** – The data is valid but the data is below the normal operational range.

**2** – The data is erratic, intermittent, or incorrect.

**3** – The voltage is above normal or the voltage is shorted high.

**4** – The voltage is below normal or the voltage is shorted low.

**5** – The current is below normal or the circuit is open.

**6** – The current is above normal or the circuit is grounded.

**7** – The mechanical system is not responding properly.

**8** – There is an abnormal frequency, an abnormal pulse width, or an abnormal time period.

**9** – There has been an abnormal update.

**10** – There is an abnormal rate of change.

**11** – The failure mode is not identifiable.

**12** – The device or the component is damaged.

**Flash Programming** – Flash programming is the method of programming or updating an ECM with an electronic service tool over the data link.

**Fuel Injector E-Trim** – Fuel injector E-trim is a software process that allows precise control of fuel injectors by parameters that are programmed into the ECM for each fuel injector. With the use of the electronic service tool, the service technician can read status information for the E-Trim. Data for E-Trim can also be programmed.

**Flash Memory** – See Programmable Software.

**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 Pump** – See “Fuel Injection Pump”.

**Fuel Rail** – This item is sometimes referred to as the High Pressure Fuel Rail or high pressure fuel manifold. The fuel rail supplies fuel to the electronic unit injectors. The fuel injection pump and the fuel rail pressure sensor work with the ECM in order to maintain the desired fuel pressure in the fuel rail. This pressure is determined by calibration of the engine in order to enable the engine to meet emissions and performance requirements.

**Fuel Rail Pressure Sensor** – The fuel rail pressure sensor sends an electronic signal to the ECM that is dependent on the pressure of the fuel in the fuel rail.

**Fuel Injection Pump** – This item is sometimes referred to as the High Pressure Fuel Rail Pump. This is a device that supplies fuel under pressure to the fuel rail (high pressure fuel rail).

**The Solenoid Valve for the Fuel Injection Pump** – This is sometimes referred to as the High Pressure Fuel Rail Pump Solenoid Valve. This is a control device in the fuel injection pump. The ECM controls the pressure in the fuel rail by using this valve to divert excess fuel from the pump to the fuel tank.

**Full Load Setting (FLS)** – The FLS is the number that represents the fuel system adjustment. This adjustment is made at the factory in order to fine tune the fuel system. The correct value for this parameter is stamped on the engine information ratings plate. This parameter must be programmed.

**Glow Plug** – The glow plug is an optional starting aid for cold conditions. One glow plug is installed in each combustion chamber in order to improve the ability of the engine to start. The ECM uses information from the engine sensors such as the engine temperature to determine when the glow plug relay must provide power to each glow plug. Each of the glow plugs then provides a very hot surface in the combustion chamber in order to vaporize the mixture of air and fuel. This improves ignition during the compression stroke of the cylinder.

**Glow Plug Relay** – The glow plug relay is controlled by the ECM in order to provide high current to the glow plugs that are used in the starting aid system.

**Harness** – The harness is the bundle of wiring (loom) that connects all components of the electronic system.

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

**High Pressure Fuel Rail Pump** – See “Fuel Rail Pump”.

**High Pressure Fuel Rail Pump Solenoid Valve** – See “Fuel Rail Pump Solenoid Valve”.

**High Pressure Fuel Rail** – See “Fuel Rail”.

**Injector Trim Files** – Injector trim files are downloaded from a disk to the ECM. The injector trim files compensate for variances in manufacturing of the electronic unit injector. The serial number for the electronic unit injector must be obtained in order to retrieve the correct injector trim file.

**Inlet Manifold Air Temperature Sensor** – The inlet manifold air temperature sensor detects the air temperature in the inlet manifold. The ECM monitors the air temperature and other data in the inlet manifold in order to adjust injection timing and other performance functions.

**Integrated Electronic Controls** – The engine is designed with the electronic controls as a necessary part of the system. The engine will not operate without the electronic controls.

**Intake Manifold Pressure Sensor** – The Intake Manifold Pressure Sensor measures the pressure in the intake manifold. The pressure in the intake manifold may be different to the pressure outside the engine (atmospheric pressure). The difference in pressure may be caused by an increase in air pressure by a turbocharger (if equipped).

**J1939 CAN Data Link** – Logged diagnostic codes are codes which are stored in the memory. These codes are meant to be an indicator of possible causes for intermittent problems. Refer to the term “Diagnostic Code” in this glossary for more information.

**Open Circuit** – An open circuit is a condition that is caused by an open switch, or by an electrical wire or a connection that is broken. When this condition exists, the signal or the supply voltage can no longer reach the intended destination.

**OEM** – OEM is an abbreviation for the Original Equipment Manufacturer. This is the manufacturer of the machine or the vehicle that uses the engine.

**Parameter** – A parameter is a value or a limit that is programmable. This helps determine specific characteristics or behaviors of the engine.

**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 a group of alphanumeric characters that is designed to restrict access to parameters. The electronic system requires correct passwords in order to change some parameters (Factory Passwords). Refer to Troubleshooting, “Factory Passwords” for more information.

**Programmable Software** – The software is programmed into the ECM. The software contains all the instructions (software) for the ECM and the software contains the performance maps for a specific engine. The software may be reprogrammed through flash programming.

**Power Cycled** – Power cycled happens when power to the ECM is cycled: ON, OFF, and ON. Power cycled refers to the action of cycling the keyswitch from any position to the OFF position, and to the START/RUN position.

**Primary Speed/Timing Sensor** – This sensor determines the position of the crankshaft during engine operation. If the primary speed/timing sensor fails during engine operation, the secondary speed/timing sensor is used to provide the signal.

**Pulse Width Modulation (PWM)** – The PWM is a signal that consists of pulses that are of variable width. These pulses occur at fixed intervals. The ratio of “TIME ON” versus total “TIME OFF” can be varied. This ratio is also referred to as a duty cycle.

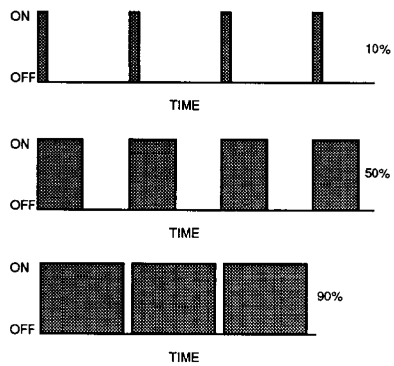


Illustration 40 g00284479

**Rated Fuel Limit** – This is a limit that is based on the power rating of the engine and on the engine rpm. The Rated Fuel Limit enables the engine power and torque outputs to conform to the power and torque curves of a specific engine model. These limits are in the flash file and these limits cannot be changed.

**Reference Voltage** – Reference voltage is a regulated voltage and a steady voltage that is supplied by the ECM to a sensor. The reference voltage is used by the sensor to generate a signal voltage.

**Relay** – A relay is an electromechanical switch. A flow of electricity in one circuit is used to control the flow of electricity in another circuit. A small current or voltage is applied to a relay in order to switch a much larger current or 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.

**Short Circuit** – A short circuit is a condition that has an electrical circuit that is inadvertently connected to an undesirable point. An example of a short circuit is a wire which rubs against a vehicle frame and this rubbing eventually wears off the wire insulation. Electrical contact with the frame is made and a short circuit results.

**Signal** – The signal is a voltage or a waveform that is used in order to transmit information typically from a sensor to the ECM.

**Secondary Speed/Timing Sensor** – This sensor determines the position of the camshaft during engine operation. If the primary speed/timing sensor fails during engine operation, the secondary speed/timing sensor is used to provide the signal.

**Supply Voltage** – The supply voltage is a continuous voltage that is supplied to a component in order to provide the electrical power that is required for the component to operate. The power may be generated by the ECM or the power may be battery voltage that is supplied by the engine wiring.

**System Configuration Parameters** – System configuration parameters are parameters that affect emissions and/or operating characteristics of the engine.

**Tattletale** – Certain parameters that affect the operation of the engine are stored in the ECM. These parameters can be changed by use of the electronic service tool. The tattletale logs the number of changes that have been made to the parameter. The tattletale is stored in the ECM.

**"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 the interpretation by the ECM of the signal from the throttle position sensor or the throttle switch.

**Throttle Position Sensor** – The throttle position sensor is an electronic sensor that is usually connected to an accelerator pedal or a hand lever. This sensor sends a signal to the ECM that is used to calculate desired engine speed.

**Throttle Switch** – The throttle switch sends a signal to the ECM that is used to calculate desired engine speed.

**Timing Calibration** – The timing calibration is the adjustment of an electrical signal. This adjustment is made in order to correct the timing error between the camshaft and the engine speed/timing sensors or between the crankshaft and the engine speed/timing sensors.

**Top Center Position** – The top center position refers to the crankshaft position when the engine piston position is at the highest point of travel. The engine must be turned in the normal direction of rotation in order to reach this point.

**Total Tattletale** – The total tattletale is the total number of changes to all the parameters that are stored in the ECM.

**Wait To Start Lamp** – This is a lamp that is included in the cold starting aid circuit in order to indicate when the wait to start period has expired. The glow plugs have not deactivated at this point in time.

**Wastegate** – This is a device in a turbocharged engine that controls the maximum boost pressure that is provided to the inlet manifold.

**Wastegate Valve** – The wastegate valve regulates the pressure in the inlet manifold to a value that is determined by the ECM. The wastegate valve provides the interface between the ECM and the mechanical system that regulates inlet manifold pressure to the desired value that is determined by the software.

# Testing and Adjusting Section

# Fuel System

i02563346

## Fuel System - Inspect

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorised personnel that have the correct training.**

**Before begining ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

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

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

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

3. Install new fuel filters.

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

5. Operate the hand priming pump (if equipped). If excessive resistance is felt, check that there is fuel in the fuel return line to the tank.

