

# Systems Operation Testing and Adjusting

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## **854E-E34TA, 854F-E34T and 854F- E34TA Industrial Engines**

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JR (Engine)  
JS (Engine)  
JT (Engine)  
JV (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.



The meaning of this safety alert symbol is as follows:

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

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

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

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

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



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

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

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# Systems Operation Section

## General Information

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### Introduction

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

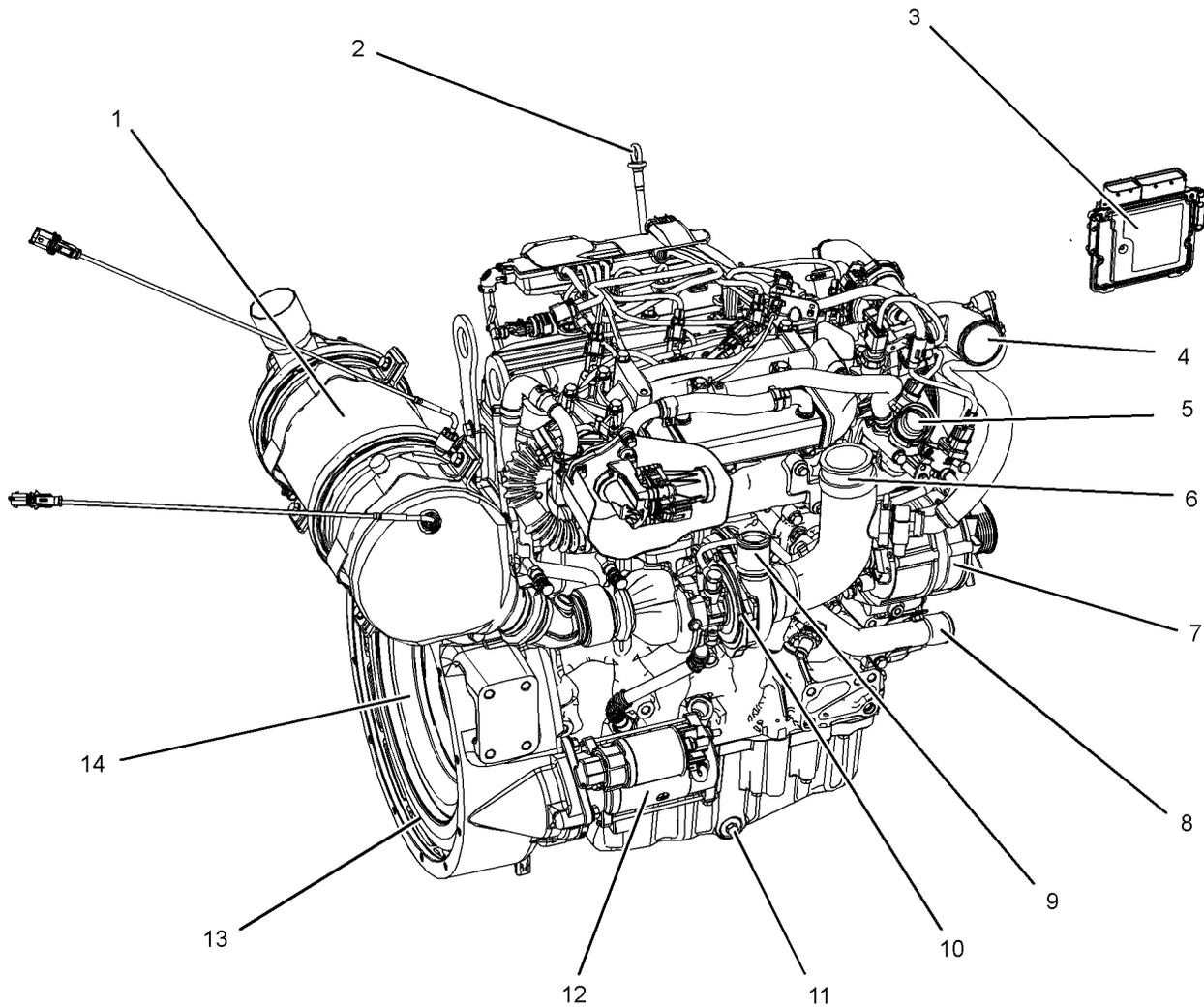


Illustration 1

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Typical example

- |   |   |                       |
|---|---|-----------------------|
| (1) Clean Emissions Module (CEM)            | (6) Air intake from air filter              | (11) Oil drain plug   |
| (2) Oil gauge (Dipstick)                    | (7) Alternator                              | (12) Starting motor   |
| (3) Electronic Control Module (ECM)         | (8) Coolant intake connection               | (13) Flywheel housing |
| (4) Air inlet connection from charge cooler | (9) Air outlet connection from turbocharger | (14) Flywheel         |
| (5) Coolant outlet connection               | (10) Turbocharger                           |                       |

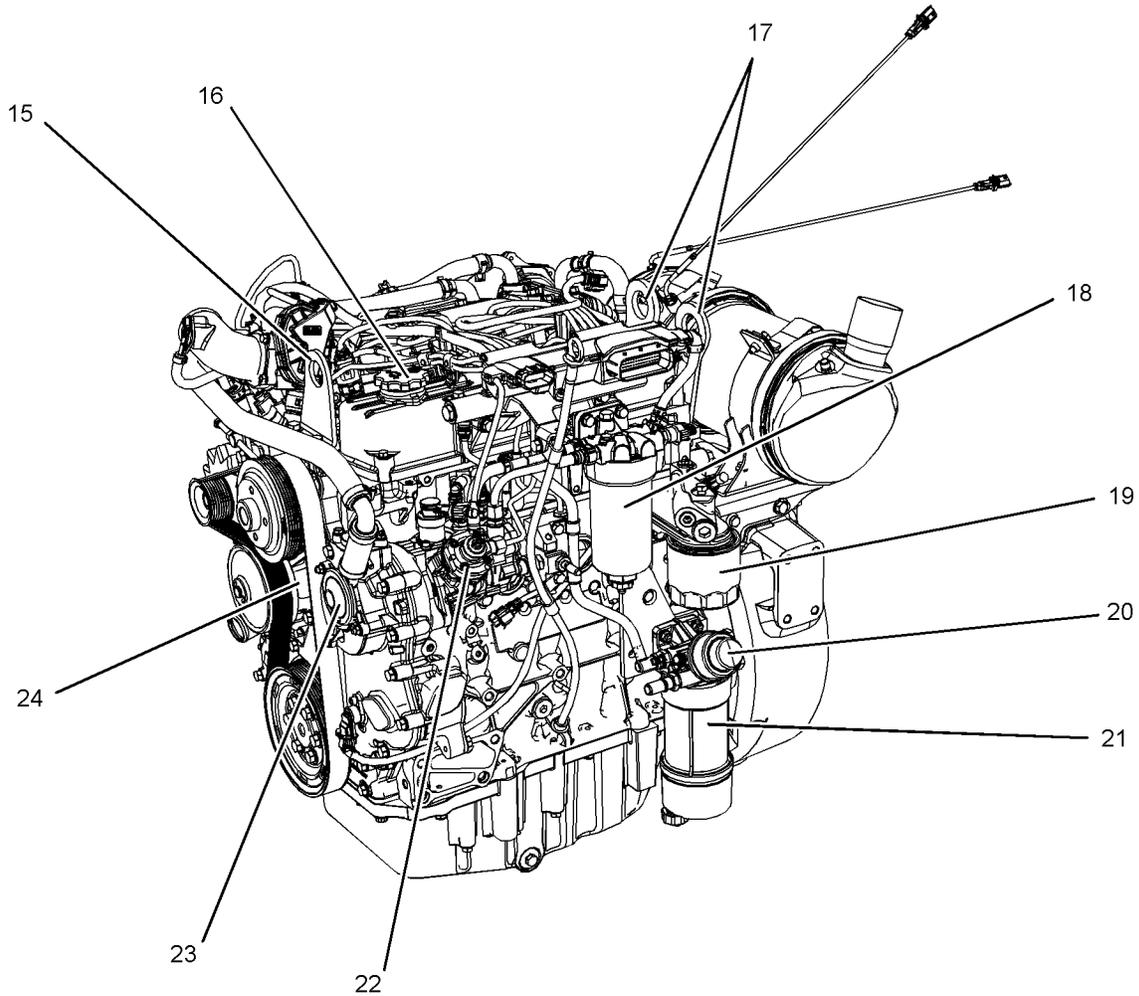


Illustration 2

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Typical example

- (15) Front lifting eye
- (16) Oil filler cap
- (17) Rear lifting eyes
- (18) Secondary fuel filter

- (19) Oil filter
- (20) Fuel priming pump
- (21) Primary fuel filter
- (22) Fuel injection pump

- (23) Crankcase breather
- (24) Water pump

**Note:** The primary fuel filter (21) may be supplied loose.

**Note:** The Electronic Control Module (ECM) (3) will be mounted to the application.

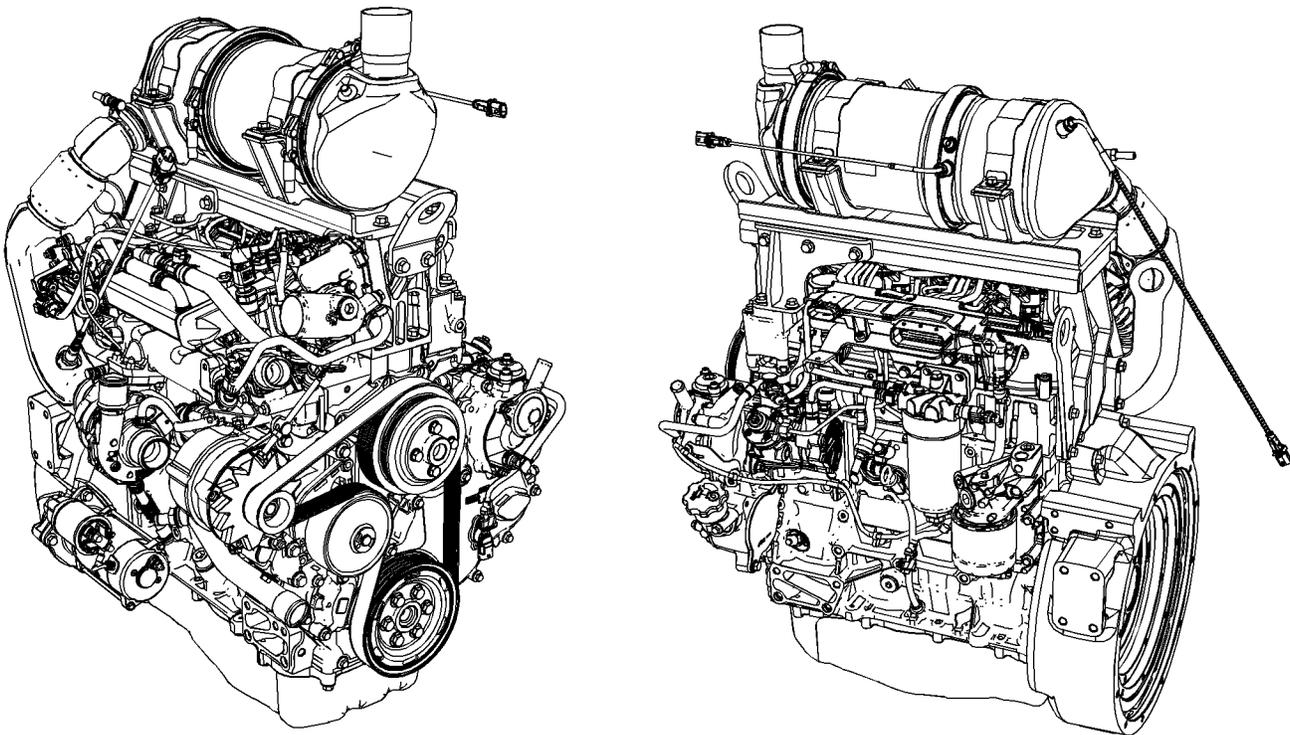


Illustration 3

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### Typical example of an engine with top mounted aftertreatment

The 854E-E34TA, 854F-E34T, and 854F-E34TA diesel engines are electronically controlled. The 854E-E34TA, 854F-E34T, and 854F-E34TA engines have an Electronic Control Module (ECM) that receives signals from the fuel injection pump and other sensors to control the electronic unit injector. The fuel injection pump supplies fuel to the fuel manifold (Rail). The fuel manifold (Rail) distributes fuel to the electronic unit injectors.

The four cylinders are arranged in-line. The cylinder head assembly has one inlet valve and one exhaust valve for each cylinder. The port for the exhaust valve is on the right side of the cylinder head. The port for the inlet valve is on the top 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 to cool the piston. The pistons have a Quiescent combustion chamber in the top of the piston to achieve clean exhaust emissions. The piston pin is off-center 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 to reduce wear of the groove. The skirt has a layer of graphite to reduce the risk of seizure when the engine is new. The correct piston height is important 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 to conform to requirements for emissions.

The crankshaft has five main bearing journals. End play is controlled by thrust washers which are on both sides of the number 3 main bearing.

The timing case is made of cast iron. Some of the timing gears are stamped with timing marks to ensure the correct assembly of the gears. When the number 1 piston is at a certain position, the marked teeth on the camshaft gear will align with the marks that are on the gear on the crankshaft.

There are no timing marks on the rear face of the timing case.

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

- the idler gear
- the idler gear for the engine oil pump
- the engine oil pump gear

## General Information

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- the accessory drive gear
- the fuel injection pump gear

The camshaft runs at half the rpm of the crankshaft. The fuel injection pump runs at one and a half times the speed as the crankshaft.

The fuel injection pump that is installed on the left side of the engine is gear-driven from the timing case. The internal fuel transfer pump is driven by the fuel injection pump. The fuel transfer pump draws low-pressure fuel from the primary fuel filter. The fuel transfer pump delivers the fuel to the secondary filter. The fuel then travels to the fuel injection pump.

The fuel injection pump increases the fuel to a maximum pressure of 160 MPa (23200 psi). The fuel injection pump delivers the fuel to the fuel manifold (Rail). The fuel injection pump is not serviceable. The engine uses speed sensors and the Electronic Control Module (ECM) to control the engine speed.

For the specifications of the 854E-E34TA, 854F-E34T, and 854F-E34T engines, refer to the Specifications, "Engine Design".

# Engine Operation

## Basic Engine

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### Introduction

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

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

### Cylinder Block

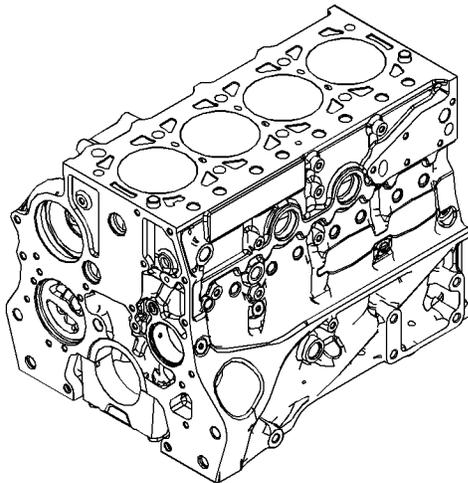


Illustration 4

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#### Typical example

The cast iron cylinder block for the engine has four cylinders which are arranged in-line. The cylinder block is made of cast iron. The cylinder block provides support for the full length of the cylinder bores. The cylinder bores are machined into the block.

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

The cylinder block has five main bearings which support the crankshaft. Thrust washers are installed on both sides of number 3 main bearing in order to control the end play of the crankshaft. The thrust washers can only be installed one way.

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

Cooling passages are cast into the cylinder block in order to allow the circulation of coolant.

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

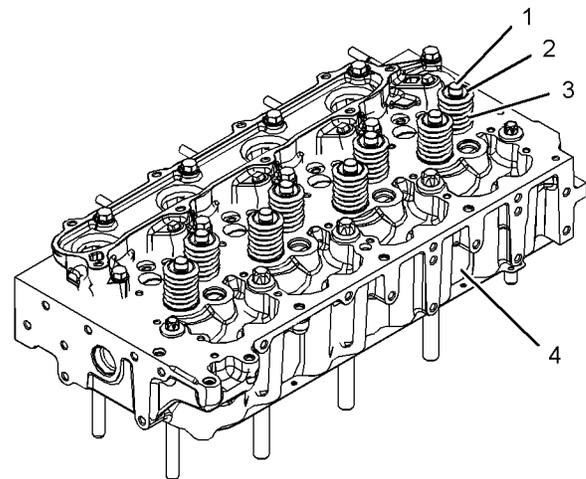


Illustration 5

g02859418

#### Typical example

- (1) Valve keepers
- (2) Valve spring retainer
- (3) Valve spring

The engine has a cast iron cylinder head (4). There is one inlet valve and one exhaust valve for each cylinder.

The port for the inlet valve is on the top of the cylinder head. The port for the exhaust valve is on the right side of the cylinder head. The valve stems move in valve guides that are pressed into the cylinder head. There is a renewable oil seal that fits over the top of the valve guide. The valve seats and the valve guides are replaceable.

## Pistons, Rings, and Connecting rods

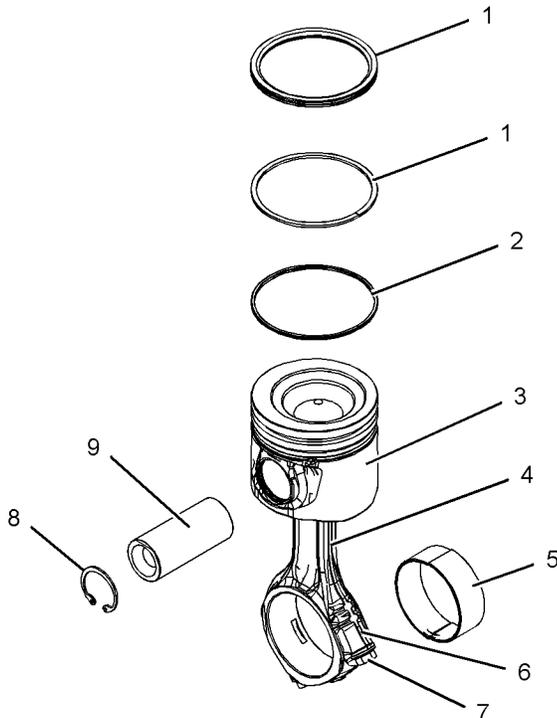


Illustration 6

g02859336

### Typical example

The pistons (3) 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 (9) is off-center in order to reduce the noise level. The position pin (9) is retained in the correct position by two circlips (8).

The pistons (3) have two compression rings (1) and an oil control ring (2). 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 (4) are machined from forged steel. The connecting rods have bearing caps (6) that are fracture split. The bearing caps (6) on fracture split connecting rods (4) are retained with bolts (7). 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.
- The correct connecting rod must be installed with the correct bearing cap. Each connecting rod and bearing cap have a unique serial number. When a connecting rod is assembled the serial numbers for the connecting rod and bearing cap must match.

## Crankshaft

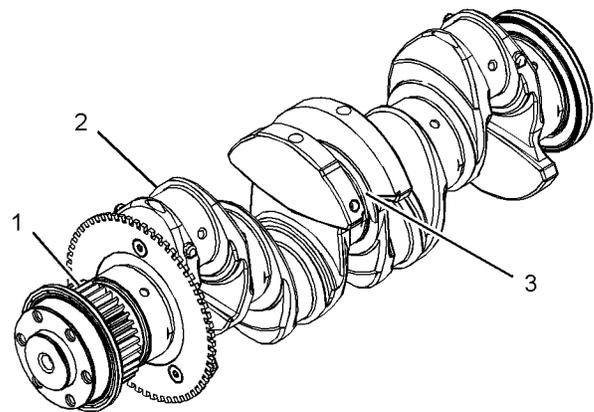


Illustration 7

g02841976

### Typical example

- (1) Crankshaft gear
- (2) Crankshaft
- (3) Crankshaft thrust washers

The crankshaft can be a spheroidal graphite iron casting.

The crankshaft has five main journals. Thrust washers are installed on both sides of number 3 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

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.

A timing ring for the balancer can be installed to the crankshaft. The timing ring for the balancer drives the balancer.