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## Air in Fuel - Test

Table 2

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 27610326 | Test Kit | 1 |
| B | 27610325 | Tee Adapter | 1 |

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorised personnel that have the correct training.**

**Before begining ANY work on the fuel system, refer to Operation and Maintenance Manual, "General Hazard Information and High Pressure Fuel Lines" for safety information.**

**Refer to Systems Operation, Testing and Adjusting Manual, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

**Note:** Ensure that the tools are stored with the caps in place. Store the tools in a clean plastic bag.

1. Ensure that the fuel level in the fuel tank is above the level of the suction pipe in the fuel tank.

2. Inspect the fuel system thoroughly for leaks. If necessary, repair the fuel system.

3. Check all low pressure fuel lines from the fuel tank for restrictions. Replace any damaged components.

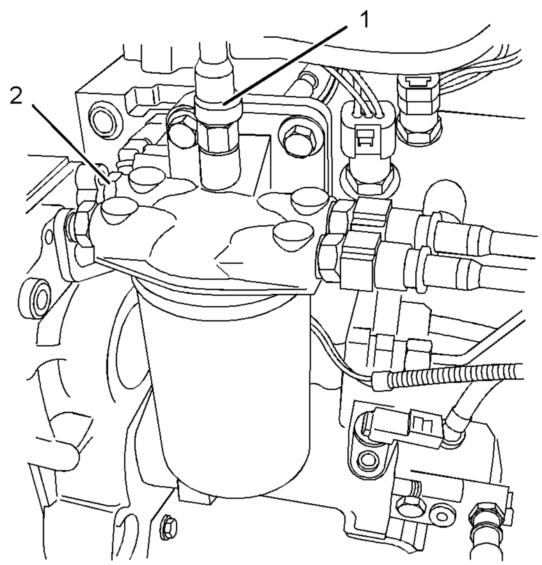


Illustration 41 g01323442

Typical example

4. Remove the connection (1) from the top of the secondary fuel filter base. Insert the end of the connection into a suitable container.

5. Fit a suitable tube to the top of the secondary fuel filter base. Insert the other end of the tube into a suitable container.

6. Install new fuel filters. Refer to Operation and Maintenance Manual for the correct procedure.

7. Prime the fuel system. Refer to Operation and Maintenance Manual, “Fuel System - Prime” for the correct procedure. Check that fuel is flowing from the secondary fuel filter base. If there is no flow of fuel, check the operation of the fuel transfer pump. If there is still no flow of fuel, replace the secondary fuel filter base. Refer to Disassembly and Assembly, “Fuel Filter Base - Remove and Install - Secondary Fuel Filter” for the correct procedure.

8. Stop the engine. Refer to Operation and Maintenance Manual for the correct procedure.

9. Remove the low pressure fuel line from the inlet connection (2) of the secondary fuel filter base.

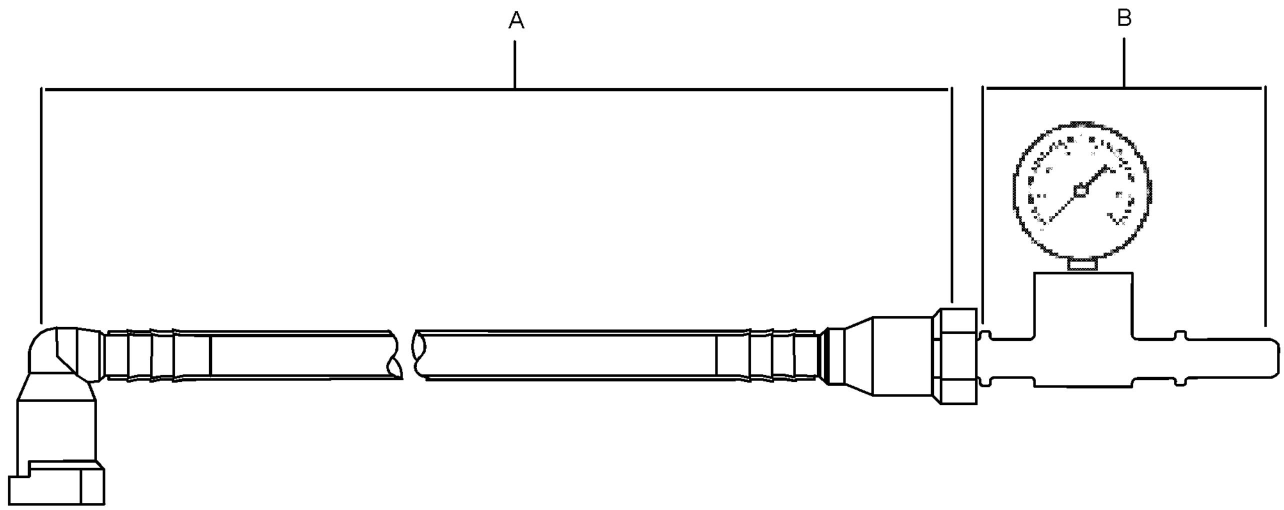


Illustration 42 g01340073

**10.** Connect Tooling (A) and (B) to the low pressure fuel line. Insert the open end of the tube into a suitable container.

**11.** Prime the fuel system to flush fuel through Tooling (A) and (B). This will minimize the risk of contaminating the system by introducing dirt from the service tool. Refer to Operation and Maintenance Manual, “Fuel System - Prime” for the correct procedure.

**12.** Connect the open end of the tube to the inlet connection (2) of the secondary fuel filter base. Prime the fuel system. Refer to Operation and Maintenance Manual, “Fuel System - Prime” for the correct procedure.

**13.** Ensure that Tooling (A) and Tooling (B) are secured and clear of rotating parts.

**14.** Start the engine. Refer to Operation and Maintenance Manual for the correct procedure. Refer to steps 14.a to 14.c for the procedure for testing the fuel pressure. Refer to steps 14.d to 14.h for the procedure for testing the air in fuel.

**Note:** The pressure at the fuel transfer pump should not be measured when the engine is cranked. The pressure will be low and inconsistent. The engine should still start even if transfer pressure is zero. The fuel injection pump will deliver residual fuel in the fuel injection pump and the secondary fuel filter.

**a.** Run the engine at a speed of 1000 rpm. The fuel pressure should be 300 to 550 kPa (44 to 80 psi).

**b.** If the fuel pressure is more than 600 kPa (87 psi), there is a problem with the pressure regulator for the fuel transfer pump. Replace the fuel transfer pump. Refer to Disassembly and Assembly, “Fuel Transfer Pump - Remove” for the correct procedure.

**c.** If the pressure is less than 300 kPa (44 psi), check for restrictions in the low pressure fuel lines between the fuel transfer pump and the secondary fuel filter base. Check for excessive air in the fuel. If no faults are found, replace the fuel transfer pump. Refer to Disassembly and Assembly, “Fuel Transfer Pump - Remove” for the correct procedure.

**d.** Run the engine high idle.

**e.** Run the engine for two minutes. There should be no air in the fuel flow through the sight tube. Small bubbles that are spaced more than 2.5 cm (1.0 inch) are acceptable. Do not manipulate the connections during the test for the air in fuel.

**f.** The presence of large bubbles or a continuous stream of bubbles indicates a leak before the transfer pump.

**g.** Investigate potential leaks and rectify any potential leaks in the low pressure fuel system between the fuel tank and the inlet at the fuel transfer pump.

**h.** Inspect the primary filter base for damaged connections. Inspect the main fuel inlet connection from the fuel tank. Ensure that all the connections are correctly installed. If necessary, replace the connections.

**15.** Remove Tooling (A) and (B). Reconnect the low pressure lines.

i02406195

# Finding Top Center Position for No. 1 Piston

Table 3

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Name** | **Qty** |
| **A** | 21825576 | Crankshaft Turning Tool | 1 |
| **B** | 27610212 | Camshaft Timing Pin | 1 |
| **C** | 27610286 | Crankshaft Timing Pin | 1 |

**1.** Remove the front cover. Refer to Disassembly and Assembly Manual, “Front Cover - Remove and Install”.

**2.** Use Tooling (A) in order to rotate the crankshaft until the hole (X) in the camshaft gear (1) aligns with the hole in the front housing. Refer to illustration 43.

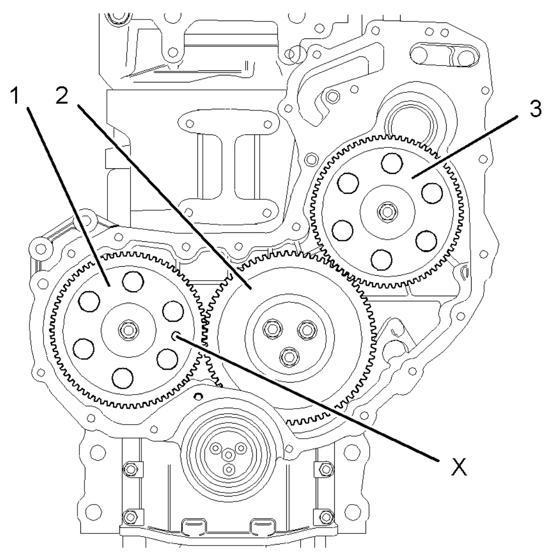


Illustration 43 g01194629

Typical example

**3.** Install Tooling (B) through the hole (X) in the camshaft gear (1) into the front housing. Use Tooling (B) in order to lock the camshaft in the correct position.

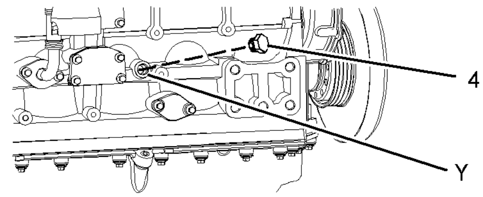


Illustration 44 g01195325

**4.** Remove the plug (4) from the cylinder block. Install Tooling (C) into the hole (Y) in the cylinder block. Use Tooling (C) in order to lock the crankshaft in the correct position.

**Note:** Do not use excessive force to install Tooling (C). Do not use Tooling (C) to hold the crankshaft during repairs.

i02406196

# Fuel Injection Timing - Check

Table 4

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| **A** | 27610302 | Fuel Injection Pump Timing Tool | 1 |

NOTICE

**Ensure that all adjustments and repairs that are carried out to the fuel system are performed by authorised personnel that have the correct training.**

**Before begining ANY work on the fuel system, refer to Operation and Maintenance Manual, “General Hazard Information and High Pressure Fuel Lines” for safety information.**

**Refer to Testing and Adjusting Manual, “Cleanliness of Fuel System Components” for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

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

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

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

**2.** Carefully remove the fuel injection pump from the front housing. Refer to Disassembly and Assembly Manual, "Fuel Injection Pump - Remove" for the correct procedure.

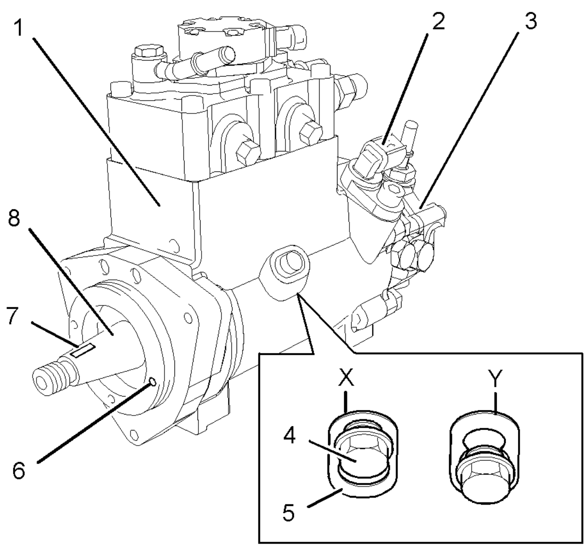


Illustration 45 g01200897

**3.** To check the fuel injection pump timing, follow Steps 3.a and 3.b.

**a.** Position Tooling (A) onto the shaft (8) of the fuel injection pump. Align the lever of Tooling (A) with the key slot (7). Engage the lever into the key slot.

**b.** Insert the locking pin of Tooling (A) into the hole (6) in fuel injection pump.

If the locking pin can be inserted into the hole, the fuel injection pump timing is correct.

If the locking pin cannot be inserted into the hole, the fuel injection pump timing is not correct.

**Note:** There should be no resistance when the locking pin is inserted.

**4.** If the fuel injection pump timing has been lost follow Steps 5 through 9 in order to reset the fuel injection pump timing.

**5.** If necessary, loosen the locking screw (4) on the fuel injection pump. Slide the spacer (5) into position (X). Tighten the locking screw (4) to a torque of 9 N·m (80 lb in). This will prevent the locking screw from tightening against the shaft (8).

The fuel injection pump is now unlocked.

**6.** Position Tooling (A) onto the shaft (8) of the fuel injection pump. Align the lever of Tooling (A) with the key slot (7) in the fuel injection pump. Engage the lever into the key slot.

**7.** Use the lever of Tooling (A) to rotate the shaft (8) until the pin of Tooling (A) can be engaged into the hole (6). Engage the pin of Tooling (A) into the hole.

**8.** Loosen the locking screw (4) in the fuel injection pump. Slide the spacer (5) into position (Y). Tighten the locking screw (4) against the shaft of the fuel injection pump to a torque of 9 N·m (80 lb in).

The fuel injection pump is now locked.

**9.** Remove Tooling (A).

**10.** Reinstall the fuel injection pump to the front housing. Refer to Disassembly and Assembly Manual, "Fuel Injection Pump - Install" for the correct procedure.

There are functional tests in order to ensure that electronic unit injectors operate correctly. Refer to Troubleshooting for further information.

i02563386

# Fuel Quality - Test

**Note: Refer to Systems Operation, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

Ensure that all adjustments and repairs are performed by authorized personnel that have had the correct training.

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

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

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

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

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

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

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

i02674782

# Fuel System - Prime

**⚠ WARNING**

**Contact with high pressure fuel may cause fluid penetration and burn hazards. High pressure fuel spray may cause a fire hazard. Failure to follow these inspection, maintenance and service instructions may cause personal injury or death.**

Refer to the Operation and Maintenance Manual , "General Hazard Information and High Pressure Fuel Lines" before adjustments and repairs are performed.

**Note: Refer to Systems Operation, "Cleanliness of Fuel System Components" for detailed information on the standards of cleanliness that must be observed during ALL work on the fuel system.**

Ensure that all adjustments and repairs are performed by authorized personnel that have had the correct training.

NOTICE

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

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

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

## Hand Fuel Priming Pump

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

**1.** Ensure that the fuel system is in working order. Restore the fuel supply.

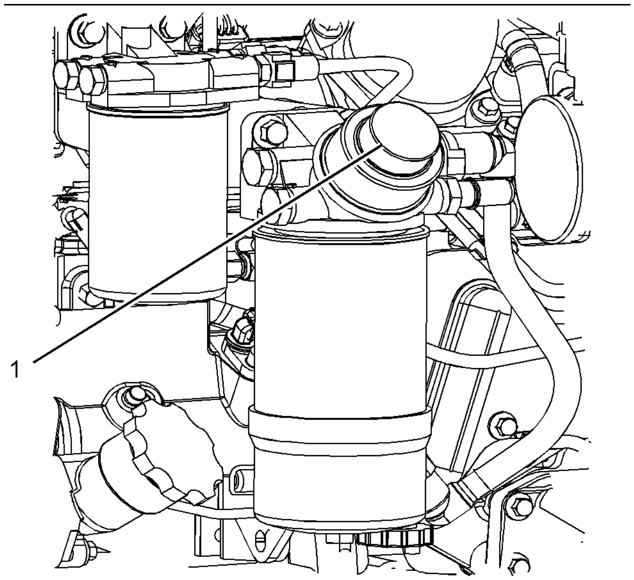


Illustration 46 g01343822

Typical example

2. Operate the fuel priming pump (1). Count the number of operations of the fuel priming pump. After 100 depressions of the fuel priming pump stop.

3. The engine fuel system should now be primed and the engine should now be able to start.

**Note:** Do not loosen the high pressure fuel line in order to purge air from the fuel system. This procedure is not required.

4. Operate the engine starter and crank the engine. After the engine has started, operate the engine at low idle for a minimum of five minutes, immediately after air has been removed from the fuel system.

**Note:** Operating the engine for this period of time will help ensure that the fuel system is free of air.

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and Assembly Manual, “Fuel Injection Lines - Install”.

If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, “General hazard Information”.

## Electric Fuel Priming Pump

1. Ensure that the fuel system is in working order. Restore the fuel supply.

NOTICE
The electric fuel priming pump will operate for 90 seconds. If necessary the electric fuel priming pump can be stopped during the 90 seconds of operation, by operation of the switch.

2. Turn the keyswitch to the “RUN” position. Operate the switch for the electric priming pump. After 90 seconds of the electric fuel priming pump operation the fuel system will be primed and the electric fuel priming pump will turn off.

3. The engine should now be able to start.

**Note:** Do not loosen the high pressure fuel line in order to purge air from the fuel system. This procedure is not required.

4. Operate the engine starter and crank the engine. After the engine has started, operate the engine at low idle for a minimum of five minutes, immediately after air has been removed from the fuel system.

**Note:** Operating the engine for this period of time will help ensure that the fuel system is free of air.

After the engine has stopped, you must wait for 60 seconds in order to allow the fuel pressure to be purged from the high pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low pressure fuel system and from the cooling, lubrication or air systems. Replace any high pressure fuel line that has leaked. Refer to Disassembly and Assembly Manual, “Fuel Injection Lines - Install”.

If you inspect the engine in operation, always use the proper inspection procedure in order to avoid a fluid penetration hazard. Refer to Operation and Maintenance Manual, “General hazard Information”.

i02652703

# Gear Group (Front) - Time

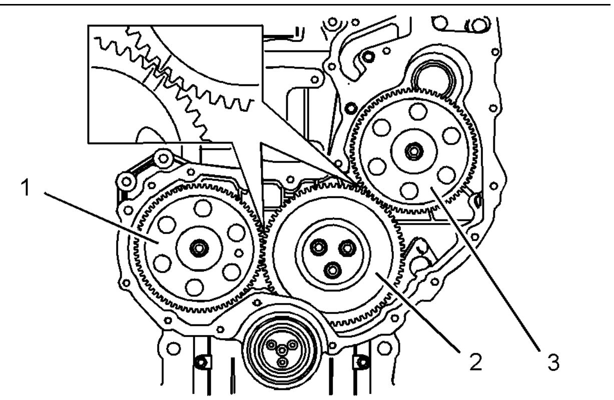


Illustration 47 g01332583

(1) Camshaft gear
(2) Idler gear
(3) Fuel Injection Pump gear

1. Install the camshaft gear (1) onto the camshaft. Refer to Disassembly and Assembly, “Camshaft Gear - Remove and Install” for the correct procedure.

**2.** Ensure that the crankshaft and the camshaft are locked in the correct position. Refer to Disassembly and Assembly, “Gear Group (Front) - Remove and Install” for the correct procedure. Ensure that the fuel injection pump is locked in the correct position. Refer to Disassembly and Assembly, “Fuel Injection Pump - Remove” for the correct procedure.

**3.** Install the idler gear (2). Refer to Disassembly and Assembly, “Idler Gear - Remove and Install” for the correct procedure.

**4.** Install the fuel injection pump gear (3). Refer to Disassembly and Assembly, “Fuel Injection Pump Gear - Install” for the correct procedure.

**5.** Make sure that the timing marks on the gears (1), (2) and (3) are in alignment. If the timing marks are not aligned, refer to Disassembly and Assembly, “Gear Group (Front) - Remove and Install”.

# Air Inlet and Exhaust System

i02652674

## Air Inlet and Exhaust System - Inspect

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

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

**WARNING**

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

**WARNING**

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

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

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

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

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

4. For engines with plastic valve mechanism covers, if you experience excessive crankcase pressure, remove the valve mechanism cover. Refer to Disassembly and Assembly, “Valve Mechanism Cover - Remove and Install” for the correct procedure. Inspect the inside of the valve mechanism cover for debris. Ensure that all of the debris is removed.