## Gears and Timing Gear Case

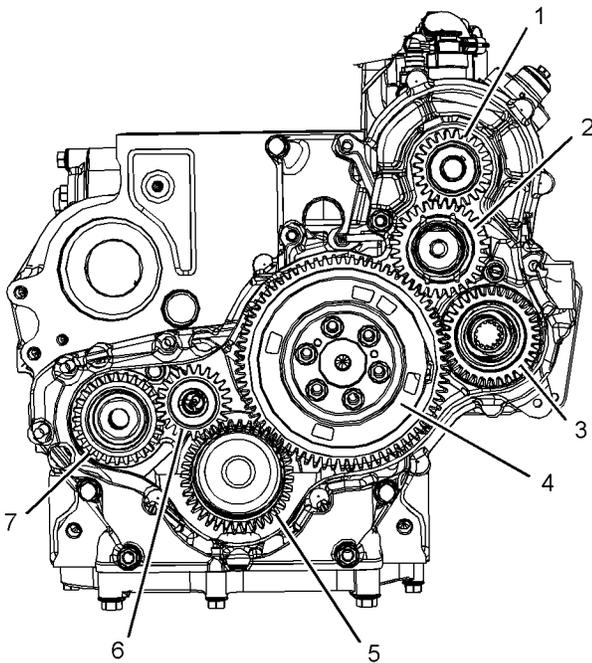


Illustration 8

g02859276

### Typical example

The crankshaft oil seal is mounted in the cover of the timing case. The timing case is made of cast iron. The timing case cover is made from aluminum.

The timing gears are made of steel.

The crankshaft gear (5) drives the camshaft gear (4) and an idler gear (6) for the engine oil pump. The idler gear (6) for the engine oil pump drives the oil pump gear (7). The camshaft gear (4) drives the idler gear (2) and the accessory drive gear (3). The idler gear (2) drives the fuel injection pump gear (1).

The camshaft gear rotates at half the engine speed. The fuel injection pump gear rotates at one and a half times engine speed.

## Camshaft

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

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

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

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## Air Inlet and Exhaust System

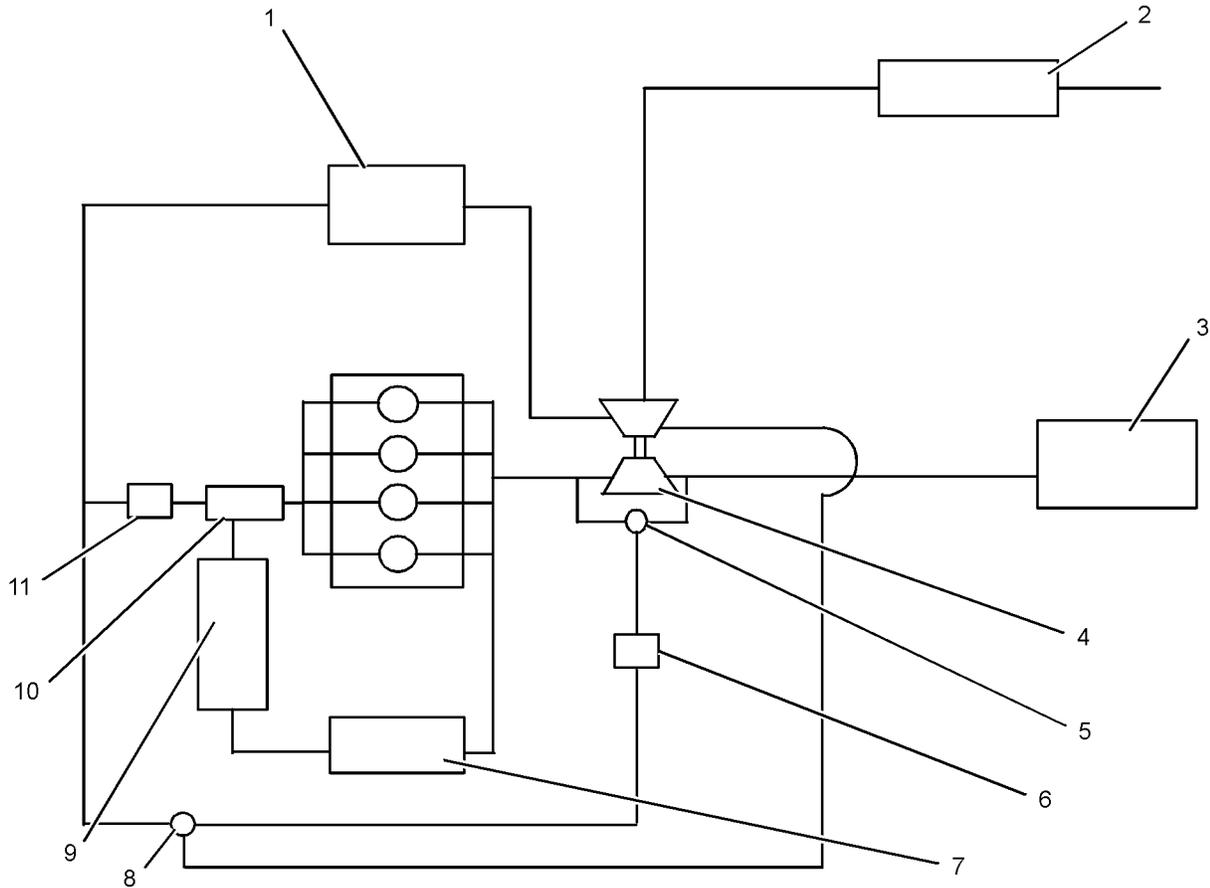


Illustration 9  
Air inlet and exhaust system

g02720982

- |                               |                             |                          |
|-------------------------------|-----------------------------|--------------------------|
| (1) Aftercooler core          | (5) Wastegate actuator      | (9) Exhaust cooler (NRS) |
| (2) Air filter                | (6) Boost pressure chamber  | (10) Inlet manifold      |
| (3) Diesel particulate filter | (7) Exhaust gas valve (NRS) | (11) Throttle valve      |
| (4) Turbocharger              | (8) Wastegate regulator     |                          |

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
- Exhaust cooler (NRS)
- Exhaust gas valve (NRS)
- Turbocharger
- Aftercooler
- Inlet manifold
- Cylinder head, injectors, and glow plugs
- Valves and valve system components
- Piston and cylinder
- Exhaust manifold
- Diesel oxidation catalyst
- Diesel particulate filter
- Throttle valve

Air is drawn in through the air cleaner into the air inlet of the turbocharger by the turbocharger compressor wheel. The air is compressed to a pressure of about 150 kPa (22 psi) and the compression heats the air to about 120° C (248° F) before the air is forced to the aftercooler. As the air flows through the aftercooler the temperature of the compressed air lowers to about 55° C (131° F). Cooling of the inlet air assists the combustion efficiency of the engine. Increased combustion efficiency helps achieve the following benefits:

- Lower fuel consumption
- Increased power output
- Reduced NOx emission
- Reduced particulate emission

From the aftercooler, air is forced into the inlet manifold. Air flow from the inlet manifold to the cylinders is controlled by inlet valves. There is one inlet valve and one exhaust valve for each cylinder. The inlet valve opens when the piston moves down on the intake stroke. When the inlet valve opens, 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 valve closes. The cool compressed air is compressed further. This additional compression generates more heat.

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

Just before the piston reaches the top center (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 valve opens. The exhaust gases are forced through the open exhaust valve into the exhaust manifold.

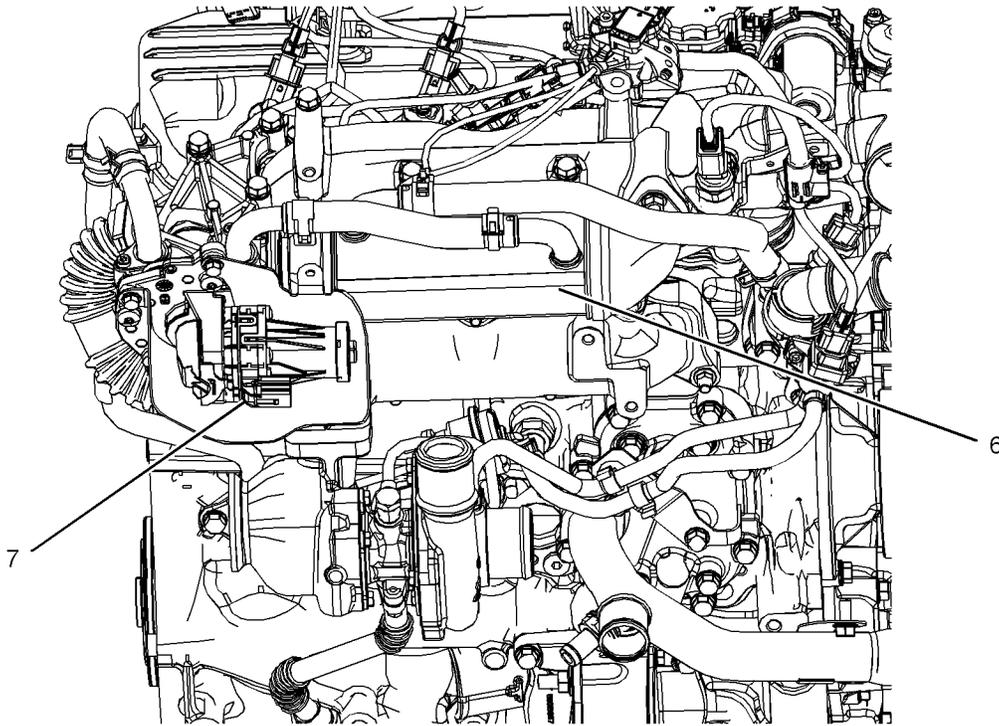


Illustration 10

g02720984

### Typical example

The NOx Reduction System (NRS) operates with the transfer of the hot exhaust gas from the exhaust manifold to the assembly of the exhaust gas valve.

The assembly of the exhaust gas valve consists of an exhaust gas valve and an electronically controlled actuator.

As the electronically controlled actuator (7) starts to open the flow of exhaust gas from the exhaust gas valve mixes with the air flow from the charge air aftercooler. The mixing of the exhaust gas and the air flow from the charge air aftercooler reduces the oxygen content of the gas mixture. This results in a lower combustion temperature, so decreases the production of NOx.

As the demand for more exhaust gas increases the electronically controlled actuator opens further. The further opening of the actuator increases the flow of exhaust gas from the exhaust gas valve. As the demand for exhaust gas decreases, the electronically controlled actuator closes. This decreases the flow of exhaust gas from the exhaust gas valve.

The hot exhaust gas is then cooled in the exhaust cooler (6). The cooled gas then travels from the exhaust cooler (6) to the inlet manifold.

Exhaust gases from the exhaust manifold enter the inlet of the turbocharger in order to turn the turbocharger turbine wheel. The turbine wheel is connected to a shaft that rotates. The exhaust gases pass from the turbocharger through the following components: exhaust outlet, Diesel Oxidation Catalyst (DOC), Diesel Particulate Filter (DPF) and exhaust pipe.

# Turbocharger

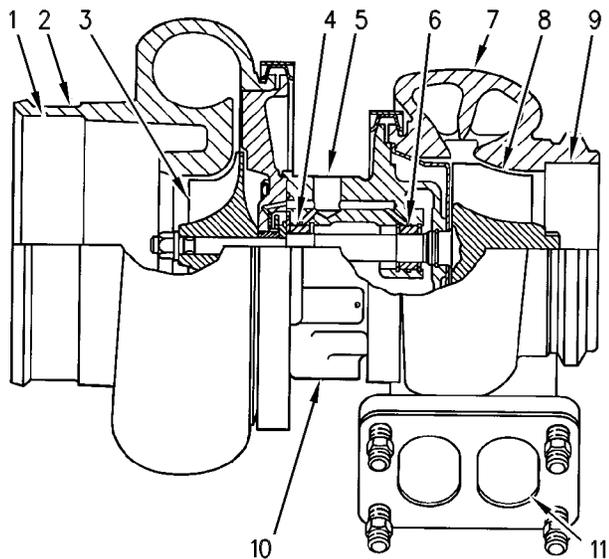


Illustration 11 g00302786

## Typical example of a cross section of a 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. 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. The rotation of the compressor wheel causes the intake air to be pressurized through the compressor housing (2) of the turbocharger.

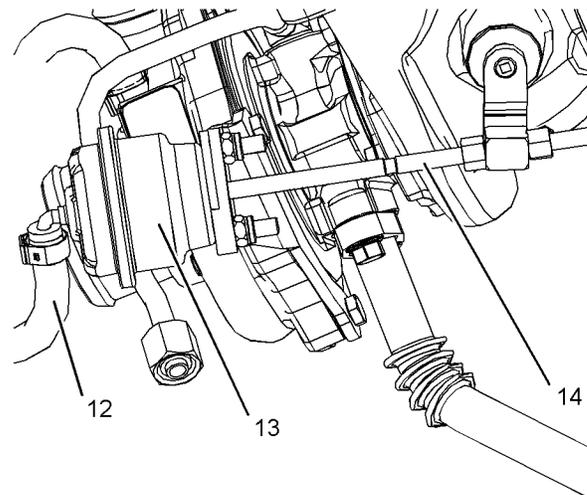


Illustration 12 g02720975

## Typical example

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

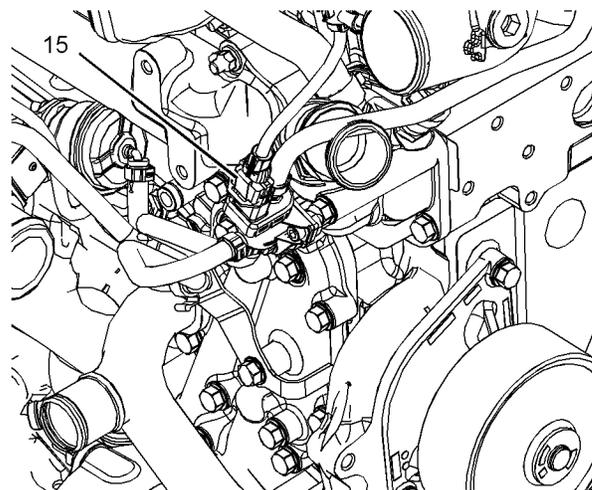


Illustration 13 g02720981

## Typical example

- (15) Wastegate regulator

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. The more efficient burning of fuel 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. The diaphragm is spring loaded in the wastegate actuator which varies the amount of exhaust gas that flows into the turbine.

The wastegate regulator (15) 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 wastegate regulator, that 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 regulator. This causes high pressure in the inlet manifold to act on the diaphragm within the wastegate actuator (13). The actuating rod (14) 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 regulator. This causes high pressure in the air inlet pipe (12) to act on the diaphragm within the wastegate actuator (13). The actuating rod (14) 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 a 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.

## Crankcase Breather

### NOTICE

The crankcase breather gases are part of the engines measured emissions output. Any tampering with the breather system could invalidate the engines emissions compliance.

The crankcase breather has a centrifugal separator. The centrifugal separator has a special coating. Engine oil that has been separated from the breather gas is returned to the timing case. The crankcase breather is driven by the shaft of the fuel injection pump.

A heated connection may be installed on the pipe for the crankcase breather. The purpose of the heated connection is to prevent the formation of ice in cold climates, that could lead to an obstruction of the pipe.

## Valve System Components

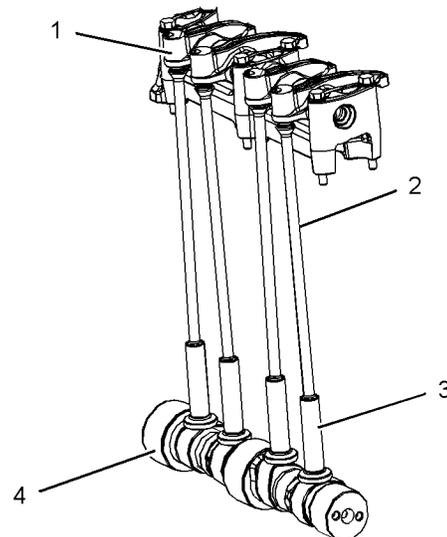


Illustration 14

g02720989

### Valve system components

- (1) Rocker arm
- (2) Pushrod
- (3) Lifter
- (4) Camshaft

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. 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 the inlet valve or the exhaust valve. As the camshaft turns, lobes on the camshaft cause the lifter to move the pushrod up and down. Upward movement of the pushrod against rocker arm results in a downward movement.

This action opens a pair of valves which compresses the valve springs. 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 under compression start to expand. The valve stems are under tension of the springs. The stems are pushed upward. The continued rotation of the camshaft causes the rocker arm, the pushrods and the lifters to move downward until the lifter reaches the bottom of the lobe. The valves are now closed. The cycle is repeated for all the valves on each cylinder.

The rocker arm incorporates a hydraulic lash adjuster which removes valve lash from the valve mechanism. The hydraulic lash adjuster uses engine lubricating oil to compensate for wear of system components so that no service adjustment of valve lash is needed.

The engine lubricating oil enters the hydraulic lash adjuster through a non-return valve. The engine lubricating oil increases the length of the hydraulic lash adjuster until all valve lash is removed. If the engine is stationary for a prolonged period the valve springs will cause the hydraulic lash adjuster to shorten so that when the engine is started engine valve lash is present for the first few seconds.

After cranking restores oil pressure the hydraulic lash adjuster increases in length and removes the valve lash. When load is removed from a hydraulic lash adjuster during service work by the removal of the rocker shaft the hydraulic lash adjuster increases in length to the maximum extent. Refer to Systems Operation, Testing and Adjusting, "Position the Valve Mechanism Before Maintenance Procedures" for the correct procedure.

During reassembly of the rocker shaft the engine must be put into a safe position to avoid engine damage. After load is imposed on the lifters by reassembling the rocker assembly, the engine must be left in safe position for a safe period until the lifters have reduced to the correct length. Refer to Disassembly and Assembly, "Rocker Shaft and Pushrod - Install" for the correct procedure.

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## Clean Emissions Module

To meet current emissions legislation requirements, a small amount of certain chemical compounds that are emitted by the engine must not be allowed to enter the atmosphere. The Clean Emissions Module (CEM) that is installed to the engine is designed to convert these chemical compounds into less harmful compounds.

The Engine Aftertreatment System for the engine consists of the following components.

- Diesel Oxidation Catalyst (DOC)
- Diesel Particulate Filter (DPF)

The Diesel Oxidation Catalyst (DOC) oxidizes the carbon monoxide and the hydrocarbons that are not burnt in the exhaust gas into carbon dioxide and water. The Diesel Oxidation Catalyst (DOC) is a through flow device that will continue to operate during all normal engine operating conditions.

The Diesel Particulate Filter (DPF) collects all solid particulate matter in the exhaust gas.

The solid particulate matter that is collected by the DPF consists of soot (carbon) from incomplete combustion of the fuel and inorganic ash from the combustion of any oil in the cylinder.

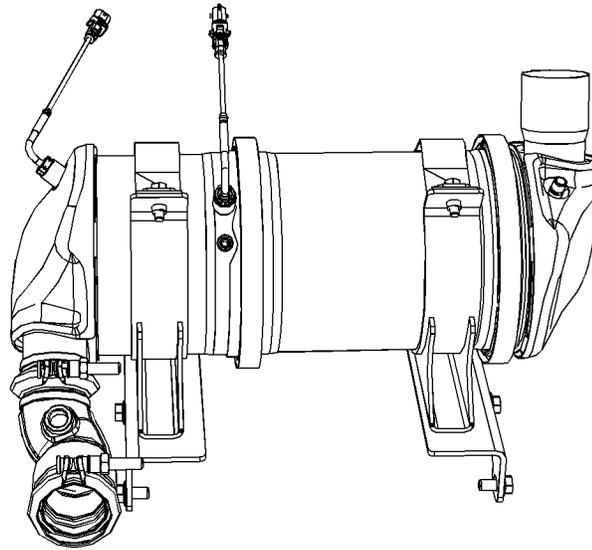


Illustration 15

g03343187

A typical example of a CEM with a wall flow Diesel Particulate Filter (DPF)

For engines with a power rating of 55 kW or higher, a wall flow Diesel Particulate Filter (DPF) is used.

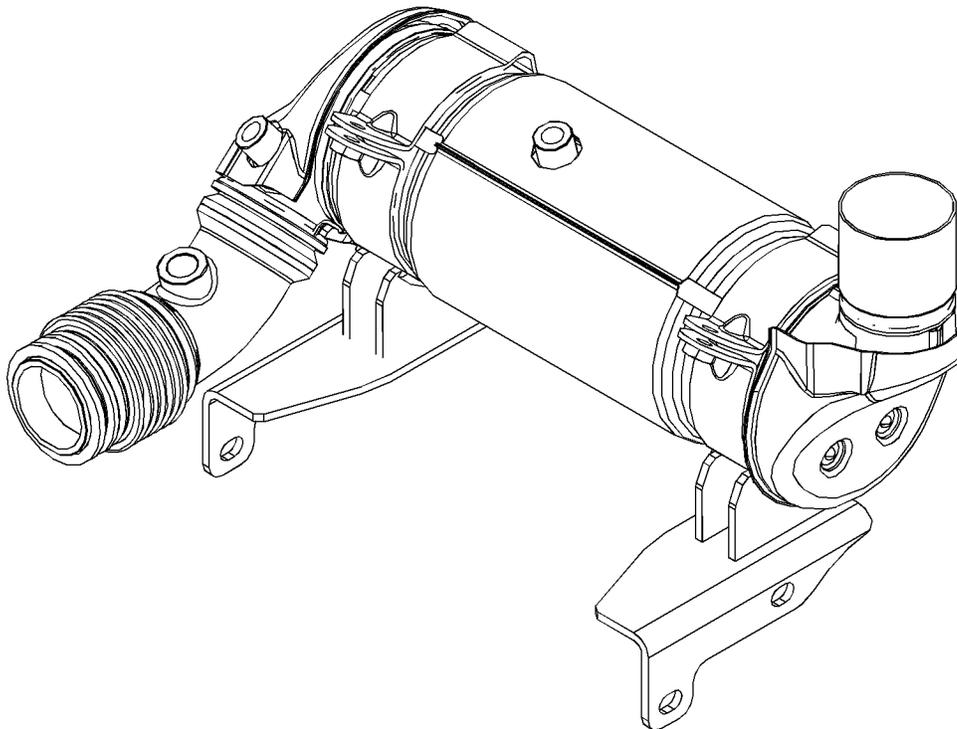


Illustration 16

g03343192

A typical example of a CEM with a through flow Diesel Particulate Filter (DPF)

For engines with a power rating of 55 kW or lower, a through flow Diesel Particulate Filter (DPF) is used.

The wall flow Diesel Particulate Filter (DPF) is designed to contain all the ash up to the ash service interval. Refer to Operation and Maintenance Manual for more information.

No ash service is required for the through flow Diesel Particulate Filter (DPF).

The engine aftertreatment system is designed to oxidize the soot in the DPF at the same rate as the soot is produced by the engine. The oxidization of the soot will occur when the engine is operating under normal conditions. The soot in the DPF is constantly monitored.

The regeneration system is passive with an additional Oxy-Exotherm system. The Oxy-Exotherm system operates by injecting fuel after the main fuel injection period. The fuel is then burnt over a catalyst to raise the temperature of the exhaust gases to 650° C (1202° F).

If the engine is operated in a way that produces more soot than the oxidized soot, the engine management system will automatically activate systems to raise the exhaust temperature. The raising of the exhaust temperature will ensure that more soot is oxidized than the soot that is produced by the engine. The oxidization of more soot returns the DPF to a reduced level of soot. The systems are then deactivated when the soot level has been reduced.

The engine ECM must know how much soot is in the DPF. Measurement of soot is accomplished through the following means:

- Soot Load Estimation Model that is based on engine operating conditions
- Delta pressure measurement across the DPF used to estimate the soot load by evaluation of the flow resistance of the Diesel Particulate Filter (DPF)

The Electronic Control Module (ECM) uses the soot measurement information to determine if the engine operating conditions need to be adjusted in order to oxidize the soot at an increased rate.

i04169911

## Cooling System

### Introduction

The cooling system has the following components:

- Radiator
- Water pump
- Cylinder block
- Oil cooler

- Exhaust gas cooler (NRS)
- Cylinder head
- Water temperature regulator (thermostat)

## Coolant Flow

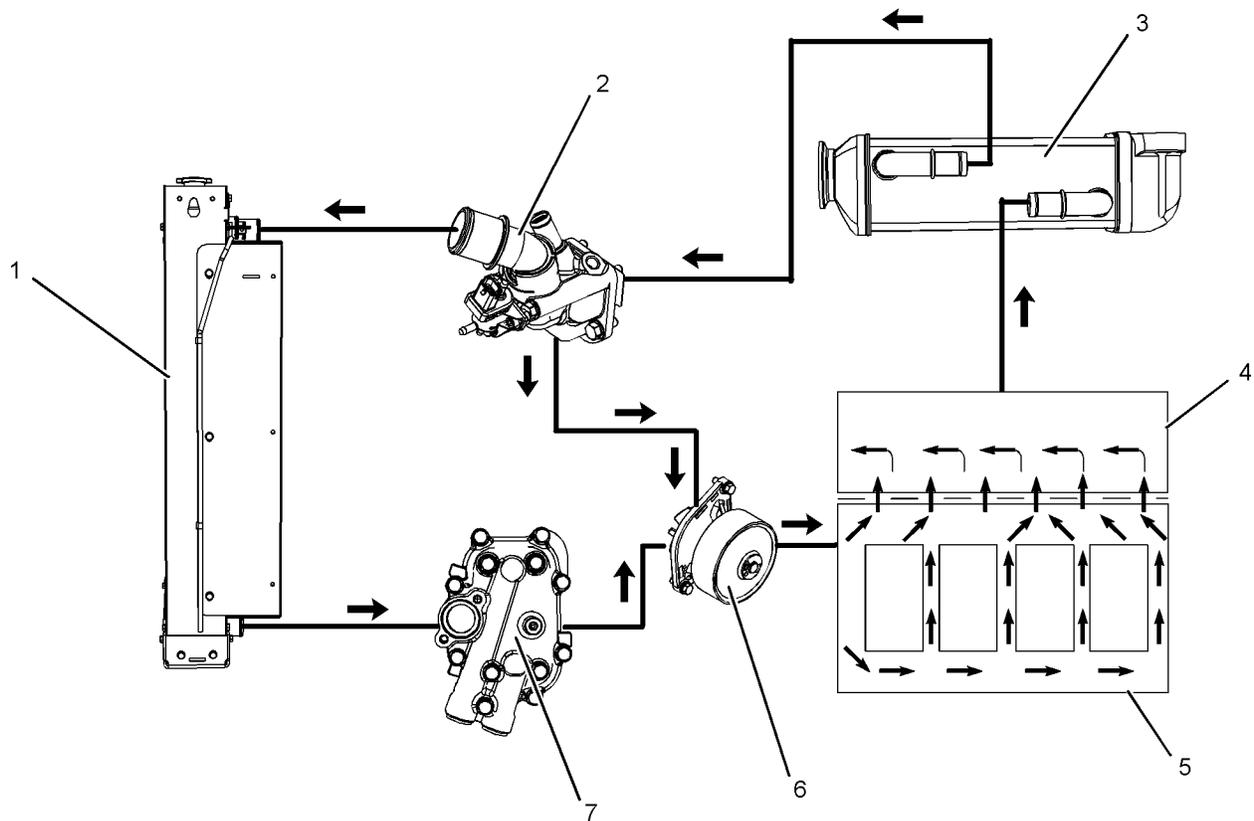


Illustration 17

g02847496

### Typical example

(1) Radiator  
(2) Water temperature regulator and housing

(3) Exhaust gas cooler (NRS)  
(4) Cylinder head  
(5) Cylinder block

(6) Water pump  
(7) Engine oil cooler

The coolant flows from the bottom of the radiator (1) to the engine oil cooler (7). The engine oil cooler (7) is installed on the right-hand side of the engine. The coolant flows from the engine oil cooler (7) to the water pump (6).

The water pump (6) contains a rotary seal that uses the engine coolant as a lubricating medium. This will ensure that an adequate sealing film is created. The sealing film is maintained in order to reduce heat generation. Heat that is generated by the rotating sealing faces under normal operating conditions causes a small flow of coolant to be emitted into a chamber. The water pump pumps the coolant through a passage to the main coolant gallery in the cylinder block (5).

Coolant flows around the outside of the cylinders then flows from the cylinder block (5) into the cylinder head (4).

The coolant flows forward through the cylinder head (4). Some coolant is diverted into the exhaust gas cooler (NRS) (3) by a coolant pipe in the right-hand side of the cylinder block (5). The coolant then flows from the exhaust gas cooler (NRS) (3) back to the housing of the water temperature regulator (2).

The coolant then flows into the housing of the water temperature regulator (2). If the water temperature regulator is closed, the coolant goes directly through a bypass to the inlet side of the water pump. If the water temperature regulator is open, and the bypass is closed then the coolant flows to the top of the radiator (1).

i04169606

## Lubrication System

Lubricating oil from the oil pan flows through a strainer and a pipe to the suction side of the engine oil pump. Pressure for the lubrication system is supplied by the oil pump. The crankshaft gear drives a lower idler gear. The lower idler gear drives the oil pump gear. The pump has an inner rotor and an outer rotor. The axis of rotation of the rotors are off-center relative to each other. There is an interference fit between the inner rotor and the drive shaft.

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

The lubricating oil flows from the outlet side of the oil pump through a passage to a plate type oil cooler. The oil cooler is located on the right side of the cylinder block.

The lubricating oil flows from the oil cooler through a passage to the oil filter head. The oil then flows through a bypass valve that permits the lubrication system to function if the oil filter becomes blocked. Under normal conditions, the oil then flows to the oil filter.

The oil flows from the oil filter through a passage that is drilled across the cylinder block to the oil gallery. The oil gallery is drilled through the total length of the left side of the cylinder block.

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

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

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

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

i04169852

## 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

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 ignition switch is deactivated once the desired engine speed has been achieved. The circuit is disconnected. The armature will stop rotating. Return springs that are located on the shafts and the solenoid will disengage the pinion from flywheel ring gear back to the rest position.

The armature of the starting motor and the mechanical transmissions may be damaged if the increases in the speed of the engine are greater than the pinion of the starting motor. Damage may occur when the engine is started or after the engine is started. An overrunning clutch prevents damage to the armature of the starting motor and mechanical transmissions.

## 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 for charging and machine load requirements. A warning lamp can be connected via the ignition switch. This wiring is optional.

i04173673

## 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. Washing the engine will remove dirt and loose debris before a repair on the fuel system is started. Ensure that no high-pressure water is directed at the seals for the injectors or electrical connectors.

### Environment

When possible, the service area should be positively pressurized. 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 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 that is free from contamination. Ultra Low Sulfur Diesel (ULSD) must be used. The content of sulfur in Ultra Low Sulfur Diesel (ULSD) fuel must be below 15 PPM 0.0015%.

Biodiesel may be used. The neat biodiesel must conform to the latest "EN14214 or ASTM D6751" (in the USA). The biodiesel can only be blended in mixture of up to 20% by volume in acceptable mineral diesel fuel meeting latest edition of "EN590 or ASTM D975 S15" designation.

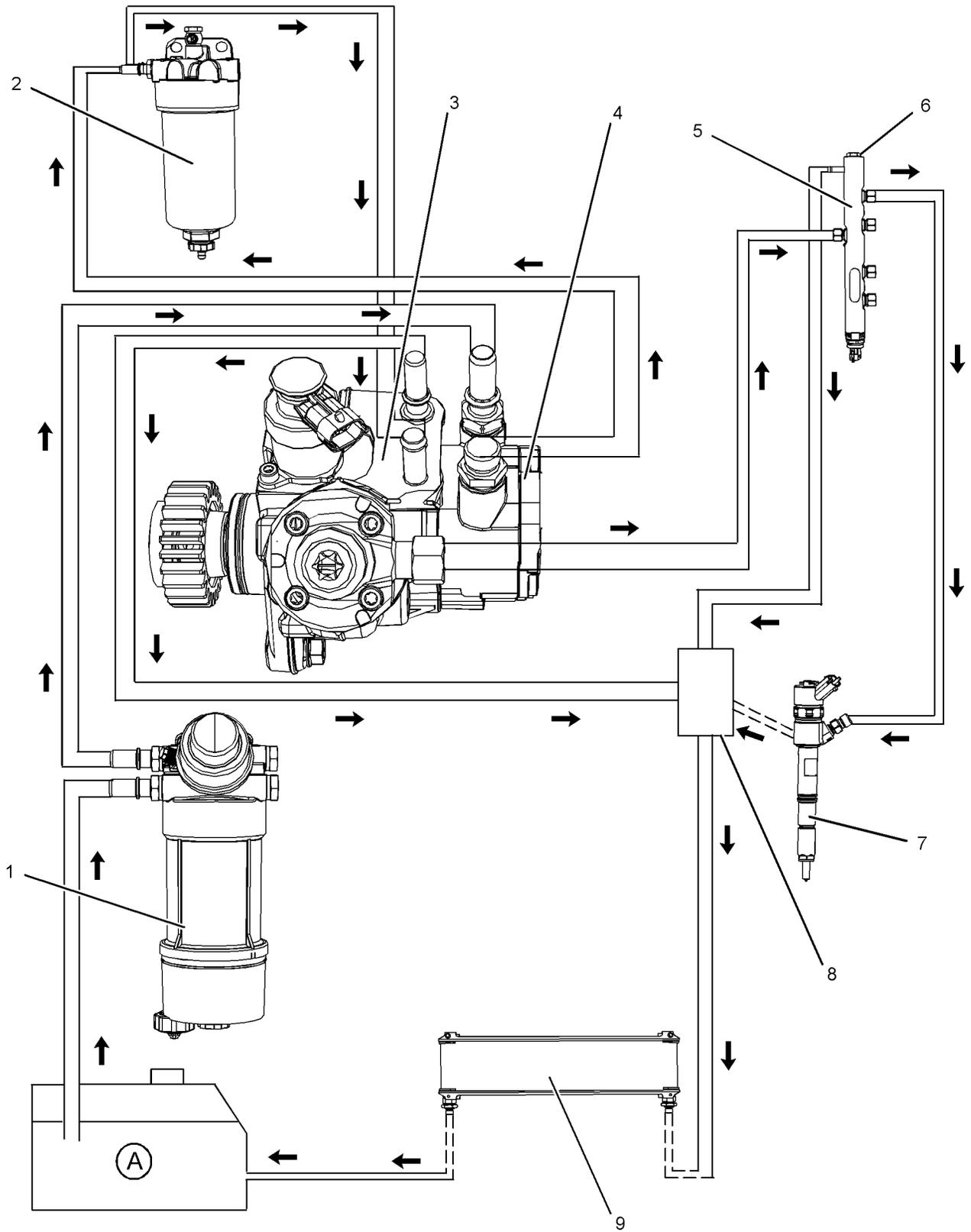
In United States, Biodiesel blends of B6 to B20 must meet the requirements listed in the latest edition of "ASTM D7467" (B6 to B20) and must be of an API gravity of 30-45.

For more information, refer to Operation and Maintenance Manual, "Fluid Recommendations".

i04175249

## **Fuel Injection**

### **Introduction**



### Typical example

- |                           |                              |                               |
|---------------------------|------------------------------|-------------------------------|
| (1) Primary fuel filter   | (5) Fuel manifold (rail)     | (9) Fuel cooler (if equipped) |
| (2) Secondary fuel filter | (6) Pressure relief valve    | (A) Fuel tank                 |
| (3) Fuel Injection Pump   | (7) Electronic unit injector |                               |
| (4) Fuel transfer pump    | (8) Manifold connector       |                               |

Fuel is drawn from the fuel tank to the 10 micron primary fuel filter and a water separator. The fuel then flows to the fuel transfer pump. The fuel transfer pump is part of the fuel injection pump.

Fuel then flows from the fuel transfer pump to the 4 micron secondary fuel filter. Fuel flows from the secondary fuel filter to the fuel injection pump.

At the fuel injection pump, the fuel is pumped at an increased pressure of up to 160 MPa (23200 psi) fuel manifold (rail).

Fuel that has too high a pressure from the fuel manifold (rail) returns through the pressure relief valve to the return line. Fuel that is leak off from the electronic unit injectors flows to the return line. The fuel may then flow through a fuel cooler (if equipped) on the way back to the fuel tank.

## High Pressure Fuel System

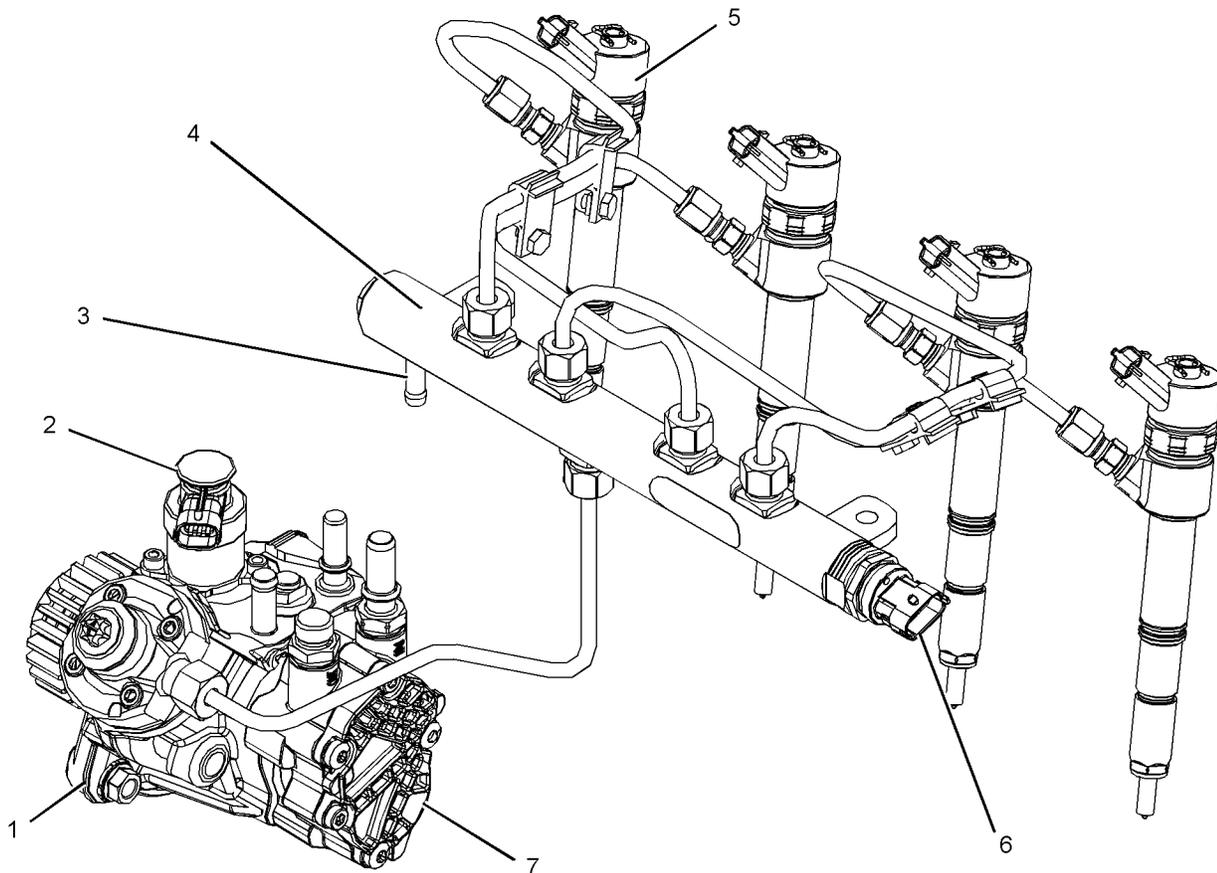


Illustration 19

g02493876

### Typical example

- |   |                              |                          |
|---|------------------------------|--------------------------|
| (1) Fuel injection pump                               | (3) Pressure relief valve    | (6) Fuel pressure sensor |
| (2) Suction control valve for the fuel injection pump | (4) Fuel manifold (rail)     | (7) Fuel transfer pump   |
|   | (5) Electronic unit injector |                          |

The fuel injection pump (1) feeds fuel to the high-pressure fuel manifold (rail) (4). The fuel is at a pressure of up to 160 MPa (23200 psi). A pressure sensor (6) in the high-pressure fuel manifold (rail) (4) monitors the fuel pressure in the high-pressure fuel manifold (rail). The ECM controls a suction control valve (2) in the fuel injection pump in order to maintain the actual pressure in the high-pressure fuel manifold at the desired level. The high-pressure fuel is continuously available at each injector (5). The ECM determines the correct time for activation of the correct electronic unit injector (5) which allows fuel to be injected into the cylinder. The leakoff fuel from each injector passes through an external pipe above the electronic unit injectors. The leakoff fuel then flows to a connector block on the left-hand side of the engine. A pipe is connected from the connector block in order to return the leakoff fuel to the fuel tank.

## Components of the Fuel Injection System

The fuel injection system has the following mechanical components:

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

- Fuel pressure sensor
- Fuel temperature sensor
- Water in fuel sensor

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

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

For the correct procedure to prime the fuel system, refer to Systems Operation, Testing and Adjusting, "Fuel System - Prime".

## Primary Filter/Water Separator

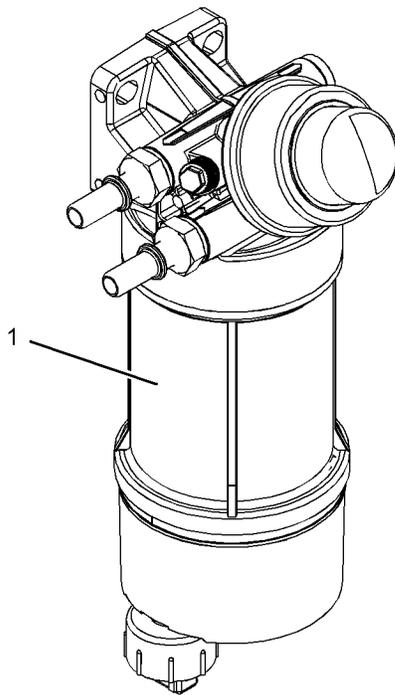


Illustration 20

g02848802

### Typical example

The primary filter/water separator (1) is located between the fuel tank and the fuel transfer pump. The primary filter/water separator (1) provides a 10 micron filtration level.