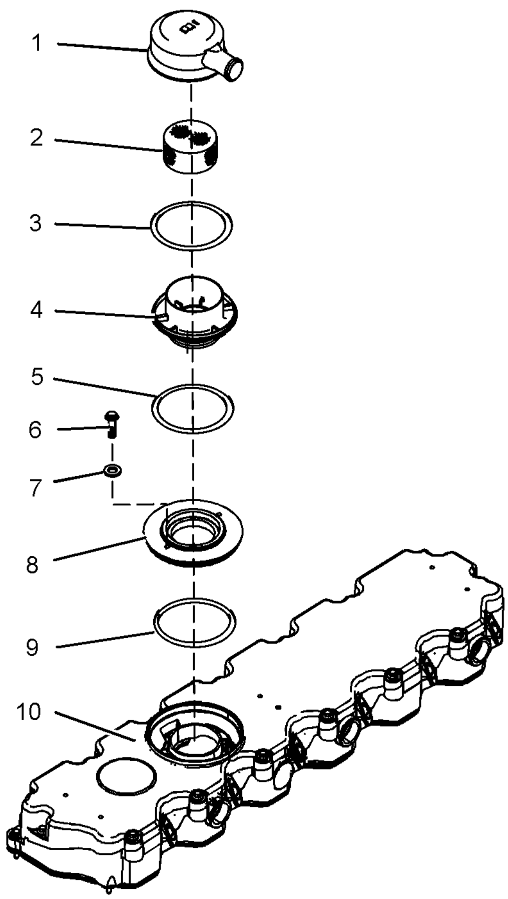


Illustration 48 g01332578

(1) Cover
(2) Gauze
(3) O-ring seal
(4) Breather body
(5) O-ring seal
(6) Setscrew
(7) Washer
(8) Adapter plate
(9) O-ring seal
(10) Valve mechanism cover

5. If the breather tube is made of plastic, use low pressure air to check for a blockage in the breather tube. If a blockage is inside the cover (1), remove the cover (1). Refer to Disassembly and Assembly, “Crankcase Breather - Remove and Install” for the correct procedure. When possible, remove the blockage from the cover (1). If necessary, replace the cover (1).

i02406191

# Turbocharger - Inspect

**⚠ WARNING**

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

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

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

Dispose of all fluids according to local regulations and mandates.

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

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

- Inspection of the compressor and the compressor housing
- Inspection of the turbine wheel and the turbine housing
- Inspection of the wastegate

## Inspection of the Compressor and the Compressor Housing

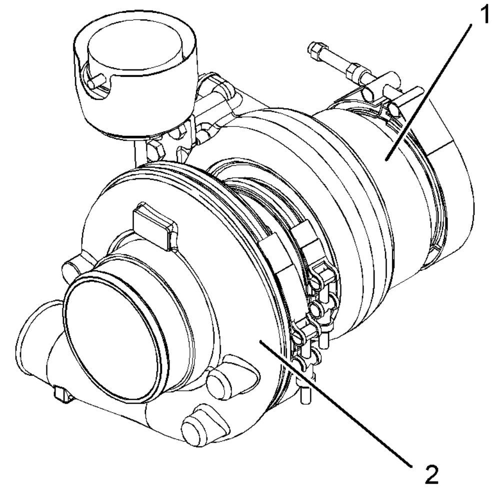


Illustration 49 g01207602

Typical example of a turbocharger

(1) Turbine housing
(2) Compressor housing

1. Inspect the compressor wheel for damage from a foreign object. If there is damage, determine the source of the foreign object. Replace the turbocharger. If there is no damage, go to Step 2.

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

3. Inspect the compressor and the compressor wheel housing for oil leakage. An oil leak from the compressor may deposit oil in the aftercooler. If oil is found in the aftercooler, then drain and clean the aftercooler.

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

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

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

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

## Inspection of the Turbine Wheel and the Turbine Housing

Remove the air piping from the turbine housing.

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

2. Inspect the turbine wheel for the carbon and other foreign material. Inspect turbine housing (1) for carbon and foreign material. Replace the turbocharger, if necessary. If there is no buildup of carbon or foreign material, go to Step 3.

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

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

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

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

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

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

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

## Inspection of the Wastegate

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

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

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

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

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

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

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

### Check the Wastegate for Proper Operation

Table 5

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| **A** | 21825617 | Dial Gauge | 1 |

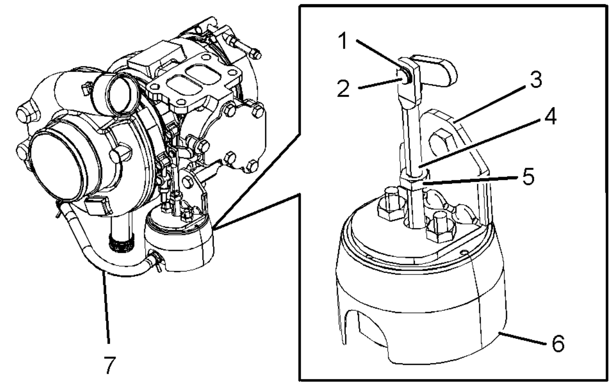


Illustration 50 g01207591

Typical example

1. Disconnect the pipe for the boost sensor (7) at the wastegate actuator (6). Connect an air supply to the wastegate actuator that can be adjusted accurately.

2. Install Tooling (A) to the turbocharger so that the end of the actuator rod (4) is in contact with Tooling (A). This will measure axial movement of the actuator rod (4).

3. Slowly apply air pressure to the wastegate so that the actuator rod (4) moves 1.0 mm (0.039 inch). Refer to Specifications, “Turbocharger” for the correct pressure for the wastegate. 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. If the operation of the wastegate is not correct, the actuator rod (4) can be adjusted.

5. Remove Tooling (A) from the turbocharger.

6. When the air pressure is applied, loosen the nut (5) on the actuator. Remove the circlip (1). Remove the pin (2) from the actuator rod (4).

7. When the air pressure is too low, adjust the end of the actuator rod (4) in order to reduce the length of the actuator rod (4). If the air pressure is too high, adjust the end of the actuator rod (4) in order to increase the length of the actuator rod (4).

8. Install the pin (2) to the actuator rod (4). Install the circlip (1) to the actuator rod (4). Tighten the nut (5) to a torque of 5 N·m (44 lb in).

9. Repeat steps 2 to 3 in order to repeat the pressure test.

10. If the air pressure is correct, remove the air supply. Remove Tooling (A). Install the pipe for the boost sensor (7).

i02406192

# 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 glow plugs are removed.
- The fuel supply is disconnected.

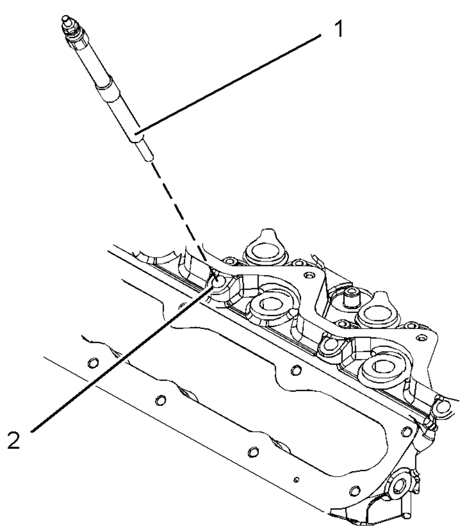


Illustration 51 g01198769

Typical example

1. Remove the glow plug (1) from the hole in the cylinder head (2). Refer to Disassembly and Assembly Manual, “Glowplugs - Remove and Install” for the correct procedure for the removal of the glow plug (1).

2. Install a suitable gauge for measuring the cylinder compression in the hole for a glow plug.

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

4. Repeat steps 1 to 3 for all cylinders.

i02481785

# Engine Valve Lash - Inspect/Adjust

Table 6

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 27610298 | Angled feeler gauge | 1 |

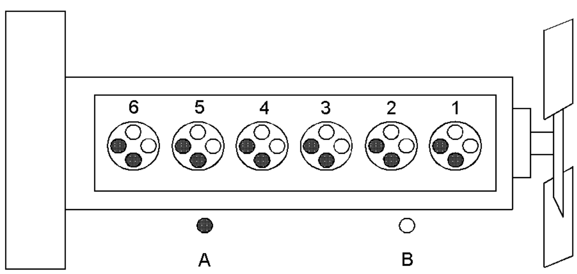


Illustration 52 g01127295

Cylinder and valve location

(A) Exhaust valve
(B) Inlet valve

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

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

Valves become worn due to the following causes:

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

Too much valve lash can cause broken valve stems, springs, and spring retainers. This will produce emissions in excess of the correct specification.

Too much valve lash can be an indication of the following problems:

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

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

## Valve Lash Check

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

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

## Valve Lash Adjustment

Table 7

| | Inlet Valves | Exhaust Valves |
|---|---|---|
| Valve Lash | 0.35 ± 0.05 mm (0.0138 ± 0.0020 inch) | 0.35 ± 0.05 mm (0.0138 ± 0.0020 inch) |
| Firing Order | 1-5-3-6-2-4[2] | |

(2) The No. 1 Cylinder is at the front of the engine.

**Note:** For new engines, the valve lash should be checked and reset after the first 500 hours and after the next 500 hours. The valve lash will then be checked at service intervals of 1000 hours.

**Note:** For example, if the pushrods in a remanufactured engine have been replaced with new parts then Adjust the valve lash to 0.25 ± 0.05 mm (0.0098 ± 0.0020 inch) for the initial rebuild.
The tappets should be reset to 0.35 ± 0.05 mm (0.0138 ± 0.0020 inch) at the normal service intervals thereafter.