The primary filter/water separator can either be engine mounted or supplied loose. The primary filter/water separator is supplied with water in fuel sensor. The water in fuel sensor has to be connected.

## Secondary Fuel Filter

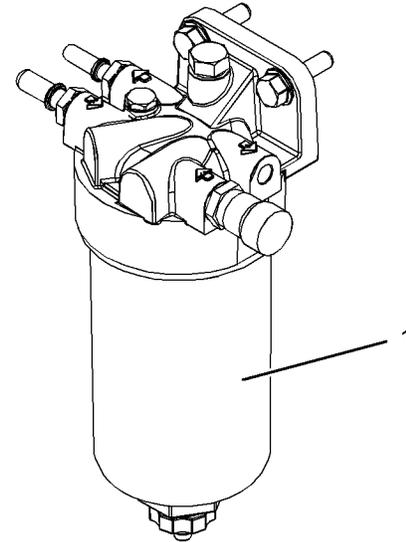


Illustration 21

g02848803

### Typical example

The secondary fuel filter (1) is located after the fuel transfer pump. The secondary fuel filter (1) provides a 4 micron filtration level.

The fuel temperature sensor measures the temperature of the fuel. The ECM receives the signal from the fuel temperature sensor. The ECM calculates the volume of fuel.

## Fuel Pump Assembly

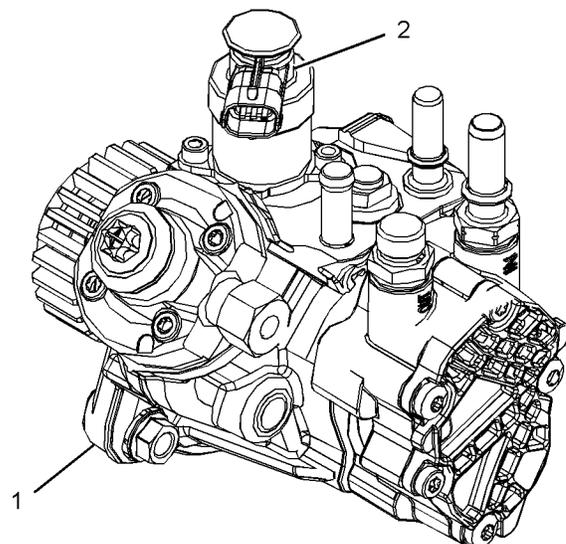


Illustration 22

g02493877

### Typical example

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 one and a half times the engine speed. The fuel injection pump (1) has one plunger that is driven by a camshaft. The stroke of the plunger is fixed but the volume of fuel that is provided by the fuel injection pump is controlled by the suction control valve.

The injector will use only part of the fuel that is delivered by each stroke of the pistons in the pump. The suction control valve (2) for the fuel injection pump is controlled by the ECM. This maintains the fuel pressure in the fuel manifold (rail) at the correct level. A feature of the fuel injection pump allows fuel to return to the tank continuously.

**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 the demand of fuel pressure.

**Shutoff**

The engine shuts off by preventing the electronic unit injectors from injecting. The ECM then closes the suction control valve to prevent the pressure in the fuel manifold (rail) from increasing.

Control

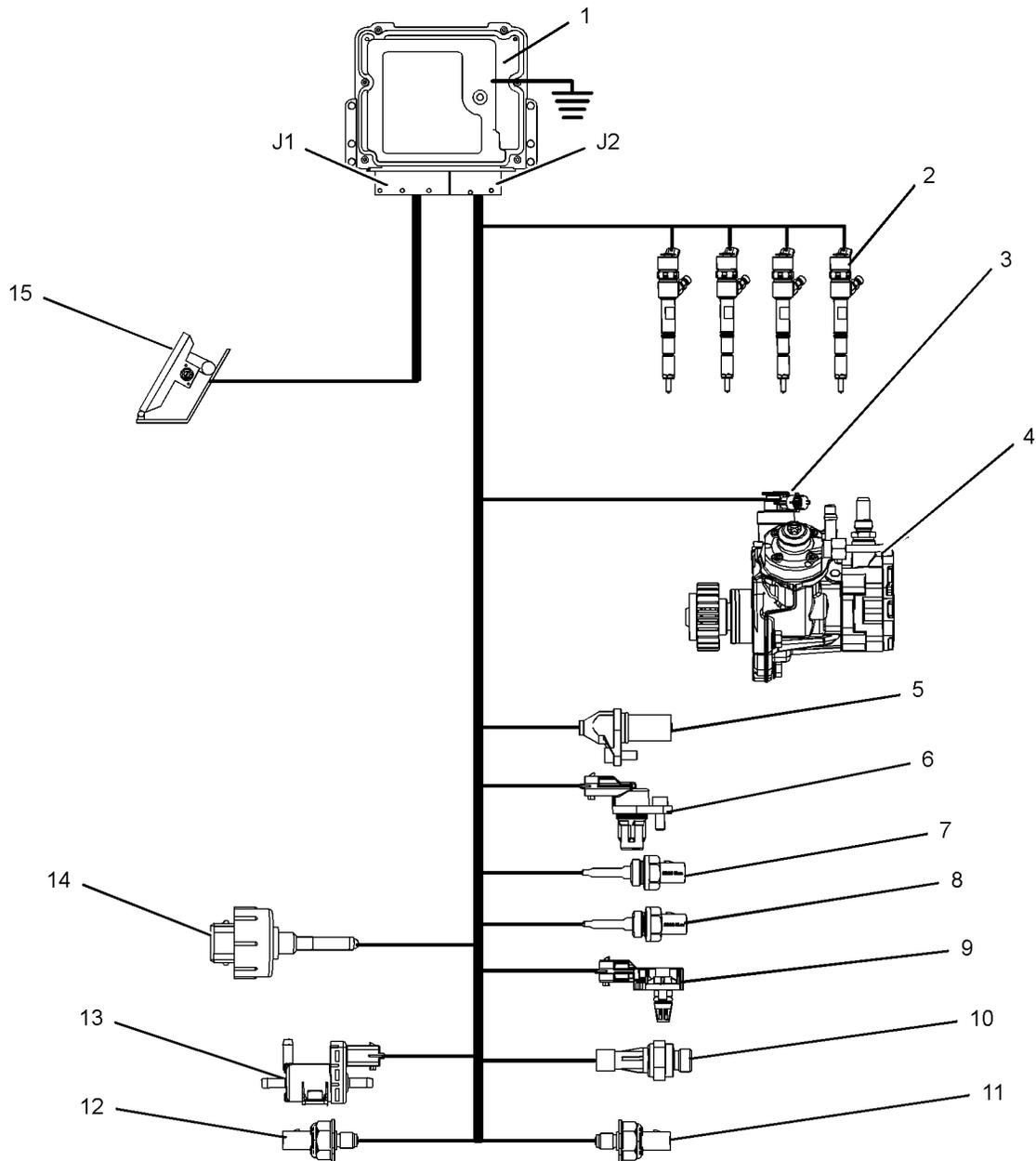


Illustration 23

g02511078

Typical example of the electrical control system for the fuel system

- |                                     |  |   |
|-------------------------------------|--|---|
| (1) Electronic Control Module (ECM) | (7) Coolant temperature sensor                         | (12) Pressure sensor for the NOx Reduction System (NRS) |
| (2) Electronic unit injectors       | (8) Fuel temperature sensor                            | (13) Wastegate regulator                                |
| (3) Suction control valve           | (9) Inlet manifold air temperature and pressure sensor | (14) Water in fuel sensor                               |
| (4) Fuel injection pump             | (10) Oil pressure switch                               | (15) Throttle position sensor                           |
| (5) Crankshaft position sensor      | (11) Fuel pressure sensor                              |   |
| (6) Camshaft position sensor        |  |   |

## Engine Operation

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 timing and the flow of fuel by actuating the injector solenoid.

The amount of fuel is injected is a function of fuel pressure in the fuel manifold and the duration of the signal to the injector solenoid.

The ECM controls the fuel pressure by increasing or decreasing the flow of fuel from the fuel injection pump.

## Fuel Injectors

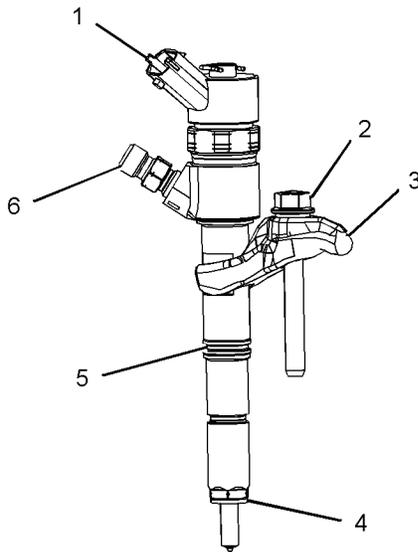


Illustration 24

g02493878

### Typical example

- (1) Electrical connections
- (2) Bolt
- (3) Clamp
- (4) Combustion washer
- (5) O-ring
- (6) Fuel inlet

The fuel injectors contain no serviceable parts apart from the O-ring seal and the combustion washer. The clamp and setscrew are serviced separately.

The injector nozzle and control piston volume are continuously connected to the fuel manifold (rail) through the high-pressure fuel line. The nozzle needle is controlled by the control piston, which in turn is controlled by the pressure in the control piston volume. The injector contains a solenoid valve that controls the spill flow from the control piston volume. The control piston volume has an inlet throttle and an outlet throttle. The sizing of the throttles determines the rate of pressure decay in the control volume and hence the rate of nozzle opening. By opening the solenoid valve, fuel flows out of the control volume lowering its internal pressure which allows nozzle pressure to lift the needle and control piston, this enables injection to occur.

To end injection, the solenoid valve is closed. Closing the solenoid valve blocks off the control volume outlet orifice which causes the control volume pressure to increase. By increasing control volume pressure, this forces the control piston, and needle, back down until the needle reseats in the nozzle. The injection process ends.

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

The electronic unit injectors can be instructed to inject fuel multiple times during the combustion process. A close pilot injection occurs before the main injection. The close pilot injection helps to reduce NOx and noise. The main injection period helps to increase the torque of the engine. The after injection period helps to reduce the amount of smoke that is produced.

## Fuel Manifold

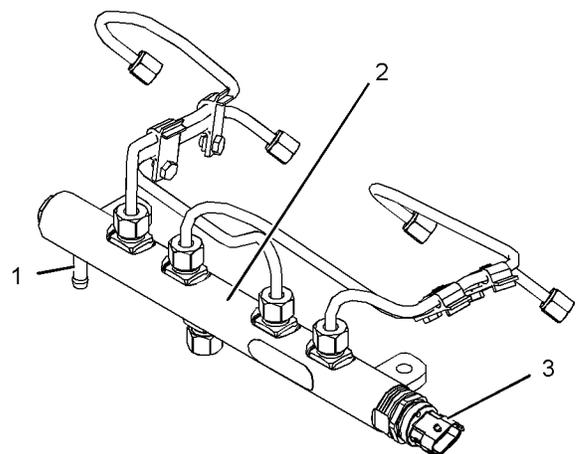


Illustration 25

g02493879

### Typical example



## Engine Operation

---

(16) Engine exhaust gas temperature sensor	(22) Oil pressure switch	(28) Primary fuel filter with water-in-fuel sensor
(17) Crankshaft speed/timing sensor	(23) Coolant temperature sensor	(29) Inlet manifold air temperature/pressure sensor
(18) Camshaft speed/timing sensor	(24) ECM	(30) Secondary fuel filter with fuel temperature sensor
(19) Electronic unit injectors	(25) Engine	(31) Fuel tank
(20) Fuel injection pump	(26) Glow plugs	
(21) Fuel pressure sensor	(27) Glow plug Control Unit (GCU)	

**Note:** A separate intake manifold air pressure sensor and intake manifold temperature sensor are installed on the 55 kW (74 hp) engine.

**Note:** The ECM is not mounted on the engine.

The electronic control system has the following components:

- ECM
- Pressure sensor
- Temperature sensors
- Crankshaft speed/timing sensor
- Camshaft speed/timing sensor
- The suction control valve for the fuel injection pump
- Wastegate solenoid
- Electronic unit injectors

## Sensor Locations for the Engine

The illustrations in this section show the typical locations of the sensors for the industrial engine. Specific engines may appear different from the illustration due to differences in applications.

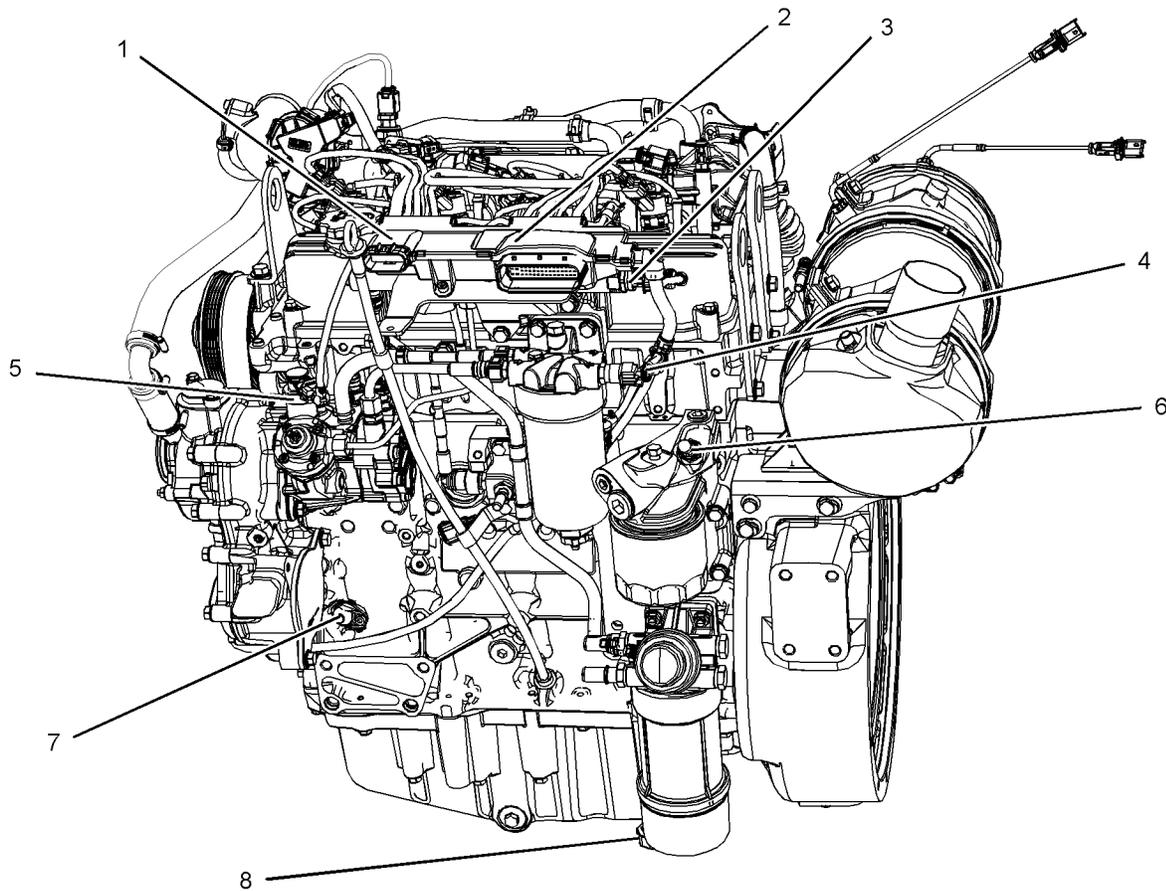


Illustration 27

g03343020

**Sensors and electrical connector locations on the left side of the engine**

- |                                       |  |                                    |
|---------------------------------------|--|------------------------------------|
| (1) 10-pin engine interface connector | (4) Fuel temperature sensor                          | (6) Oil pressure switch            |
| (2) 62-pin engine interface connector | (5) Inlet metering valve for the fuel injection pump | (7) Crankshaft speed/timing sensor |
| (3) Fuel pressure sensor              |  | (8) Water In Fuel (WIF) sensor     |

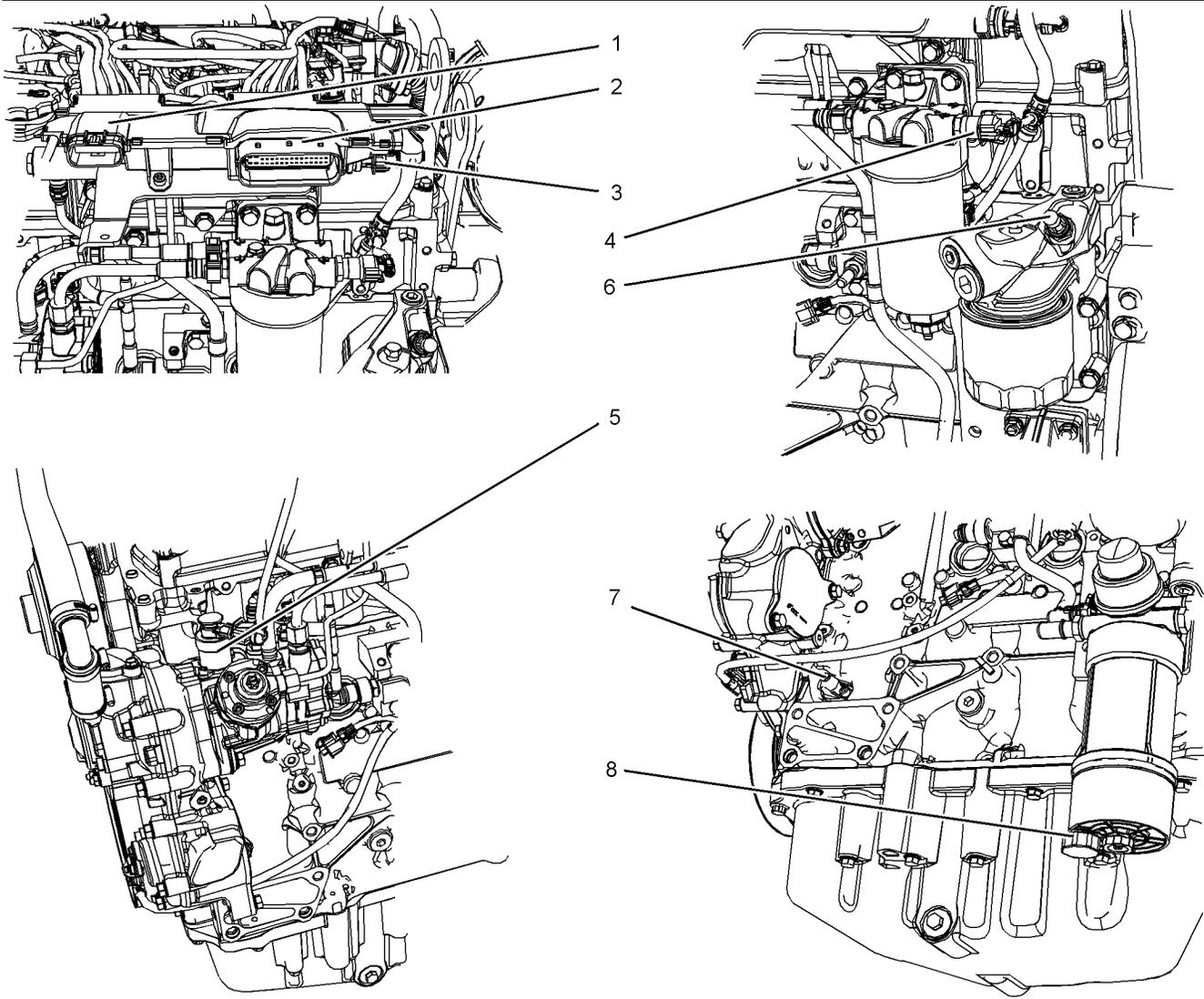


Illustration 28

g03343021

### Close up views of the sensor locations on the left side of the engine

- |                                       |  |                                    |
|---------------------------------------|--|------------------------------------|
| (1) 10-pin engine interface connector | (4) Fuel temperature sensor                          | (6) Oil pressure switch            |
| (2) 62-pin engine interface connector | (5) Inlet metering valve for the fuel injection pump | (7) Crankshaft speed/timing sensor |
| (3) Fuel pressure sensor              |  | (8) Water In Fuel (WIF) sensor     |

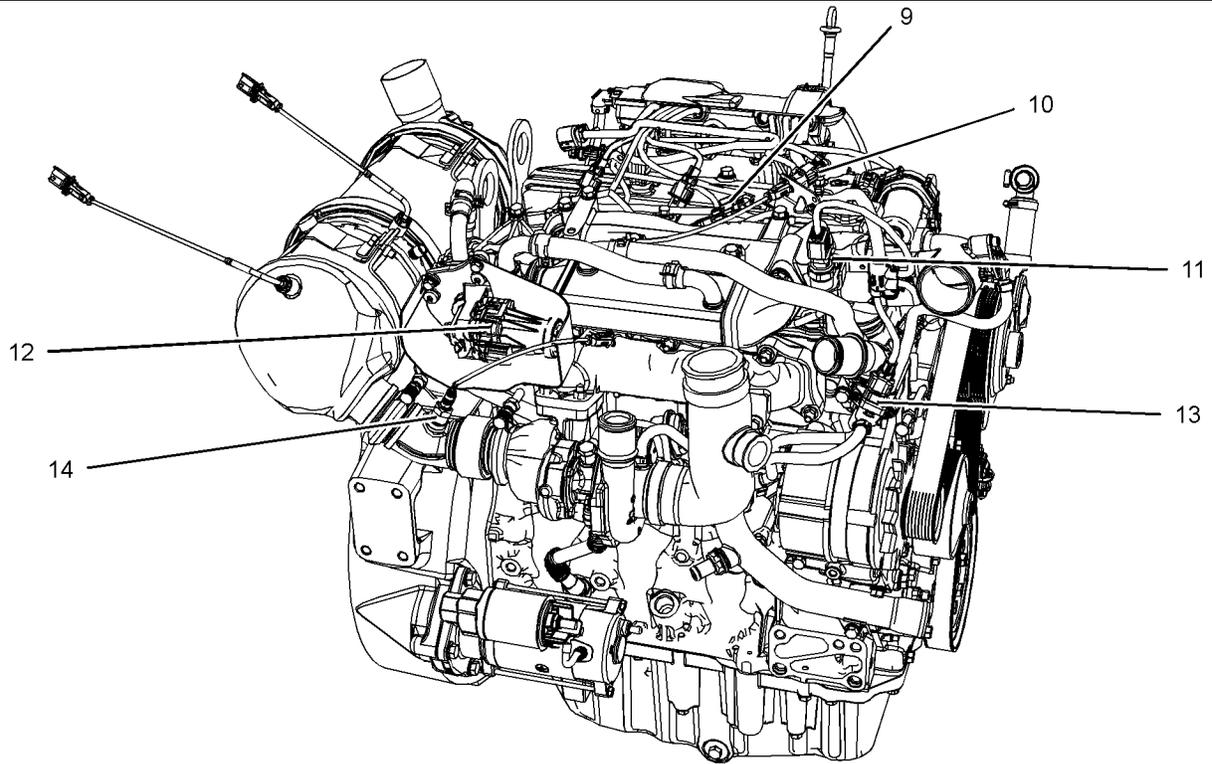


Illustration 29

g02737956

A typical example of sensors and electrical connector locations on the right side of the 854E-E34TA (model JR) and 854F-E34TA (model JV) engines

- |  |   |                          |
|--|---|--------------------------|
| (9) Inlet manifold air pressure and temperature sensor           | (11) Pressure sensor (NOx Reduction System)               | (13) Wastegate regulator |
| (10) Connector for the temperature sensor (NOx Reduction System) | (12) Exhaust gas valve for the NOx Reduction System (NRS) | (14) Oxygen sensor       |

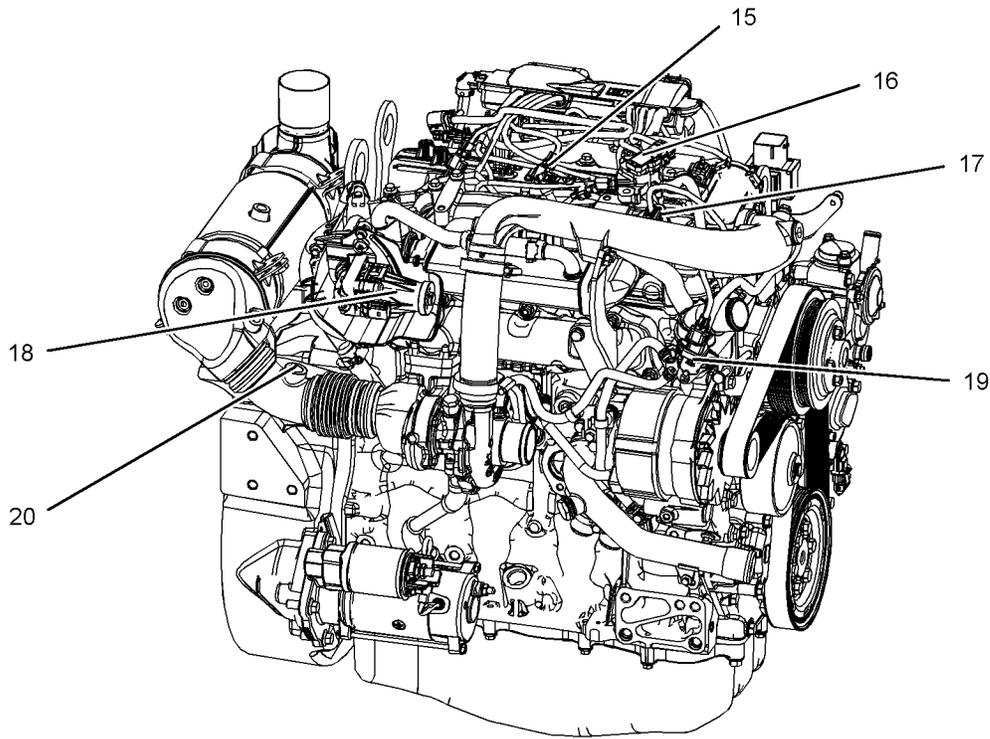


Illustration 30

g03356014

A typical example of sensors and electrical connector locations on the right side of the 854F-E34T (model JS) and 854F-E34T (model JT) engines

(15) Inlet manifold temperature sensor  
(16) Inlet manifold air pressure sensor  
(17) Pressure sensor (NOx Reduction System)

(18) Exhaust gas valve for the NOx Reduction System (NRS)  
(19) Wastegate regulator  
(20) Oxygen sensor

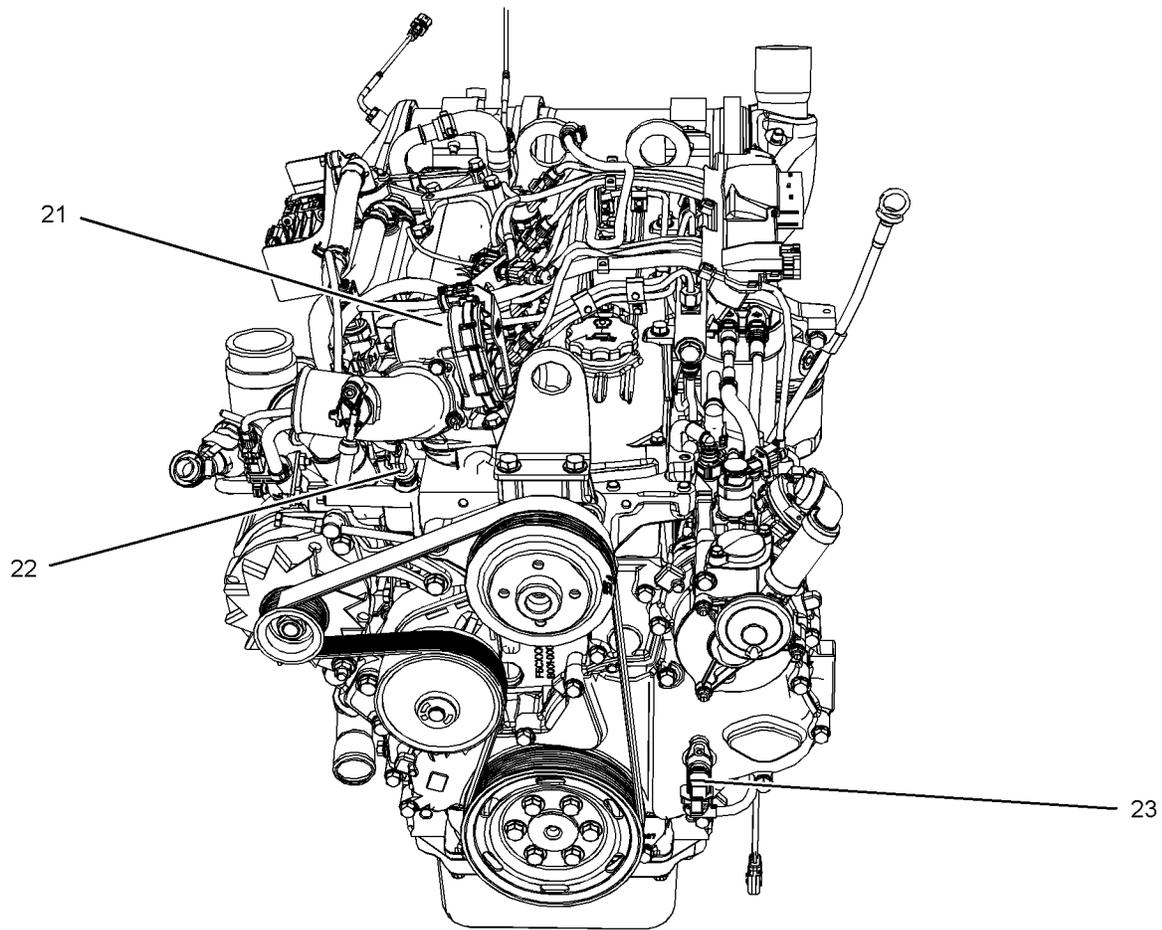


Illustration 31

g03356021

Sensors and electrical connection locations on the front of the engine.

(21) Intake throttle valve for the NOx  
Reduction System (NRS)

(22) Coolant temperature sensor  
(23) Camshaft position sensor

## Sensor Locations for the Clean Emissions Module

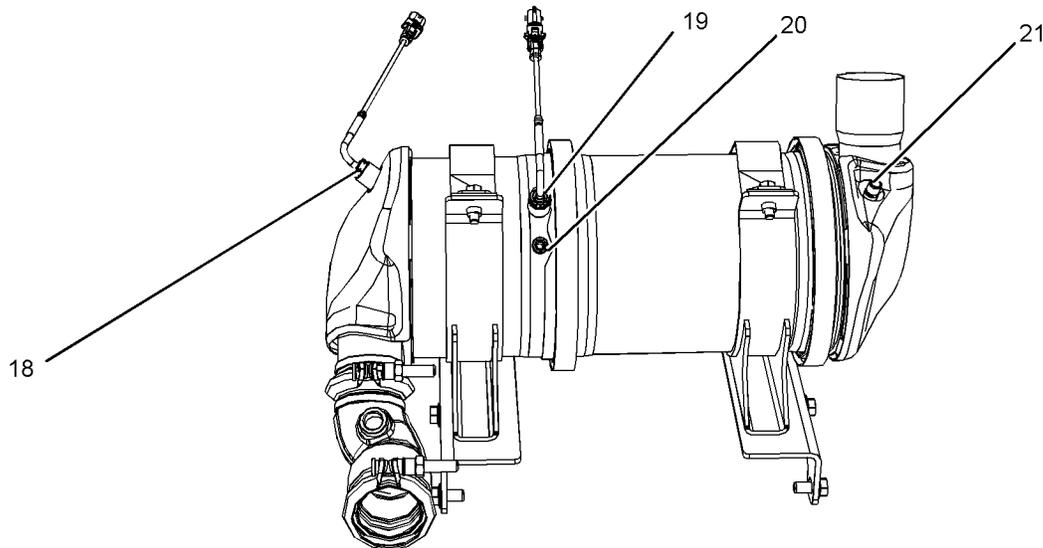


Illustration 32

g02738216

### Typical view of the sensor locations

(18) Diesel Oxidation Catalyst (DOC) inlet temperature sensor  
(19) Diesel Particulate Filter (DPF) inlet temperature sensor

(20) Inlet connection for the DPF differential pressure sensor  
(21) Outlet connection for the DPF differential pressure sensor

## ECM

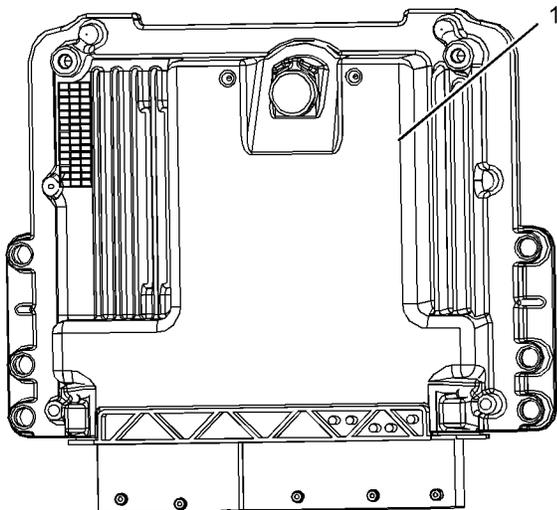


Illustration 33

g02722357

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

- Engine rating
- Torque curves
- High and low idle speed (rpm)
- Emissions
- Injection timing

Passwords restrict changes to authorized personnel. Refer to Troubleshooting 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 programmable software contains all the fuel setting information. The information determines the engine performance.

Flash programming is the method of programming or updating the programmable software. Refer to Troubleshooting, "Flash Programming" for the instructions on the flash programming of the programmable software.

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

## Engine Speed

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. These decisions are based on the actual conditions and the desired conditions at any given time.

The ECM has software that compares the desired engine speed to the actual engine speed. The actual engine speed is determined through the crankshaft speed/timing sensor and the camshaft speed/timing sensor. If the desired engine speed is greater than the actual engine speed, the ECM will instruct the electronic unit injector to inject more fuel to increase engine speed.

## Timing Considerations

Once the ECM has determined the amount of fuel that is required, the software must determine the timing of the fuel injection. 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
- Oxygen sensor

At start-up, the ECM determines the TOP CENTER position of the number 1 cylinder from the secondary speed/timing sensor on the camshaft. 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 manifold. 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 volume of fuel that enters the plungers. By controlling the volume of fuel that enters the plungers, this controls the pressure in the fuel manifold. 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 programmable software 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 to control the engines 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 programmable software and these limits cannot be changed.

The ECM controls the following characteristics:

- Boost pressure
- Operation of the NOx reduction system

## Diagnostic Codes

When the ECM detects an electronic system problem, the ECM generates a diagnostic code. Also, the ECM logs the diagnostic code to indicate the time of the problems occurrence. The ECM also logs the number of occurrences of the problem. Diagnostic codes are provided to indicate that the ECM has detected an electrical problem or an electronic problem with the engine control system. Sometimes, 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.

## Speed/Timing Sensors

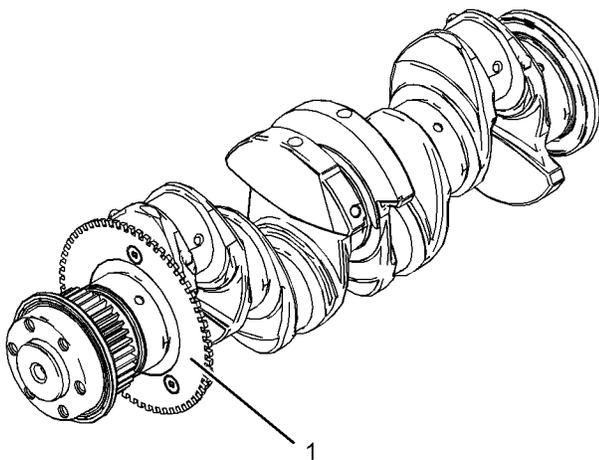


Illustration 34 g02722354

### Typical example

The crankshaft speed/timing sensor generates a signal by detecting the movement of the teeth that are on the crankshaft timing ring (1). The signal that is generated by the speed/timing sensor is transmitted to the ECM. The ECM uses the signal from the speed/timing sensor to calculate the position of the crankshaft. The signal is also used to determine the engine speed.

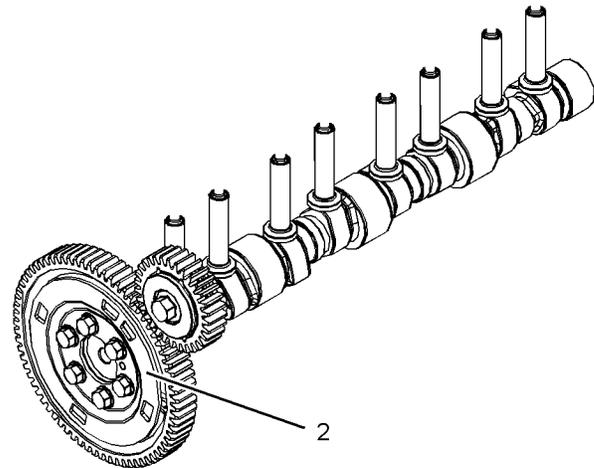


Illustration 35 g02722355

### Typical example

The camshaft speed/timing sensor generates a signal that is related to the camshaft position. The camshaft speed/timing sensor detects the movement of the position wheel on the front of the camshaft (2). The signal that is generated by the speed/timing sensor is transmitted to the ECM. The ECM calculates the speed and the rotational position of the engine by using the signal.

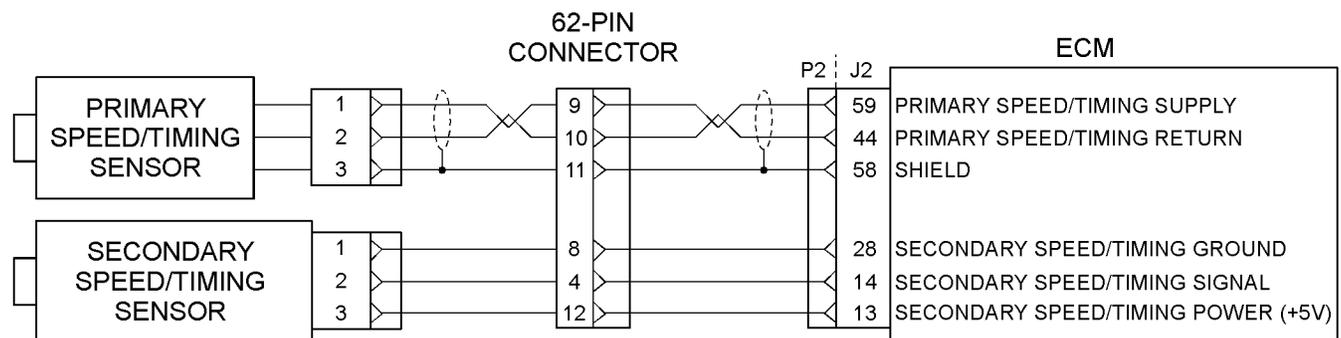


Illustration 36  
Schematic for speed/timing sensor

When the engine is cranking, the ECM uses the signal from the speed/timing sensor on the camshaft. 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