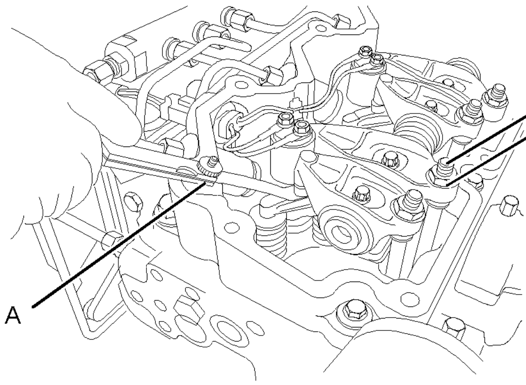


Illustration 53 g01193809

Setting the valve lash

(A) Angled feeler gauge
(1) Adjustment screw
(2) Locking screw

**WARNING**

**Accidental engine starting can cause injury or death to personnel.**

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

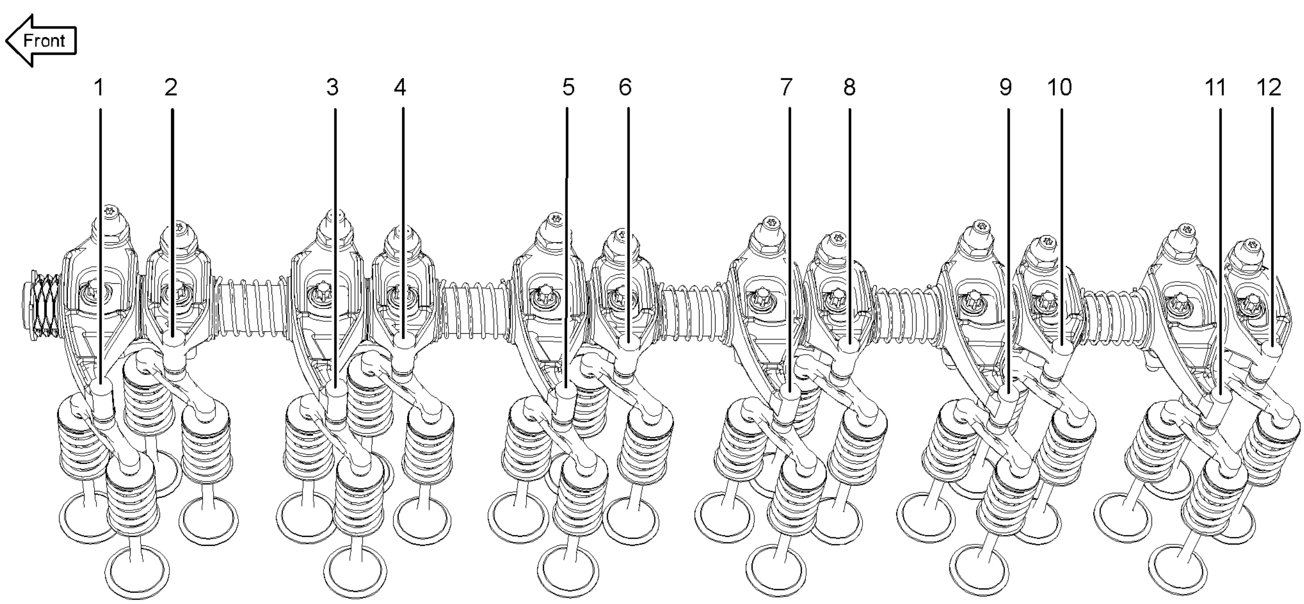


Illustration 54 g01194217

1. Remove the valve mechanism cover. Refer to Disassembly and Assembly, “Valve Mechanism Cover - Remove and Install” for the removal procedure.

**Note:** When the valve mechanism cover is removed or installed, the electrical harness must be checked. Do not trap the injector harness when the valve mechanism cover is installed. Do not allow the harness to be in contact with the valve mechanism cover. Renew the harness, if the harness is damaged.

Table 8

| Rotate the crankshaft until inlet valves are fully open. | Set valve lash for the following : | |
|---|---|---|
| | Inlet valves “**(Cylinder number)**” | Exhaust valve “**(Cylinder number)**” |
| 11 | 9 **(5)** | 10 **(5)** |
| 3 | 5 **(3)** | 6 **(3)** |
| 7 | 11 **(6)** | 12 **(6)** |
| 1 | 3 **(2)** | 4 **(2)** |
| 9 | 7 **(4)** | 8 **(4)** |
| 5 | 1 **(1)** | 2 **(1)** |

**2.** See illustration 54. Rotate the crankshaft clockwise until the pair of inlet valves (11) is fully open. Measure the valve lash on inlet valves (9) and exhaust valves (10). If necessary, adjust the valve lash to the settings in Table 7. Complete the sequence of checks according to Table 8 until all the cylinders have been checked or adjusted.

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

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

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

**3.** Complete the sequence of checks according to Table 8 until all the cylinders have been checked or adjusted. Reinstall the valve mechanism cover. Refer to Disassembly and Assembly, “Valve Mechanism Cover - Remove and Install” for the installation procedure.

i02556739

## Valve Depth - Inspect

Table 9

| Required Tools | | | |
|---|---|---|---|
| **Tool** | **Part Number** | **Part Description** | **Qty** |
| **A** | 21825617 | Dial gauge | 1 |
| **B** | 21825496 | Dial gauge holder | 1 |

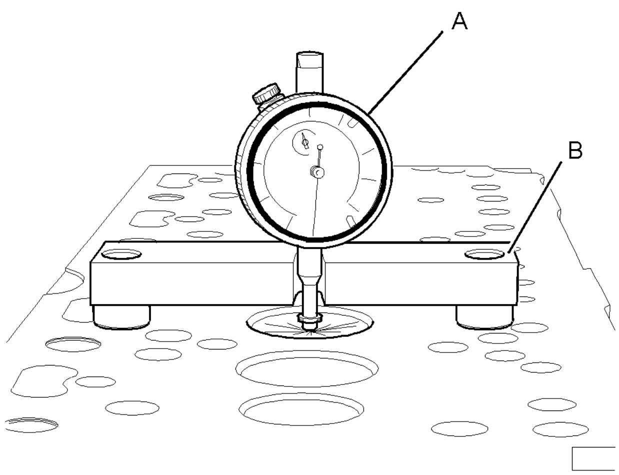


Illustration 55 g01201916

Typical example

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

2. Use the Tooling (A) to check the depths of the inlet valves and the exhaust valves below the face of the cylinder head. Use Tooling (B) to zero Tooling (A).

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

   Inlet valves

   Minimum .................. 0.905 mm (0.0356 inch)
   Maximum ................. 1.163 mm (0.0458 inch)

   Exhaust valves

   Minimum .................. 0.876 mm (0.0345 inch)
   Maximum ................. 1.131 mm (0.0445 inch)

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

   - Valves

   - Valve inserts

   Wear limit for inlet valves .. 1.41 mm (0.0555 inch)

   Wear limit for exhaust valves ................. 1.38 mm (0.0543 inch)

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

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

i02648161

## Valve Guide - Inspect

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

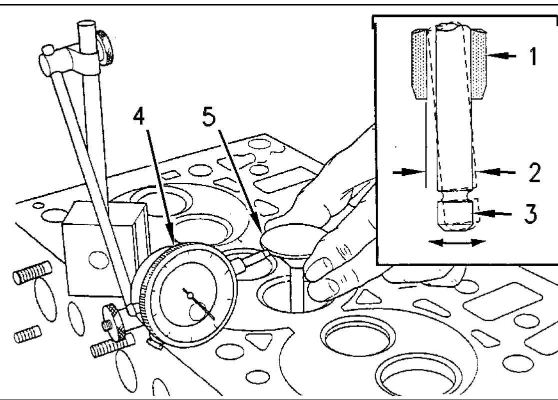


Illustration 56 g00314806

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

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

1. Place a new valve in the valve guide.

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

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

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

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

The maximum clearance for the inlet valve stem in the valve guide with a valve lift of 15.0 mm (0.60 inch) is the following value. ........... 0.08 mm (0.0031 inch)

The maximum clearance for the exhaust valve stem in the valve guide with a valve lift of 15.0 mm (0.60 inch) is the following value. ........... 0.09 mm (0.0035 inch)

The original valve guides are bored into the cylinder head. When new valve guides(1) are installed, new valves and new valve seat inserts must be installed. The cylinder head must be rebored in order to install the new valve guide. For more information, contact your distributor or your dealer.

# Lubrication System

i02648880

## 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.

The minimum oil pressure at the maximum engine speed and at normal operating temperature is 315 kPa (45 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.

i02400036

## Engine Oil Pump - Inspect

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

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

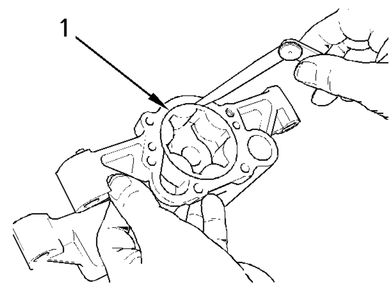


Illustration 57 g00938064

1. Remove the oil pump from the engine. Remove the cover of the oil pump.
2. Remove the outer rotor (1). Clean all of the parts. Look for cracks in the metal or other damage.
3. Install the outer rotor. Measure the clearance of the outer rotor to the body .

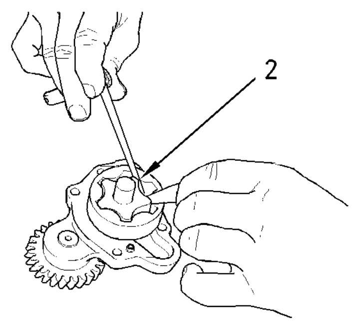


Illustration 58 g00938061

Clearance for the inner rotor body

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

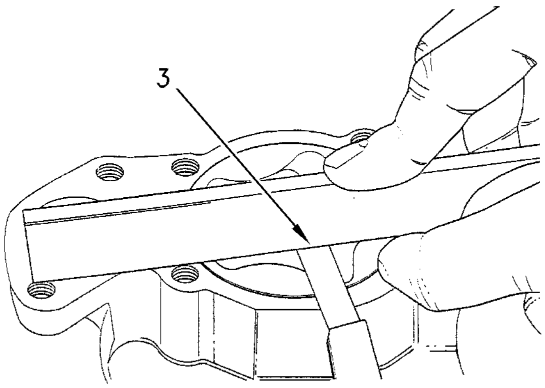


Illustration 59 g00938799

End play measurement of the rotor

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.

i01126690

# Excessive Bearing Wear - Inspect

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

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

i02414692

# 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:

- Failed valve stem seals
- 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.

i02414679

# Increased Engine Oil Temperature - Inspect

Look for a restriction in the oil passages of the oil cooler. The oil temperature may be higher than normal when the engine is operating. In such a case, the oil cooler may have a restriction.