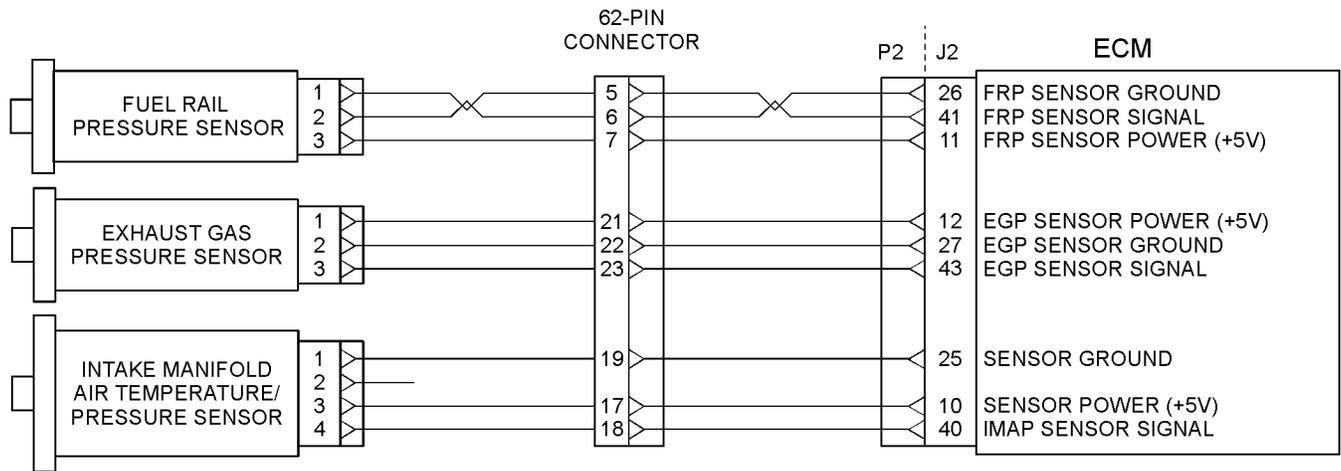


Illustration 37

g03360401

Schematic for the pressure sensors for the 854E-E34TA (model JR) engine

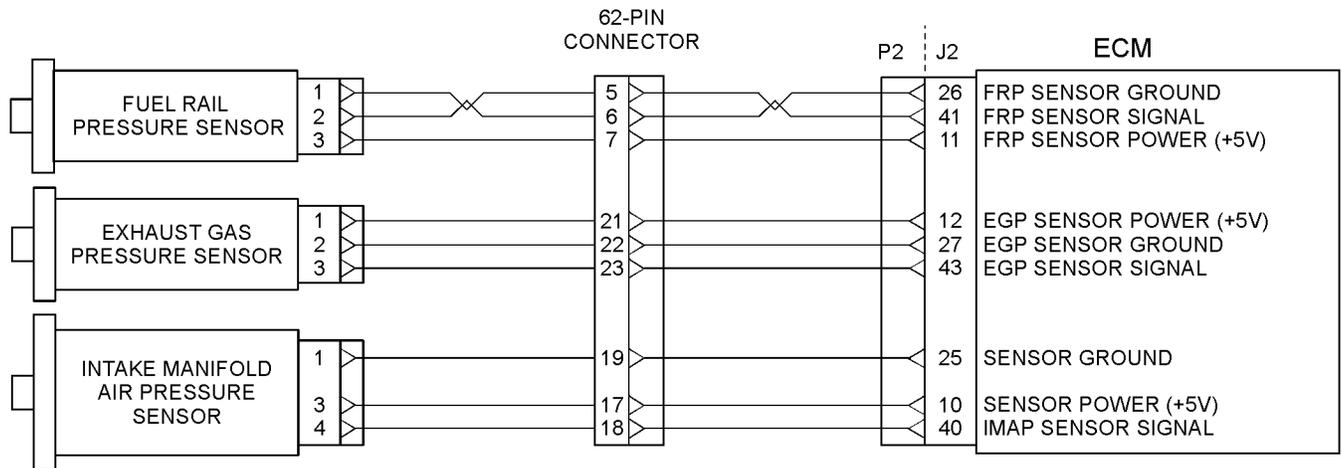


Illustration 38

g03360409

Schematic for the pressure sensors for the 854F-E34T (model JS) engine and 854F-E34T (model JT) engine

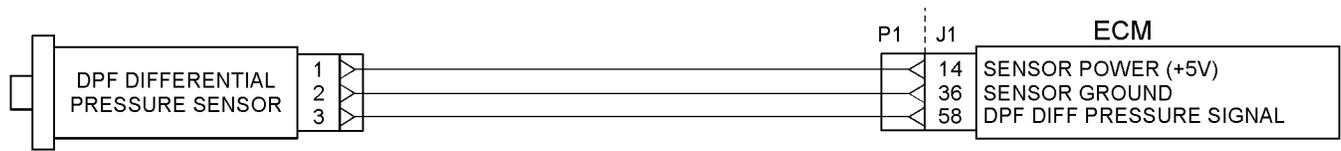


Illustration 39

g03360405

Schematic for the DPF differential pressure sensor for the 854E-E34TA (model JR) engine and 854F-E34T (model JS) engine

The boost pressure sensor is an active sensor.

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

An engine oil pressure switch is installed to the engine. While the engine is running and oil pressure is detected, the switch will be open. When no oil pressure is detected, the switch will be closed.

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 switch . . . . . 30 kPa to 90 kPa ((4 psi to 13 psi))

## Temperature Sensors

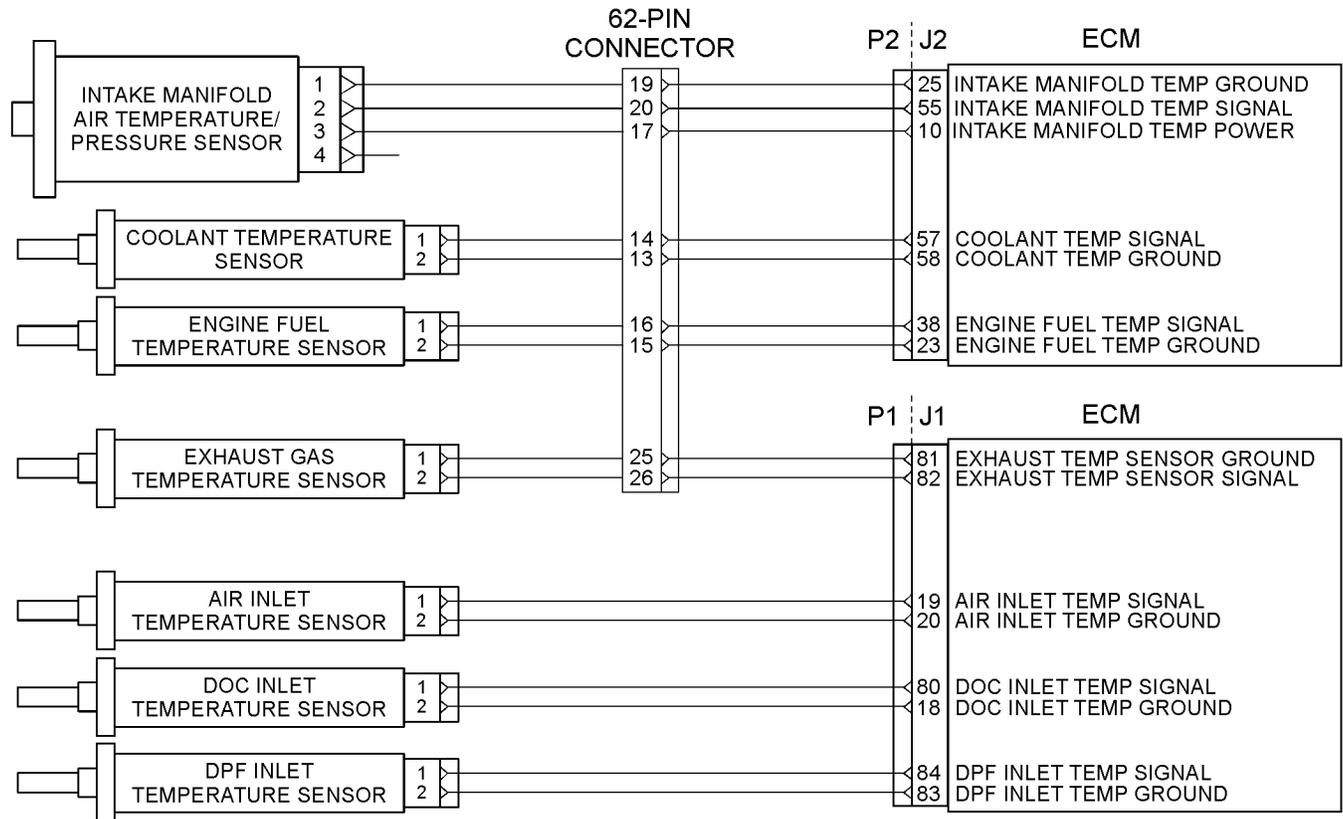


Illustration 40

g03360451

Schematic for the temperature sensors for the 854E-E34TA (model JR) engine

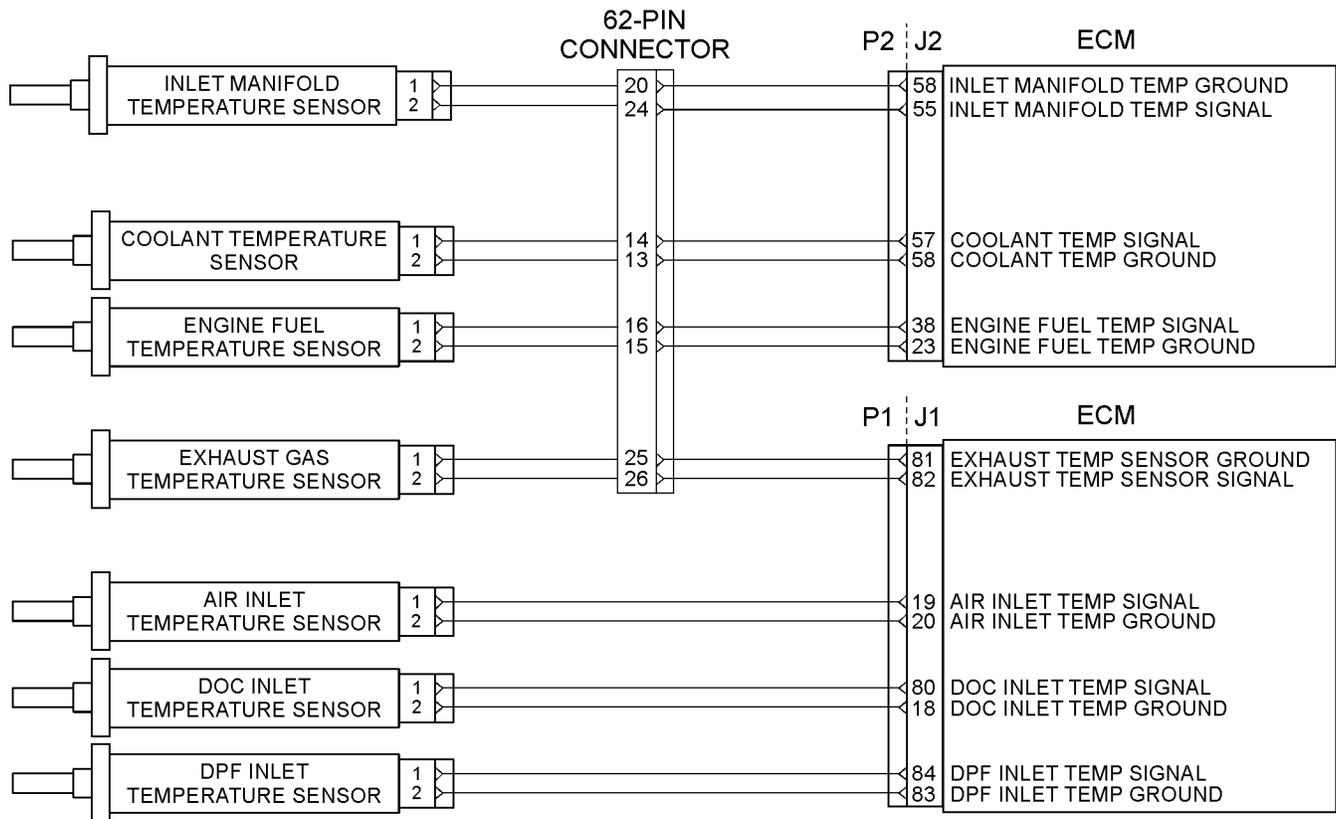


Illustration 41

g03360457

Schematic for the temperature sensors for the 854F-E34T (model JS) engine and 854F-E34T (model JT) engine

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 solenoid for the wastegate
- Diagnostic connector
- Electronic unit injectors

The glow plugs are powered directly from the battery.

The sensors are also used for engine monitoring.

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## Power Sources

### Introduction

The engine supplies power to the ECM. The ECM powers the following components:

- All sensors
- The control valve for the fuel injection pump

## ECM Power Supply

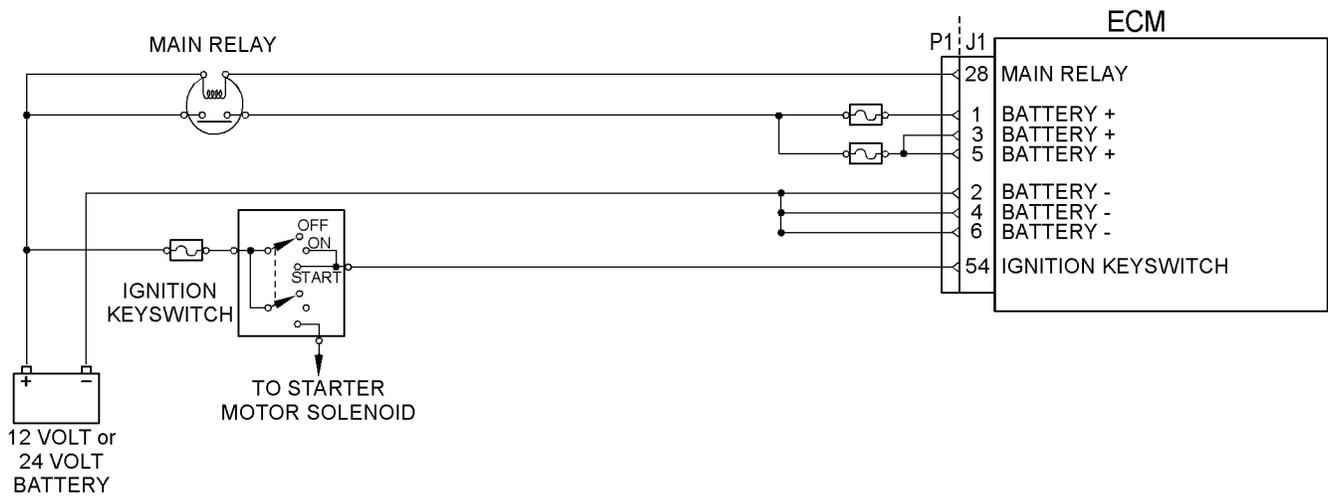


Illustration 42

g02720990

### Typical example

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

- Battery
- Disconnect switch
- Ignition keyswitch
- 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 ignition keyswitch turns on the ECM.

The main relay will remain energized for a time period after the keyswitch has been turned to the OFF position.

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

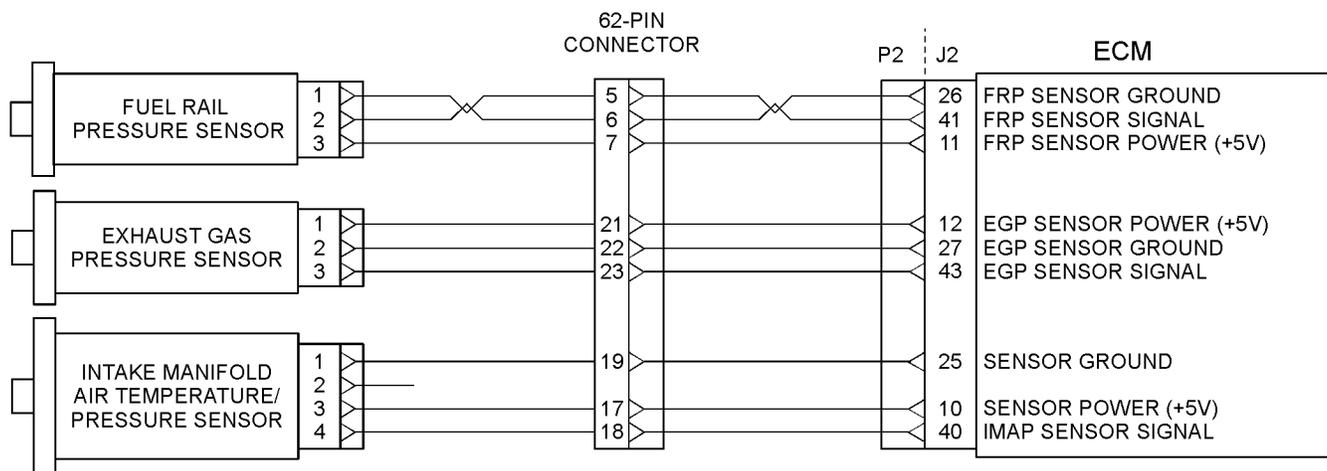


Illustration 43

g03360401

Schematic for the pressure sensors for the 854E-E34TA (model JR) engine

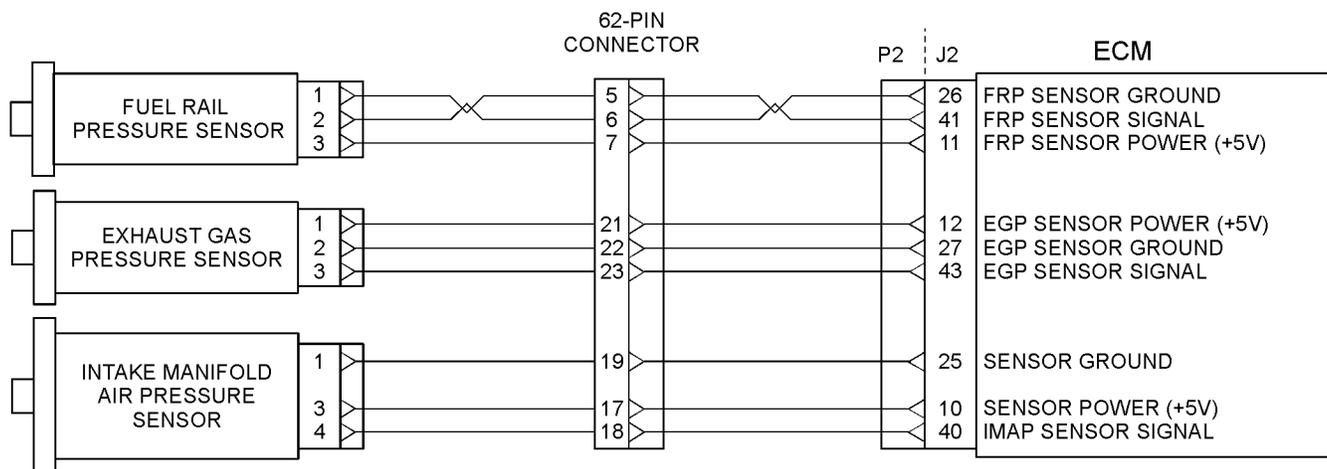


Illustration 44

g03360409

Schematic for the pressure sensors for the 854F-E34T (model JS) engine and 854F-E34T (model JT) engine

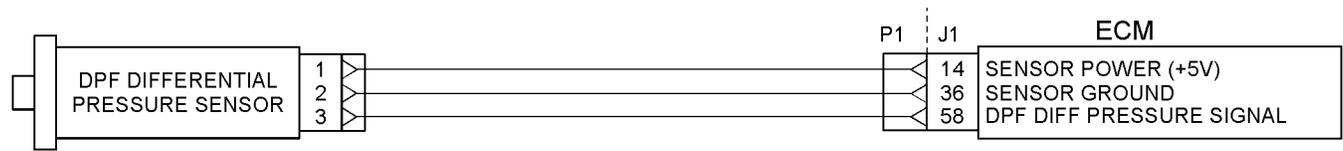


Illustration 45

g03360405

Schematic for the DPF differential pressure sensor for the 854E-E34TA (model JR) engine and 854F-E34T (model JS) engine

The ECM supplies 5 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

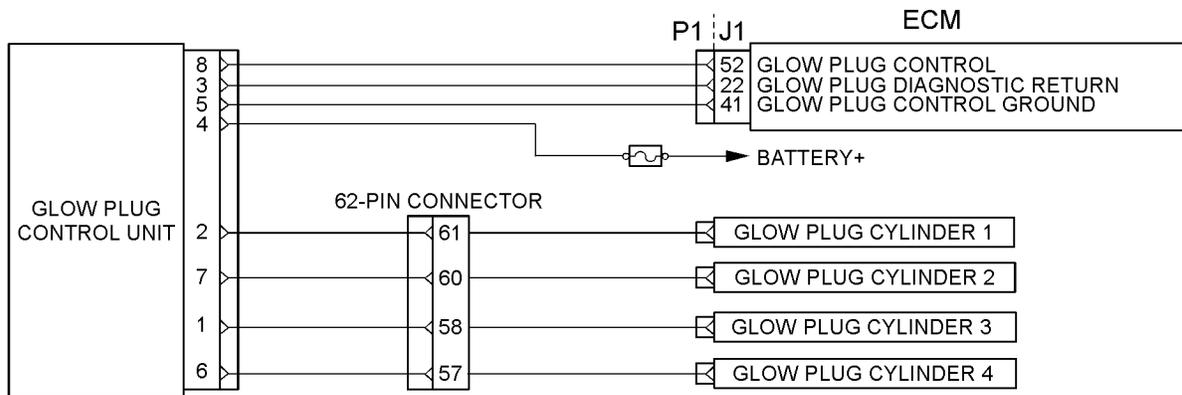


Illustration 46

g02381262

### Typical example

The ECM supplies 5 DC volts through the ECM connector to the glow plug control unit. The glow plug control unit controls the glow plugs.