 

# Cooling System

i02419296

## Cooling System - Check

### Engine And Cooling System Heat Problems

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

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

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

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

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

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

**b.** Inspect the poly v-belt for wear or for damage. If necessary, replace the poly v-belt. Refer to Disassembly and Assembly Manual, “Alternator Belt - Remove and Install” for the correct procedure.

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

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

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

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

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

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

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

i01626003

## Cooling System - Inspect

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

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

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

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

### Visual Inspection Of The Cooling System

**1.** Check the coolant level in the cooling system.

**2.** Look for leaks in the system.

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

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

**4.** Inspect the drive belt for the fan.

5. Inspect the blades of the fan for damage.

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

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

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

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

i02414661

# 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 60. 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.

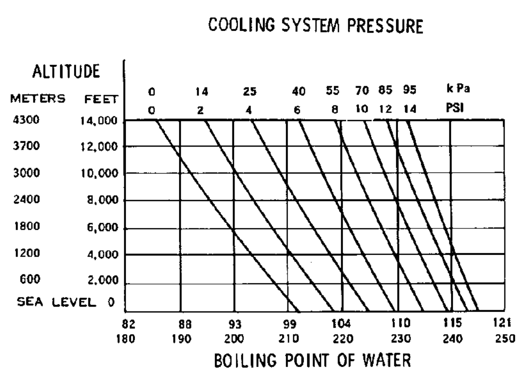


Illustration 60 g00286266

Cooling system pressure at specific altitudes and boiling points of water

**⚠ WARNING**

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

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

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

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

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

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

## Making the Correct Antifreeze Mixtures

Do not add pure antifreeze to the cooling system in order to adjust the concentration of antifreeze. Refer to Operation and Maintenance Manual, “Refill Capacities” for the correct procedure. The pure antifreeze increases the concentration of antifreeze in the cooling system. The increased concentration increases the concentration of dissolved solids and undissolved chemical inhibitors in the cooling system.

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

## Checking the Filler Cap

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

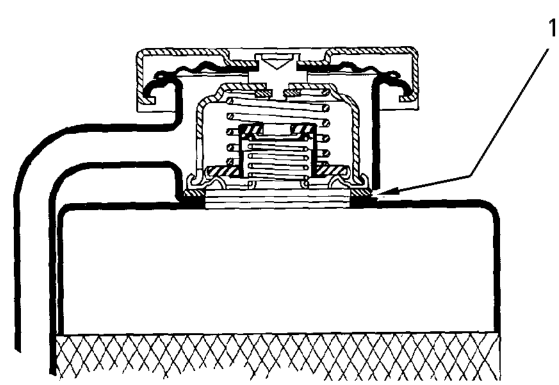


Illustration 61 g00296067

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. 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.

i02652662

# 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.**

There are two types of engine oil cooler that can be installed on this engine.

## Engine Oil Cooler with a Low Mounted Filter Base

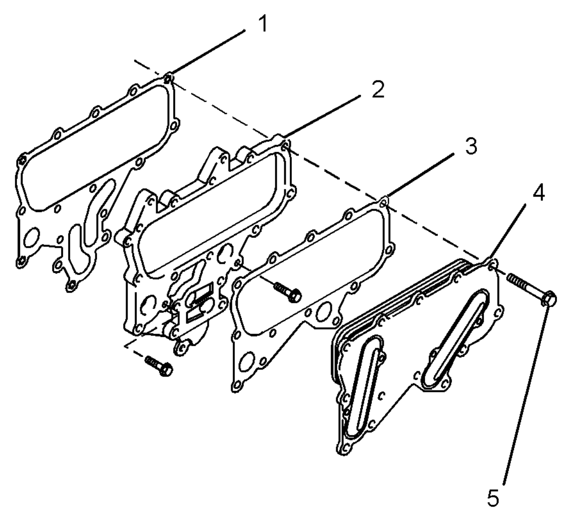


Illustration 62 g01332170

Typical example

(1) Oil cooler
(2) Long setscrew
(3) Short setscrew
(4) Joint
(5) Setscrews
(6) Housing for the oil cooler
(7) Joint

Perform the following procedure in order to inspect the engine oil cooler with the low mounted filter:

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 oil cooler (1) 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 oil cooler (1) for cracks and dents. Replace the oil cooler (1) if cracks or dents exist. Ensure that no restrictions for the flow of lubricating oil exist in the oil cooler (1).

   Dry the oil cooler (1) with low pressure air. Flush the inside of the oil cooler (1) with clean lubricating oil.

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

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

**Note:** Refer to Operation And Maintenance Manual, "Refill Capacities" for additional information.

   Check for oil or coolant leakage.

## Engine Oil Cooler with a High Mounted Filter Base

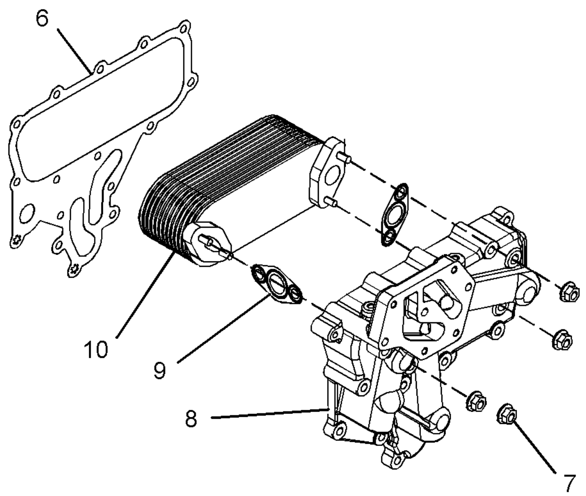


Illustration 63 g01322246

Typical example

(1) Oil cooler
(2) Joint
(3) Housing for the oil cooler
(4) Nut
(5) Long setscrew
(6) Setscrew
(7) Joint

Perform the following procedure in order to inspect the engine oil cooler with the low mounted filter:

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 oil cooler (1) 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 oil cooler (1) for cracks and dents. Replace the oil cooler (1) if cracks or dents exist. Ensure that no restrictions for the flow of lubricating oil exist in the oil cooler (1).

   Dry the oil cooler (1) with low pressure air. Flush the inside of the oil cooler (1) with clean lubricating oil.

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

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

**Note:** Refer to Operation And Maintenance Manual, "Refill Capacities" for additional information.

   Check for oil or coolant leakage.

i02414647

## Water Temperature Regulator - Test

**WARNING**

**Personal injury can result from escaping fluid under pressure.**

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

1. Remove the water temperature regulator from the engine. Refer to Disassembly and Assembly Manual, "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 in the pan of water. The water temperature regulator must be below the surface of the water. The water temperature regulator must be away from the sides and the bottom of the pan.

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

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

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

i01628133

## Water Pump - Inspect

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

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

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

# Basic Engine

i02415240

## 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.

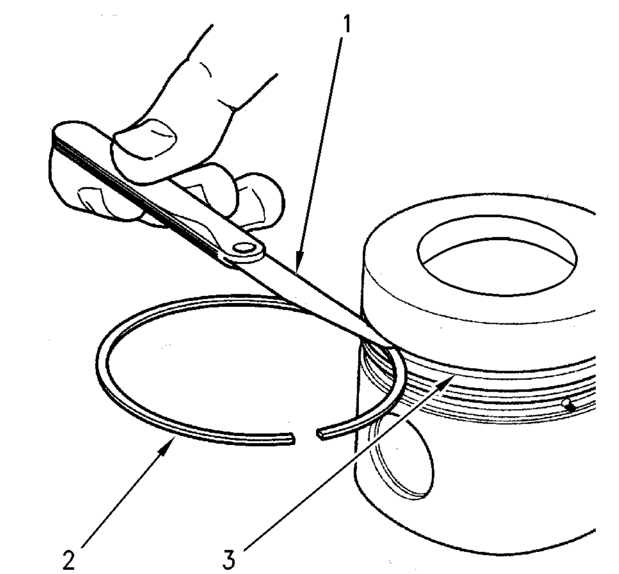


Illustration 64 g00905732

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

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

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

### Inspect the Piston Ring End Gap

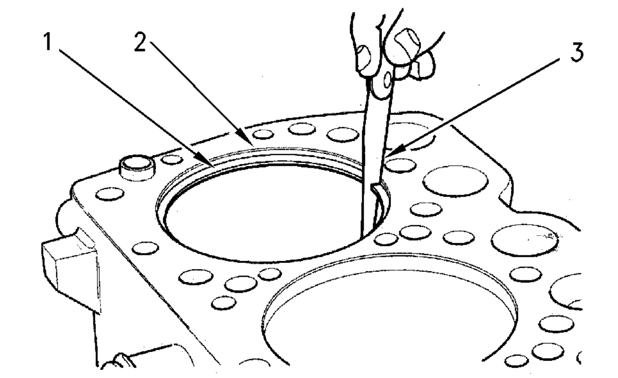


Illustration 65 g00782363

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

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

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

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

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

i02655624

## Connecting Rod - Inspect

These procedures determine the following characteristics of the connecting rod:

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

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

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

- New connecting rod assemblies that are the correct grade of length must be installed. Refer to “Length Of The Connecting Rod”.
- New piston pin bearings must be bored after installation in the original connecting rods. Refer to “Piston Pin Bearings”.

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

## Length of The Connecting Rod

The connecting rod length (CRL) is the length of the connecting rod. Refer to Table 10 for each grade of length of connecting rod.

In order to ensure that the piston height above the cylinder block is correct, three grades of connecting rods “F” to “L” are used during manufacture at the factory. Replacement connecting rods are available in three grades. These grades of connecting rod are “F” to “L”. The grade of length is identified by a letter or a color which is marked on the side of the connecting rod. The longest grade is marked with the letter “F”. The shortest grade is marked with the letter “L”. The difference in length between each grade of connecting rods is the following value: 0.076 mm (0.0030 inch)

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

If the connecting rod must be replaced, a new connecting rod assembly must be purchased and installed. Refer to Table 10 for more information.