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## Glossary of Electronic Control Terms

**Active Diagnostic Code** – An active diagnostic code alerts the operator or the service technician that an electronic system malfunction is currently present. Refer to the term “Diagnostic Trouble Code” in this glossary.

**Aftertreatment** – Aftertreatment is a system that is used to remove pollutants from exhaust gases. The system consists of a Diesel Oxidation Catalyst (DOC) and a Diesel Particulate Filter (DPF).

**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.

**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.

**Boost Pressure** – The difference between the turbocharger outlet pressure and atmospheric pressure is commonly referred to as boost pressure. The sensor for the intake 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 (see also J1939 CAN Data Link)** – The CAN Data Link is a serial communications port that is used for communication with other microprocessor-based devices.

**Clean Emissions Module** – The Clean Emissions Module (CEM) includes all the components of the engine aftertreatment system.

**Code** – Refer to “Diagnostic Trouble 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 three 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 Trouble Code** – A diagnostic trouble 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.

**Diesel Oxidation Catalyst** – The Diesel Oxidation Catalyst is also known as the (DOC). The DOC is a device in the exhaust system that oxidizes certain elements in the exhaust gases. These elements can include carbon monoxide (CO), hydrocarbons and the soluble organic fraction (SOF) of particulate matter.

**Diesel Particulate Filter** – The Diesel Particulate Filter (DPF) filters particulates from the exhaust gases. When the particulates have built up on the internal surfaces of a wall flow DPF, the temperature of the exhaust gas is raised in order to burn off the particulates. This regeneration process prevents the DPF from becoming blocked. The regeneration process therefore allows the DPF to continue to

operate efficiently. A through-flow DPF does not require an active regeneration.

**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.

**Duty Cycle** – See “Pulse Width Modulation” .

**Electronic Engine Control** – The electronic engine control is a complete electronic system. The electronic engine control monitors the engine operation under all conditions. The electronic engine control also controls the engine operation under all conditions.

**Electronic 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.

**Electronic Service Tool** – The electronic service tool is used for diagnosing various electronic controls and the electronic service tool is also used for programming various electronic controls.

**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 Switch** – The engine oil pressure switch measures engine oil pressure. The switch 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 switch that provides a digital signal to the ECM. 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 camshaft.

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

**Event Code** – An event code may be activated in order to indicate an abnormal engine operating condition. These codes usually indicate a mechanical problem instead of an electrical system problem.

**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.

**13** – The device requires calibration.

**14** – There is a special instruction for the device.

**15** – The signal from the device is high (least severe).

**16** – The signal from the device is high (moderate severity).

**17** – The signal from the device is low (least severe).

**18** – The signal from the device is low (moderate severity).

**19** – There is an error in the data from the device.

**20** – There is an error in the data from the device (high).

**21** – There is an error in the data from the device (low).

**31** – The device has failed and the engine has shut down.

**Flash File** – This file is software that is inside the ECM. The file contains all the instructions (software) for the ECM and the file contains the performance maps for a specific engine. The file may be reprogrammed through flash programming.

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

**FRC** – See “Fuel Ratio Control” .

**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).

**Fuel Manifold (Rail)** – This item is sometimes referred to as the High Pressure Fuel Rail. The fuel rail supplies fuel to the electronic unit injectors. The fuel injection pump and the fuel 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 Manifold (Rail) Pressure Sensor** – The fuel rail pressure sensor sends a signal to the ECM that is dependent on the pressure of the fuel in the fuel rail.

**Fuel Ratio Control (FRC)** – The FRC is a limit that is based on the control of the ratio of the fuel to air. The FRC is used for purposes of emission control. When the ECM senses a higher intake manifold air pressure (more air into the cylinder), the FRC increases the FRC Limit (more fuel into the cylinder).

**The Solenoid Valve for the Fuel Injection Pump** – This is sometimes referred to as the High Pressure Fuel Rail Pump Solenoid Valve or the Suction Control 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.

**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 Control Unit** – The glow plug control unit is controlled by the ECM in order to provide high current to the glow plugs.

**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 Injection Pump” .

**High Pressure Fuel Rail** – See “Fuel Manifold (Rail)” .

**Injector Trim Codes** – Injector trim codes are supplied with new injectors. The code is input through the electronic service tool into the ECM. The injector trim codes compensate for variances in manufacturing of the electronic unit injector and for the life of the electronic unit injector.

**Inlet Manifold Air Temperature/Boost Pressure Sensor** – The inlet manifold air temperature/pressure sensor detects the air temperature and pressure 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. The pressure in the inlet 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.

**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.

**J1939 CAN Data Link** – This data link is a SAE standard diagnostic communications data link that is used to communicate between the ECM and other electronic devices.

**Logged Diagnostic Codes** – Logged diagnostic codes are codes which are stored in the memory. These codes are an indicator of possible causes for intermittent problems. Refer to the term “Diagnostic Trouble Codes” for more information.

**NOx Reduction System** – The NOx Reduction System recycles a portion of the exhaust gases back into the inlet air in order to reduce the amount of nitrous oxide (NOx) in the exhaust gases. The recycled exhaust gas passes through a cooler before being introduced into the inlet air.

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

**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.

**Oxygen Sensor** – The oxygen sensor detects the level of oxygen. The level of oxygen is inputted to the combustion control.

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

**Password** – A password is a group of numeric characters or a group of alphanumeric characters that is designed to restrict access to parameters.

**Power Cycling** – Power cycling refers to the action of cycling the keyswitch from any position to the OFF position, and to the START/RUN position.

**Pressure Limiting Valve (PLV)** – The PLV is a valve in the fuel rail that prevents excessive pressure. The PLV will reduce the pressure to a safe level that will limit engine operation but the reduced pressure will not stop the engine.

**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.

**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.

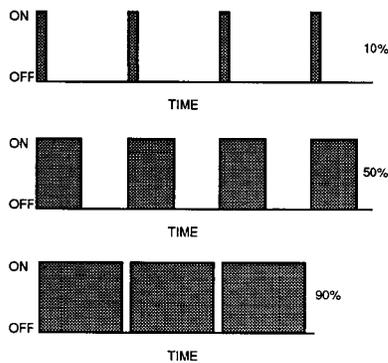


Illustration 47

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**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.

**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.

**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.

**Suction Control Valve (SCV)** – The SCV is a control device in the high-pressure fuel pump. The ECM

controls the pressure in the fuel rail by using this valve to control the amount of fuel that enters the chambers in the pump.

**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.

**“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.

**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.

**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.

**Warning Lamp** – The warning lamp is used to warn the operator of the presence of an active diagnostic code.

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

**Wastegate Regulator** – The wastegate regulator controls the pressure in the inlet manifold to a value that is determined by the ECM. The wastegate regulator 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

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#### Fuel System - Inspect

##### NOTICE

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

Before beginning 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, "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 that the valve in the fuel return line is open before the engine is started.
3. Check all low-pressure 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.
4. Install new fuel filters.

5. 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.

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#### Air in Fuel - Test

Table 1

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Sight gauge	1

##### NOTICE

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

Before beginning 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, "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.
4. Prime the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for the correct procedure.
5. Start the engine. Refer to Operation and Maintenance Manual, "Starting the Engine" for the correct procedure. Check if the problem has been resolved. Run the engine at low idle speed for 5 minutes.
6. Stop the engine. Refer to Operation and Maintenance Manual, "Stopping the Engine" for the correct procedure.

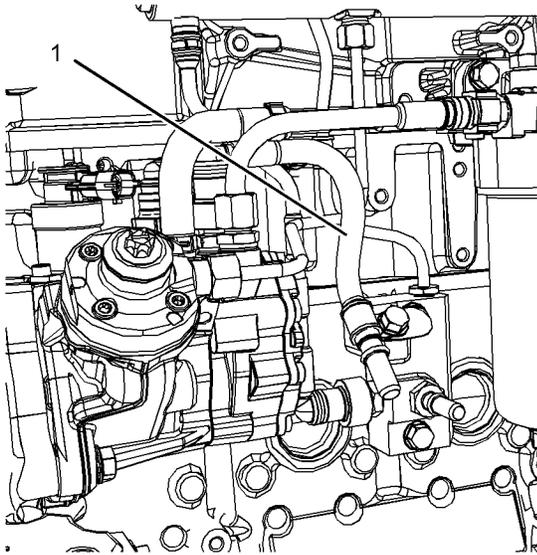


Illustration 48

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Typical example

7. If necessary, remove the low-pressure fuel line from the retaining clips. Remove the tube assembly (1) from the inlet of the fuel transfer pump.

**Note:** Ensure that the low-pressure fuel lines are not deformed.

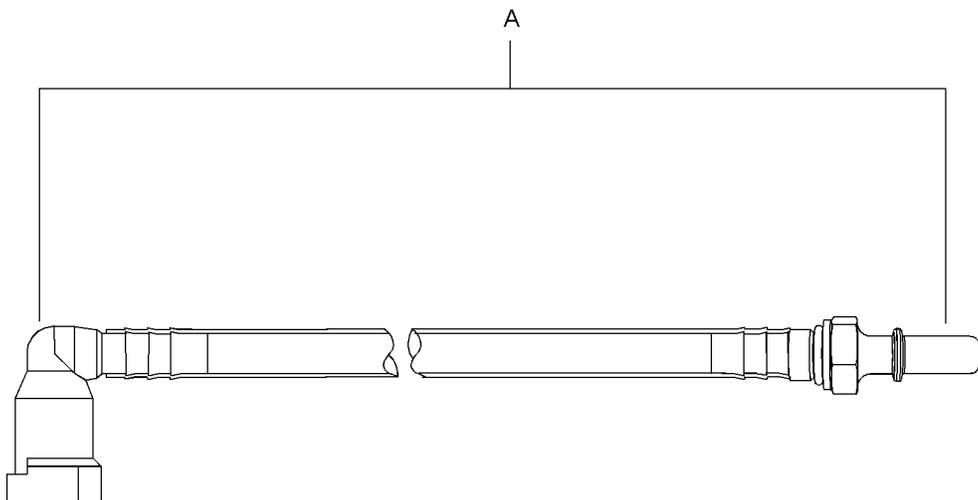


Illustration 49

Typical example

g02895617

8. Install Tooling (A) to the inlet of the fuel transfer pump and the end of tube assembly (1). Ensure that Tooling (A) is secured and clear of rotating parts.
9. Prime the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for the correct procedure.
10. Start the engine. Refer to Operation and Maintenance Manual, "Starting the Engine" for the correct procedure. Refer to steps 10.a to 10.d for the procedure for testing the air in fuel.
  - a. Run the engine a low idle speed.
  - b. Run the engine for 2 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.
  - c. The presence of large bubbles or a continuous stream of bubbles indicates a leak.
  - d. Investigate potential leaks and rectify any potential leaks in the low-pressure fuel system. Check for leaks between the fuel tank and the inlet of the fuel injection pump. If necessary, replace the low-pressure fuel lines.
11. Remove Tooling (A) from the engine. Reconnect the low-pressure lines.
12. Prime the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for the correct procedure.

i04676448

## Finding Top Center Position for No. 1 Piston

Table 2

Required Tools			
Tool	Part Number	Part Description	Qty
A <sup>(1)</sup>	27610291	Barring Device Housing	1
	27610289	Gear	1

<sup>(1)</sup> This Tool is used in the aperture for the electric starting motor.

1. Rover the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install" for the correct procedure.

2. Use Tooling (A) in order to rotate the crankshaft in the normal direction of rotation.
3. Rotate the crankshaft in the normal direction of rotation until the inlet valve of number 4 cylinder has opened and the exhaust valve of the same cylinder has not closed completely. The piston in the number 1 cylinder should be at the top center position.

i05241794

## Fuel Injection Timing - Check

Table 3

Required Tools			
Tool	Part Number	Part Description	Qty
A <sup>(1)</sup>	27610291	Barring Device Housing	1
	27610289	Gear	1
B	T400152	Camshaft Timing Pin	1

<sup>(1)</sup> This Tool is used in the aperture for the electric starting motor.

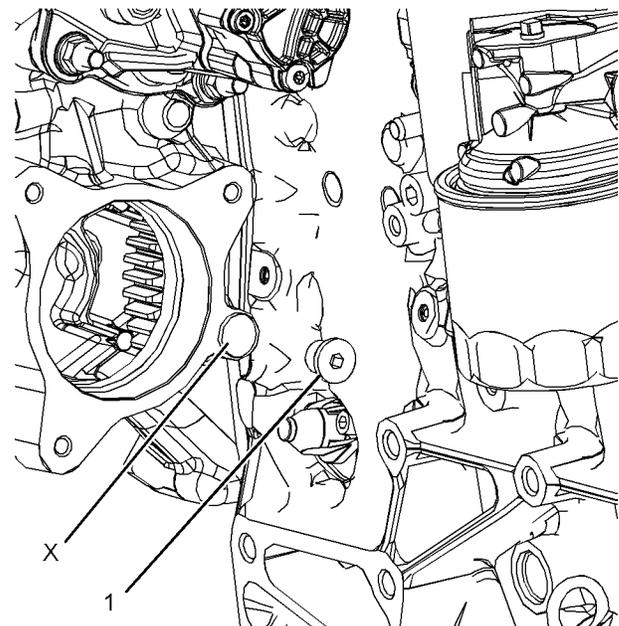


Illustration 50  
Typical example

g02862116

1. If necessary, remove the accessory drive. Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install" for the correct procedure. Remove plug (1) from the engine. Use Tooling (A) in order to rotate the crankshaft in the normal direction of rotation.
  2. Install Tooling (B) into Hole (X) in the engine. Use Tooling (B) in order to locate the camshaft in the correct position.
- Note:** Do not use excessive force to install Tooling (B). Do not use Tooling (B) to hold the camshaft during repairs.
3. If the shaft for the fuel injection pump is not in the position shown in illustration 51 , the timing of the fuel injection pump may be incorrect. If necessary, remove the fuel injection pump. Refer to Disassembly and Assembly for the correct procedure.

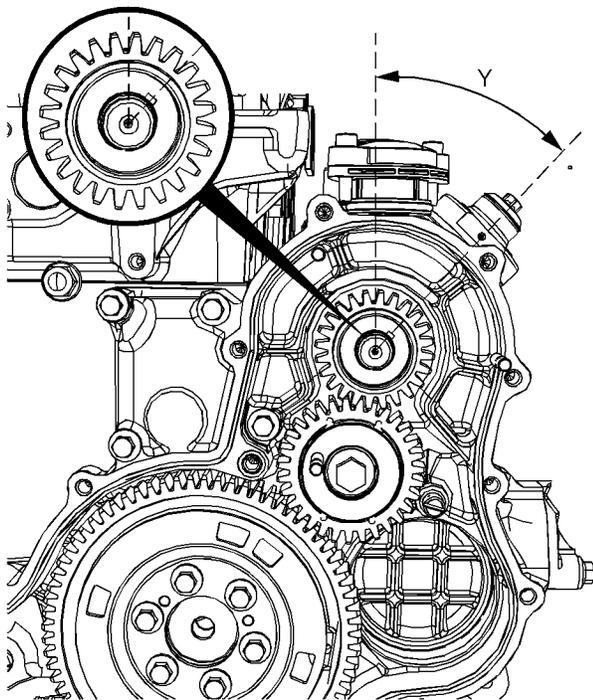


Illustration 51

g02906337

## Typical example

4. Ensure that the camshaft is in correct position. If necessary, install the fuel injection pump. Refer to Disassembly and Assembly for the correct procedure. Ensure that the fuel injection pump shaft is in the correct position as shown in illustration 51 . The Angle (Y) should be 45 degrees.

5. If necessary, remove Tooling (B). Install plug (1) to the engine.
6. If necessary, install the accessory drive . Refer to Disassembly and Assembly, "Accessory Drive - Remove and Install" for the correct procedure.

i04338389

## Fuel Quality - Test

**Note:** Refer to Systems Operation, Testing and Adjusting, "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. 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 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 like 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. 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

- Viscosity of the fuel
- Lubricity of the fuel
- Air in the fuel
- Other fuel characteristics

Refer to Operation and Maintenance Manual, "Fuel Recommendations" for more information on the cetane number of the fuel.

i04371154

## 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.

**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.

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

1. Ensure that the fuel system is in working order. Check that the fuel supply valve (if equipped) is in the "ON" position.

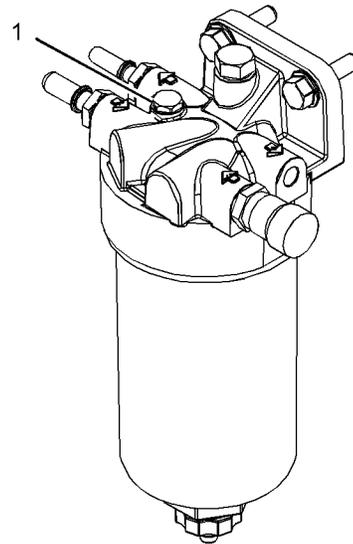


Illustration 52

g02882651

Typical example

2. Open the screw (1) on the secondary fuel filter base.

3. Operate the hand priming pump. Count the number of operations of the pump. After approximately 80 depression of the pump stop.

**Note:** As the fuel system is primed, the pressure will increase within the fuel system and this increase in pressure can be felt during priming.

4. Tighten the screw (1) to a torque of 2.5 N·m (22 lb in).

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

6. Operate the engine starter and crank the engine. After the engine has started, operate the engine at low idle for a minimum of 5 minutes. Ensure that the fuel system is free from leaks.

**Note:** Operating the engine for this period will help ensure that the fuel system is free of air. **DO NOT loosen the high-pressure fuel lines in order to purge air from the fuel system. This procedure is not required.**

After the engine has stopped, you must wait for 10 minutes 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, "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".

If the engine will not start, refer to Troubleshooting, "Engine Cranks but will not Start".

i05241801

## Fuel System Pressure - Test

Table 4

Required Tools			
Tool	Part Number	Part Description	Qty
A	-	Pressure gauge <sup>(1)</sup>	1
B	T400138	Pressure test kit	1

<sup>(1)</sup> Pressure gauge needs to be able to measure pressure in a vacuum.

### NOTICE

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

**Before beginning 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, "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 engine is stopped before installing and removing Tooling (A) and (B) or carrying out any repair work on the fuel system.