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

### Piston Pin Bearings

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

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

1. Determine the grade of length of the connecting rod. Use one of the following characteristics:
   - The mark
   - The color
   - Measuring the length
2. Ensure that the connecting rod is aligned parallel and that the connecting rod is not distorted. Refer to “Distortion Of A Connecting Rod” in this service module.
3. Remove the piston pin bearing from the connecting rod. Install a new bearing in the connecting rod. The new bearing is partially finished. The new bearing must be bored off-center to the correct diameter. This off-center position is determined by the grade of length of the connecting rod. Refer to Table 10. The correct diameter of the bore in the piston pin bearing is given in the Specifications Module, “Connecting Rod”.

   Surface finish of the bored hole in the piston pin bearing ................................. Ra 0.8 micrometers
4. Machine the ends of the piston pin bearing to the correct length. Remove any sharp edges. Refer to the Specifications Module, “Connecting Rod”.
5. If the grade of length of the connecting rod is changed, the letter that is stamped on the connecting rod must be removed. Etch a letter that is for the new grade of length on the side of the connecting rod.

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

Table 10 references the following information: Grade of letter of the connecting rod, the color code of the connecting rods, and the lengths of the connecting rods.

Table 10

| Length Grades for Connecting Rods | | |
|---|---|---|
| **Grade Letter** | **Color Code** | **Length Of The Connecting Rod (CRL)** |
| **F** | Red | 161.259 to 161.292 mm (6.3488 to 6.3501 inch) |
| **J** | Green | 161.183 to 161.216 mm (6.3458 to 6.3471 inch) |
| **L** | Blue | 161.107 to 161.140 mm (6.3428 to 6.3441 inch) |

### Measure The Length Of The Connecting Rod

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

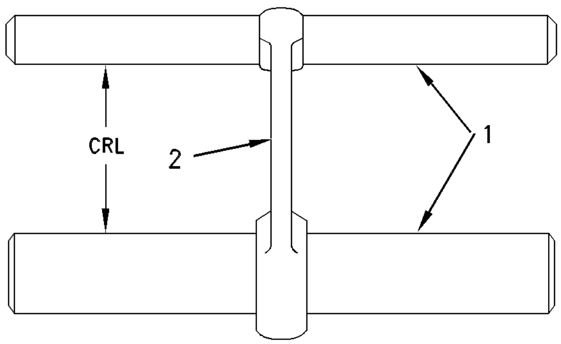


Illustration 66 g00326546

Measure the length of the connecting rod.

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

**1.** Refer to Illustration 66. Use the following tools in order to measure the length of the connecting rod:

- Appropriate gauges for measuring distance
- Measuring pins (1)

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

Measure “CRL”. Compare the “CRL” that is given in Table 10. The grade of length of the connecting rod is determined by the “CRL”. Refer to Table 10 for the correct grade of length.

## Distortion of The Connecting Rod

**1.** Use the following tools in order to measure the distances for the connecting rod (2) which are specified in Illustration 66:

- Appropriate gauges for measuring distance
- Measuring pins (1)

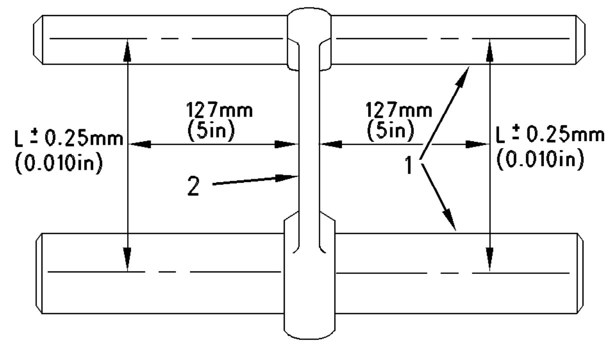


Illustration 67 g00326423

Measure the connecting rod for distortion.

(1) Measuring pins
(2) Connecting rod
(L) The length between the centers of the piston pin bearing and the crankshaft journal bearing is shown in Illustration 67.

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

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

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

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

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

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

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

i02399735

# Cylinder Block - Inspect

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

**2.** Check the cylinder block for cracks and damage.

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

**4.** Check the front camshaft bearing for wear. Refer to Specifications, "Camshaft Bearings" for the correct specification of the camshaft bearing. 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.

i02635704

## Cylinder Head - Inspect

**1.** Remove the cylinder head from the engine.

**2.** Remove the water temperature regulator housing.

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

**4.** Remove the valve springs and valves.

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

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

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

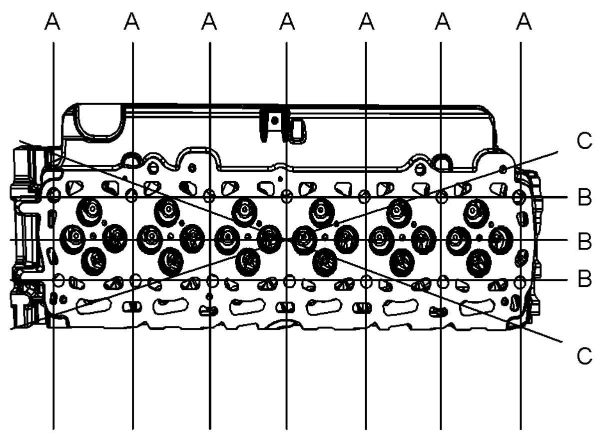


Illustration 68 g01332569

Flatness of the cylinder head (typical example)

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

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

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

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

## Resurfacing the Cylinder Head

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

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

**Note:** The thickness of the cylinder head must not be less than 94.80 mm (3.7323 inch) after the cylinder head has been machined.

i02406197

# Piston Height - Inspect

Table 11

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21825617 | Dial Gauge | 1 |
| B | 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

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.

Three 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.

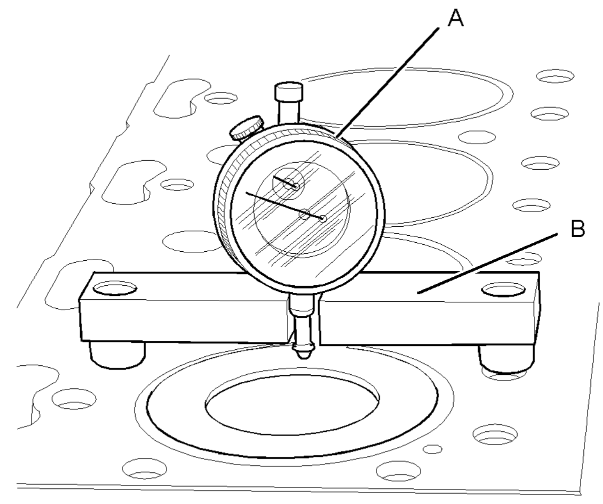


Illustration 69 g01201898

Typical example

1. Use Tooling (A) and Tooling (B) in order to measure the piston height above the cylinder block. Use the cylinder block face to zero Tooling (A).

2. Rotate the crankshaft until the piston is at the approximate top center.

3. Position Tooling (B) and Tooling (A) 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".

i02636429

# Flywheel - Inspect

Table 12

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21825617 | Dial Indicator Group | 1 |

## Alignment of the Flywheel Face

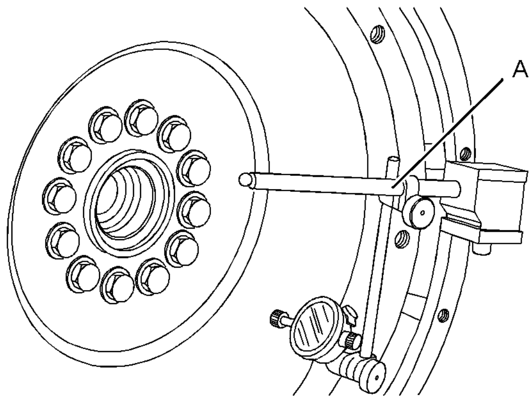


Illustration 70 g01332565

Typical example

1. Install Tooling (A) in illustration 70, as shown.

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

3. Turn the flywheel. Read the dial indicator for every 45 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

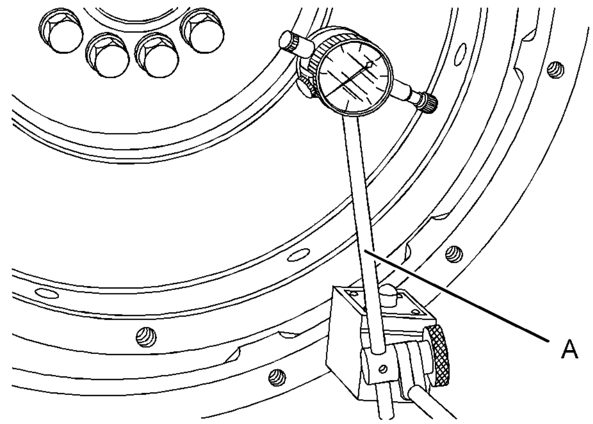


Illustration 71 g01321858

Typical example

1. Install Tooling (A) in illustration 71, as shown.

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

3. Turn the flywheel. Read the dial indicator for every 45 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).

i02406200

# Flywheel Housing - Inspect

Table 13

| Required Tools | | | |
|---|---|---|---|
| Tool | Part Number | Part Description | Qty |
| A | 21825617 | Dial Gauge | 1 |

## Concentricity of the Flywheel Housing

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

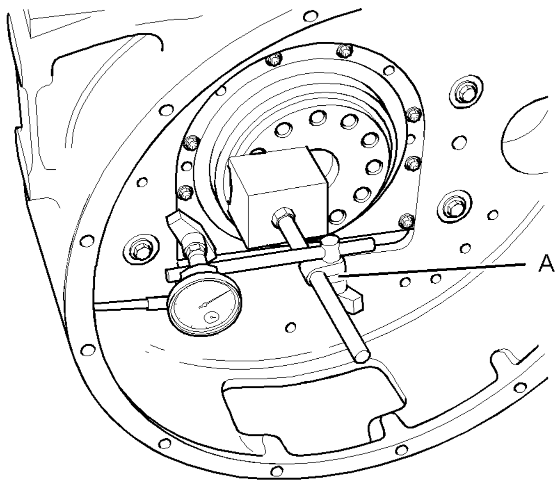


Illustration 72 g01199468

Typical example

1. Install Tooling (A). See illustration 72.

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

3. Check the concentricity at intervals of 45 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 14.

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

## Alignment of the Flywheel Housing

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

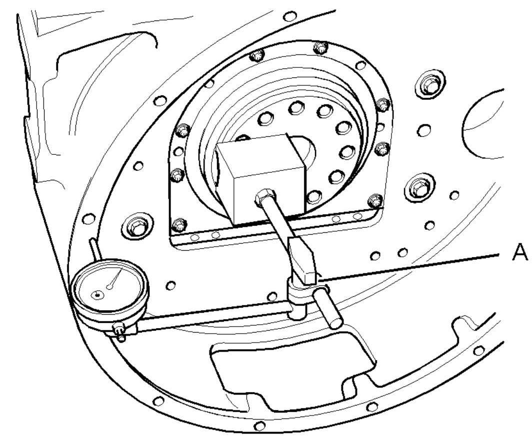


Illustration 73 g01199467

Typical example

1. Install Tooling (A). See illustration 73.

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

3. Check the alignment at intervals of 45 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 14.

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

Table 14

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

i02652636

## Gear Group - Inspect

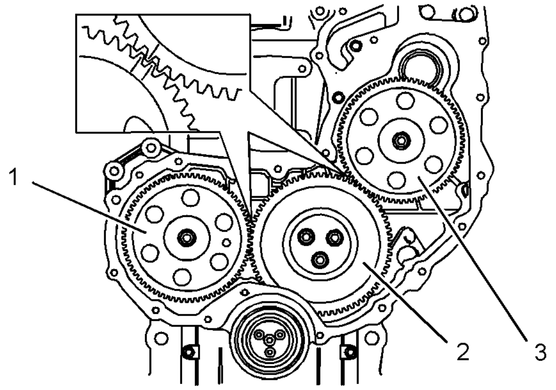


Illustration 74 g01332563

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

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

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

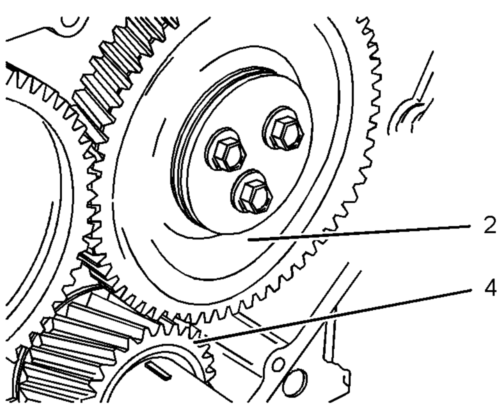


Illustration 75 g01332564

**2.** Measure the backlash between the camshaft gear (1) and the idler gear (2). Refer to Specifications, "Gear Group (Front)" for the backlash measurement.

**3.** Measure the backlash between the idler gear (2) and the crankshaft gear (4). Refer to Specifications, "Gear Group (Front)" for the backlash measurement.

**4.** Measure the backlash between the fuel injection pump gear (3) and the idler gear (2). Refer to Specifications, "Gear Group (Front)" for the backlash measurement.

**5.** Measure the end play on idler gear (2). Refer to Disassembly and Assembly, "Idler Gear - Install" for the correct procedure. Refer to Specifications, "Gear Group (Front)" for the end play measurement.

i02652633

## Vibration Damper - Check

The vibration damper is installed on the front of the crankshaft. There are two types of hub assembly that can be installed to this engine. The vibration damper is installed in order to help remove torsional vibration in the engine.

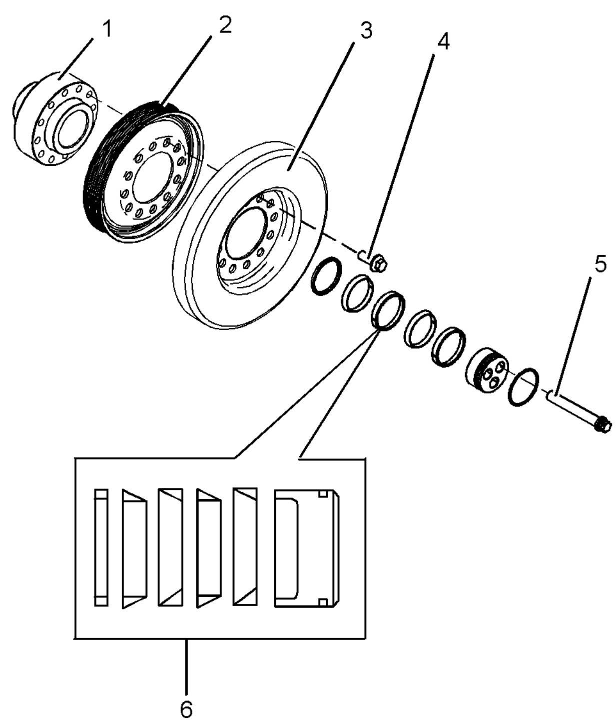


Illustration 76 g01332241

Vibration damper with hub assembly

(1) Crankshaft adapter
(2) Pulley
(3) Vibration damper
(4) Damper setscrews
(5) Setscrews for the adapter
(6) Hub assembly

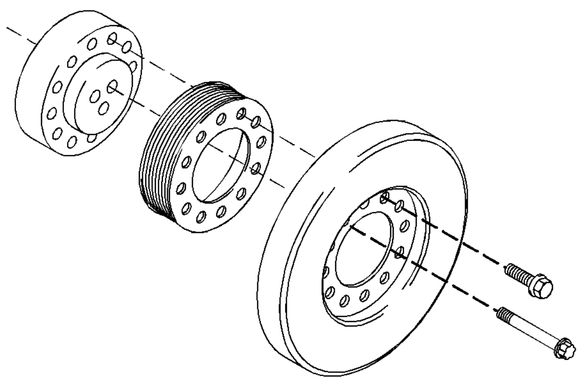

Illustration 77 g01332246

Vibration damper with out hub assembly

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

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

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

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

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

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

**3.** Rotate the crankshaft at intervals of 45 degrees and read the dial indicator.

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

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

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

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

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

# Electrical System

i02418531

## Alternator - Test

**1.** Put the positive lead "+" of a suitable multimeter on the "B+" terminal of the alternator. Put the negative "-" lead on the ground terminal or on the frame of the alternator. Put a suitable ammeter around the positive output wire of the alternator.

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

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

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

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

Table 15

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

**5.** After approximately ten minutes of operating the engine at full throttle, the output voltage of the alternator should be 14.0 ± 0.5 volts for a 12 volt system and 28.0 ± 1 volts for a 24 volt system. Refer to the Fault Conditions And Possible Causes in Table 15.

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

- The battery charge

- The ambient temperature
- The speed of the engine

Refer to the Fault Conditions And Possible Causes in Table 15.

i01126605

# Battery - Test

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

**WARNING**

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

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

NOTICE

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

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

i02418527

# 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. A large amount of water would be more than one ounce of water 28 ml per cell per week or per every 100 service hours. There are no adjustments on maintenance free batteries.

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

## Alternator Regulator

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

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

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

i02675826

# V-Belt - Test

The engine is equipped with an automatic belt tensioner. Manual adjustment of the belt is not required.

## Poly V-Belt

NOTICE
Ensure that the engine is stopped before any servicing or repair is performed.

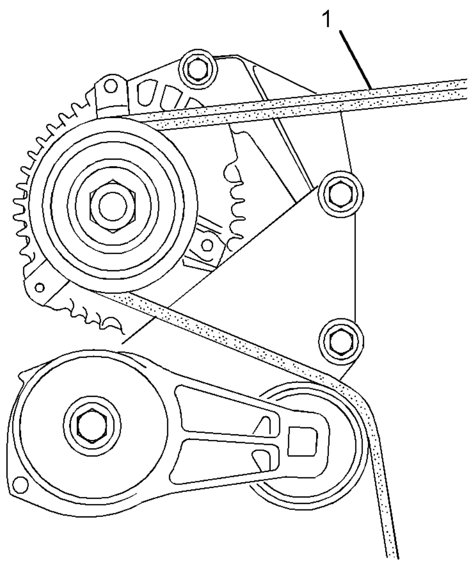


Illustration 78 g01344345

Typical example

To maximize the engine performance, inspect the poly v-belt (1) for wear and for cracking. Replace the poly v-belt if the belt is worn or damaged.

- Check the poly v-belt (1) for cracks, splits, glazing, grease, and splitting.
- If the poly v-belt (1) has more than four cracks per 25.4 mm (1.00 inch) the belt must be replaced.

To replace the poly v-belt, refer to Disassembly and Assembly Manual, “Alternator Belt - Remove and Install”. If necessary, replace the belt tensioner. Refer to Disassembly and Assembly Manual, “Alternator Belt - Remove and Install” for the correct procedure.

i02399802

# Electric Starting System - Test

## General Information

All electrical starting systems have four elements:

- Keyswitch
- Start relay
- Starting motor solenoid
- Starting motor

Keyswitches 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 keyswitch.

Power which is available during cranking varies according to the temperature and condition of the batteries. Table 16 shows the voltages which are expected from a battery at the various temperature ranges.

Table 16

| 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 |

Table 17 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 17

| 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 17 are caused most often by the following conditions:

- Loose connections
- Corroded connections
- Faulty switch contacts

## Diagnosis Procedure

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

NOTICE

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

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

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

**1.** Measure the voltage of the battery.

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

**a.** If the voltage is equal to or greater than the voltage in Table 16, then go to Step 2.

**b.** The battery voltage is less than the voltage in Table 16.

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 16.
- 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 to or greater than the voltage that is given in Table 16, 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 16. 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 17.

b. Voltage drops are equal to the voltage drops that are given in Table 17 or the voltage drops are less than the voltage drops that are given in Table 17. 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 17. 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.

i02404326

# 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 each 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 18

| 12 Volt System | |
|---|---|
| **Amp** | **Time (sec)** |
| 16.6 | Initial |
| 12 | 5.7 |
| 9 | 11.1 |
| 7 | 20 |
| 6 | 60 |

Table 19

| 24 Volt System | |
|---|---|
| **Amp** | **Time (sec)** |
| 9 | Initial |
| 7 | 3.3 |
| 6 | 5.3 |
| 3 | 60 |

6. Check the reading on each 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 faulty glow plug. If there is still no reading replace the faulty glow plug.

# Index

## A



## B



## C



## E



## F

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