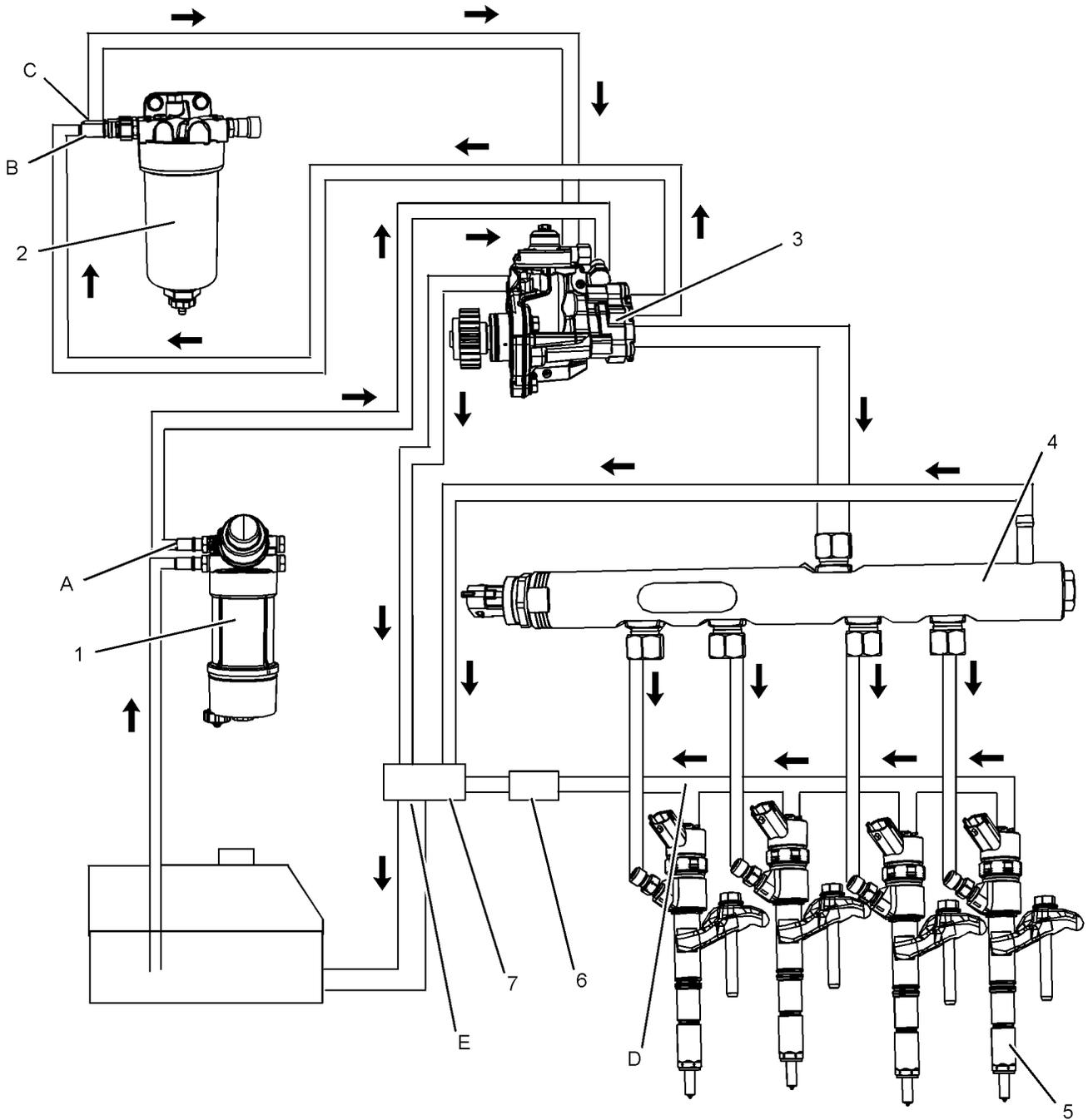


Illustration 53

g02871337

Typical example

- (1) Primary fuel filter
- (2) Secondary fuel filter
- (3) Fuel injection pump

- (4) Fuel manifold (rail)
- (5) Electronic unit injector
- (6) Check valve

- (7) Manifold connector

## Fuel System

Table 5

Position	Measurement	Minimum Pressure	Maximum Pressure
A	Inlet of fuel injection pump	50 kPa (7.25 psi)	-
B	Inlet of secondary fuel filter	400 kPa (58 psi)	650 kPa (94 psi)
C	Outlet of secondary fuel filter	400 kPa (58 psi)	650 kPa (94 psi)
D	Injector return line	30 kPa (4.35 psi)	80 kPa (11.6 psi)
E	Return line	-	20 kPa (2.9 psi)

- Remove all relevant tube assemblies. Refer to Disassembly and Assembly for the correct procedures.
  - Install Tooling (A) at location (A). Refer to illustration 53 . Install Tooling (B) at locations (B), (C), (D), and (E). Refer to illustration 53 .
  - Start the engine. Refer to Operation and Maintenance Manual for the correct procedure.
  - Use Tooling (A) and (B) to measure the pressure values in the order indicated in table 5 at both idle speed and at maximum engine speed with zero load. In both measurement conditions, the values measured must be between the minimum and maximum permissible pressure values.
  - Use Tooling (A) to measure the pressure value at position (A). If the pressure value measured is lower than the minimum permissible pressure, check that the primary fuel filter is not restricted. Check that the tube assemblies upstream of the measurement point are not restricted. Check that there are no signs of air infiltration or damage in the tube assemblies and connectors upstream of the inlet of the fuel injection pump. Replace any damaged components.
  - Use Tooling (B) to measure the pressure value at position (B). If the pressure value measured is lower than the minimum permissible pressure, check that the fuel injection pump functions correctly. Check for leaks in the circuit. If the pressure value measured is greater than the maximum permissible pressure, check that the lines between the secondary fuel filter and the fuel injection pump are not restricted. Replace any damaged components.
  - Use Tooling (B) to measure the pressure value at position (C). If the pressure value measured is lower than the minimum permissible pressure, or if the difference between the value and the value measured in step 6 is greater than 150 kPa (22 psi), check if the secondary fuel filter is restricted. If the pressure value measured is greater than the maximum permissible pressure, check that the tube assemblies between the secondary fuel filter and the fuel injection pump are not restricted. If the problem persists, check that fuel injection pump functions correctly. Replace any damaged components.
  - Use Tooling (B) to measure the pressure value at position (D). If the pressure value measured is lower than the minimum permissible pressure, check that there is no leakage from the injector return line. Check that the check valve (6) that is integrated in the injector return line is functioning correctly. If the pressure value measured is greater than the maximum permissible pressure, check that there are no restrictions in the lines of the injector return line. Check that the check valve (6) that is integrated in the injector return line is functioning correctly. If the problem persists, check that the electronic unit injectors are functioning correctly with the electronic service tool. Replace any damaged components.
  - Use Tooling (B) to measure the pressure value at position (E). If the pressure value measured is greater than the maximum permissible pressure, check that there are no restrictions in the fuel return lines. Check that the components of the high-pressure fuel system, such as the fuel injection pump, fuel manifold and electronic unit injectors are working correctly by using the electronic service tool test function to identify any faults relative to these components. Replace any damaged components.
- Note:** Check that the manifold connector (7) is functioning correctly. Check that fuel flow is visible in the transparent pipe downstream of the connector (7).
- Remove Tooling (A) and (B) at locations (A), (B), (C), (D), and (E).
  - Install all relevant tube assemblies. Refer to Disassembly and Assembly for the correct procedures.

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## Gear Group (Front) - Time

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

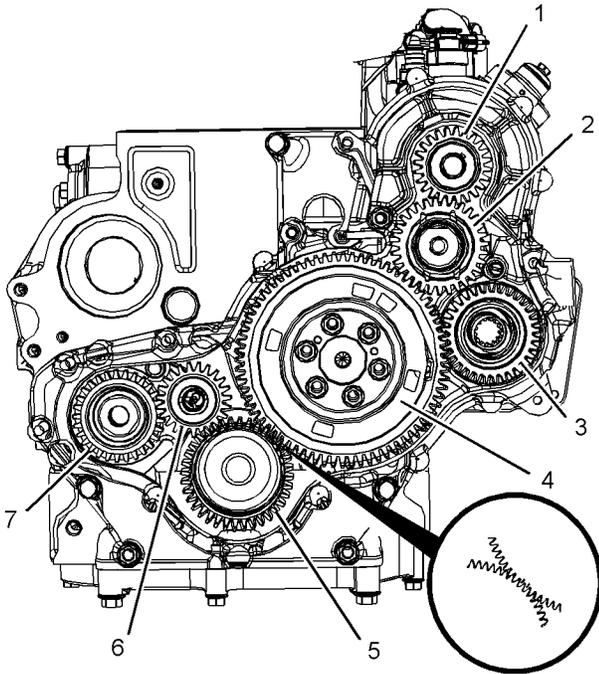


Illustration 54

g02859779

### Typical example

- (3) Accessory drive gear (if equipped)
- (5) Crankshaft gear
- (6) Oil pump idler gear
- (7) Oil pump gear

1. Install the camshaft gear (4) 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. Ensure that the fuel injection pump is 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 and gear assembly (1). Refer to Disassembly and Assembly for the correct procedure.

# Air Inlet and Exhaust System

i04170052

## 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. Refer to Operation and Maintenance Manual, "Engine Air Cleaner Element (Dual Element) - Clean/Replace" or Operation and Maintenance Manual, "Engine Air Cleaner Element (Single Element) - Replace" for the correct procedure.
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.

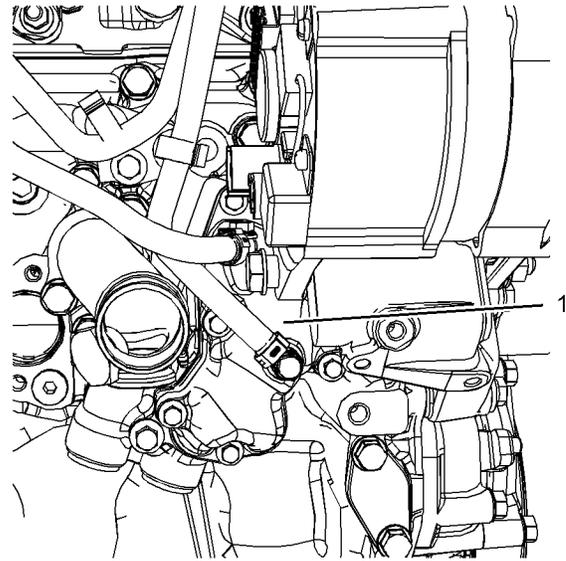


Illustration 55

g02857416

Typical example

4. Inspect the orifice in the boost pressure chamber (1) for blockages. If necessary, remove any blockages.

**Note:** The boost pressure chamber is located on the side of the engine oil cooler.

i05239437

## 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 Systems Operation, 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

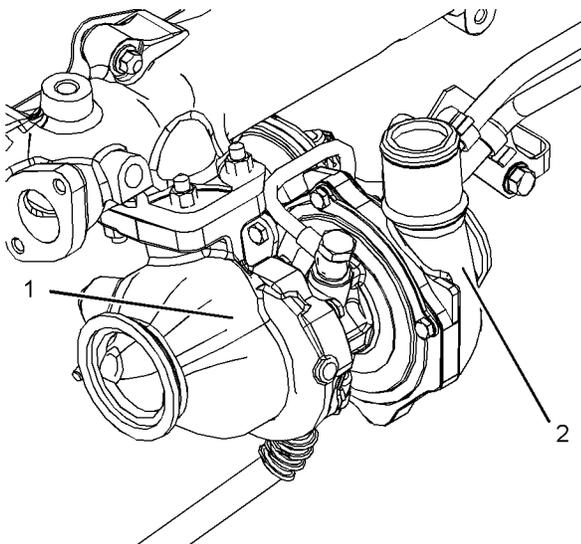


Illustration 56

g02529616

Typical example

- (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 air cleaner element. Replace a dirty engine air cleaner element with a clean engine air cleaner element. Refer to Operation and Maintenance Manual, "Engine Air Cleaner Element (Dual Element) - Clean/Replace" or Operation and Maintenance Manual, "Engine Air Cleaner Element (Single Element) - Replace" for the correct procedure. Inspect the engine air cleaner service indicator. Refer to Operation and Maintenance Manual, "Engine Air Cleaner Service Indicator - Inspect" for the correct procedure.
  - c. Inspect the engine crankcase breather. Clean the engine crankcase breather or replace the engine crankcase breather if the engine crankcase breather is plugged.
  - d. Remove the 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 the oil sludge. Inspect the oil drain hole for the oil sludge. Inspect the oil drain line for the oil sludge in the drain line. If necessary, clean the oil drain line. Replace the oil drain line if there is any sign of damage to the oil drain line.
  - e. If steps 3.a through 3.d did not reveal the source of the oil leakage, the turbocharger has internal damage. Replace the turbocharger.

## Inspection of the Turbine Wheel and the Turbine Housing

Remove the air piping from the turbine housing.

## Air Inlet and Exhaust System

1. Inspect the turbine for damage by 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. 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 the turbocharger if the 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 the oil sludge. Inspect the oil drain hole for the oil sludge. Inspect the oil drain line for the 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 the turbocharger.

## Inspection of the Wastegate

The wastegate actuator 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 a low boost (lug), a spring presses against a diaphragm in the canister. The load on the spring holds the wastegate closed. The turbocharger can then operate at maximum performance.

When a boost pressure signal acts against the diaphragm in the wastegate, the pressure overcomes the spring and the wastegate actuator 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 potential problem with the wastegate actuator or wastegate regulator:

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

**Note:** Check the operation of the wastegate regulator. Refer to Troubleshooting, "Solenoid Valve - Test".

## Check the Wastegate for Proper Operation

Table 6

Required Tools			
Tool	Part Number	Part Description	QTY
A	21825617	Dial Gauge	1

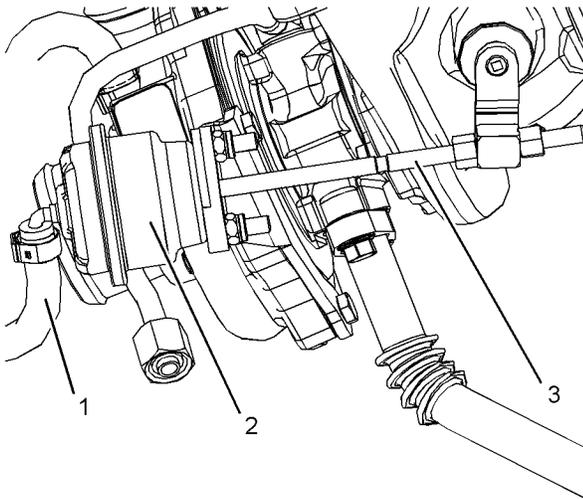


Illustration 57

g02529617

**Typical example**

1. Disconnect the pipe for the boost sensor (1) at the wastegate actuator (2). 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 (3) is in contact with Tooling (A). This will measure axial movement of the actuator rod (3).
3. Slowly apply air pressure to the wastegate so that the actuator rod (3) moves 10 mm (0.3937 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 turbocharger will need to be replaced.
5. Repeat steps 2 to 3 in order to repeat the pressure test.
6. If the air pressure is correct, remove the air supply. Remove Tooling (A). Install the pipe for the boost sensor (1).

i04552042

**Exhaust Cooler (NRS) - Test****Air Under Water Leak Test Procedure.**

1. Follow steps 1.a to 1.i in order to test the coolant side of the exhaust gas cooler (NRS).
  - a. Plug the coolant inlet of the exhaust gas cooler (NRS).
  - b. Plug the coolant outlet port with tube and pressure regulator assembly.
  - c. Make sure that the air pressure regulator is closed and connect compressed air to the pressure regulator.
  - d. Use a suitable air supply in order to apply an air pressure of 250 kPa (36 psi) to the exhaust gas cooler (NRS).
  - e. While the exhaust gas cooler (NRS) is still pressurized, submerge the cooler in water that is at ambient temperature.
  - f. Allow the exhaust gas cooler (NRS) to settle in order for the air that is trapped to escape.
  - g. Observe the exhaust gas cooler (NRS) for air bubbles that indicate a leak. If air bubbles are seen within 3 minutes, this indicates a leak with the exhaust gas cooler (NRS). Note the location or the origin of the leak. Record this information.
  - h. If no bubbles are detected after 3 minutes, the exhaust gas cooler (NRS) is reusable.
    - i. Remove the exhaust gas cooler (NRS) from the water. If the exhaust gas cooler (NRS) does not leak, the problem may be elsewhere in the cooling system or the engine. Refer the service manual in order to check for leakage. If the exhaust gas cooler (NRS) does leak, the exhaust gas cooler (NRS) should be replaced.
2. Follow steps 2.a to 2.i in order to test the gas side of the exhaust gas cooler (NRS).
  - a. Plug the gas inlet of the exhaust gas cooler (NRS).
  - b. Plug the gas outlet port with tube and pressure regulator assembly.
  - c. Make sure that the air pressure regulator is closed and connect compressed air to the pressure regulator.
  - d. Use a suitable air supply in order to apply an air pressure of 250 kPa (36 psi) to the exhaust gas cooler (NRS).
  - e. While the exhaust gas cooler (NRS) is still pressurized, submerge the cooler in water that

is at ambient temperature.

- f. Allow the exhaust gas cooler (NRS) to settle in order for the air that is trapped to escape.
- g. Observe the exhaust gas cooler (NRS) for air bubbles that indicate a leak. If air bubbles are seen within 3 minutes, this indicates a leak with the exhaust gas cooler (NRS). Note the location or the origin of the leak. Record this information.
- h. If no bubbles are detected after 3 minutes, the exhaust gas cooler (NRS) is reusable.
- i. Remove the exhaust gas cooler (NRS) from the water. If the exhaust gas cooler (NRS) does not leak, the problem may be elsewhere in the cooling system or the engine. Refer the service manual in order to check for leakage. If the exhaust gas cooler (NRS) does leak, the exhaust gas cooler (NRS) should be replaced.

i0528853

## Diesel Particulate Filter - Clean

### WARNING

**Wear goggles, gloves, protective clothing, and a National Institute for Occupational Safety and Health (NIOSH) approved P95 or N95 half-face respirator when handling a used Diesel Particulate Filter or Catalytic Converter Muffler. Failure to do so could result in personal injury.**

### WARNING

**The muffler, catalytic converter/muffler, and diesel particulate filter will become extremely hot during engine operation. A hot muffler, catalytic converter/muffler and diesel particulate filter can cause serious burns. Allow adequate cooling time before working on or near the muffler, catalytic converter/muffler and diesel particulate filter.**

The wall flow Diesel Particulate Filters (DPF) require periodic removal of ash that accumulates from engine oil.

## Cleaning Procedure

Follow this cleaning procedure for removal of the ash from the wall flow DPF. Refer to Operation and Maintenance Manual for the intervals of service hours for cleaning of the wall flow DPF.

1. Connect the engine to the electronic service tool before the wall flow DPF is removed from the engine. Once the engine is connected to the electronic service tool, then perform an ash service test. This test is a manual regeneration. The test could take an hour.

**Note:** Allow the wall flow DPF to cool until the wall flow DPF can be safely removed.

2. Remove the wall flow DPF from the Clean Emissions Module (CEM). Refer to Disassembly and Assembly for the correct procedure.

**Note:** Identify all engine fault codes if black soot is discovered on the outlet side of the center section on the wall flow DPF. Refer to Troubleshooting for problem identification and the disposition of the wall flow DPF.

3. The wall flow DPF must be cleaned. Contact your nearest Perkins distributor for assistance.
4. Reinstall the wall flow DPF onto the Clean Emissions Module (CEM). Refer to Disassembly and Assembly for the correct procedure.

## Reset the Engine Ash Model

The engine ash model must be reset whenever the filter is cleaned or replaced. Resetting the ash model places the wall flow DPF volume back to the "Clean State". The resetting will allow the regeneration of the wall flow DPF to function properly.

1. Use the electronic service tool to access the configuration parameters. Select "Service" from the top menu and highlight the "Ash Service Calibration" from the menu in the service tool.
2. Choose the correct replacement type of diesel particulate filter in the menu that appears. The types of replacements for the diesel particulate filter are the following:
  - "New filter replacement"
  - "Remanufactured filter replacement"
  - "Filter cleaned and reapplied"

**Note:** If a new filter or a remanufactured filter is used, the new serial number must be programmed into the electronic service tool.

**Note:** For the "Filter cleaned and reapplied" option, use the electronic service tool to perform the "DPF Ash Cleaning" reset.

**Note:** For the "New filter replacement" option, use the electronic service tool to perform the "DPF Replacement Reset".

- The electronic service tool will display “Ash Service Calibration Successful” when the calibration has been completed.

i04461759

## 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 correct.
- All glow plugs are removed.
- The ECM is powered.
- The fuel pressure sensor is connected.
- The suction control valve is connected.

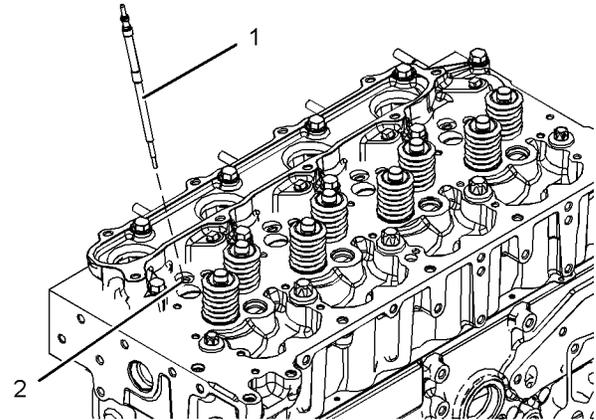


Illustration 58

g02647199

Typical example

1. Remove the glow plug (1). Refer to Disassembly and Assembly, “Glow Plugs - Remove and Install” for the correct procedure.
2. Install a suitable gauge for measuring the cylinder compression in the hole for the glow plug (2).
3. Remove the fuse for the glow plugs.
4. Operate the starting motor in order to turn the engine. Record the maximum pressure which is indicated on the compression gauge.
5. Repeat steps 2 and 4 for all cylinders.
6. Install the fuse for the glow plugs.

i04823055

## Engine Valve Lash - Inspect

Table 7

Required Tools			
Tool	Part Number	Part Description	Qty
A <sup>(1)</sup>	27610291	Barring Device Housing	1
	27610289	Gear	1

(1) This Tool is used in the aperture for the electric starting motor.

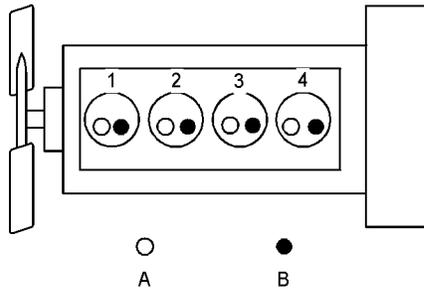


Illustration 59

g01353215

### Cylinder and valve location

- (A) Inlet valve  
(B) Exhaust valve

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

The hydraulic lifter will compensate for all normal wear of the components of the valve train.

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
- Issues with the hydraulic lash adjusters

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

### WARNING

Accidental engine starting can cause injury or death to personnel.

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

1. Find top center position for number one piston.  
Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston" for the correct procedure.

2. Check the rocker arms for an engine valve lash.  
There should be no engine valve lash.

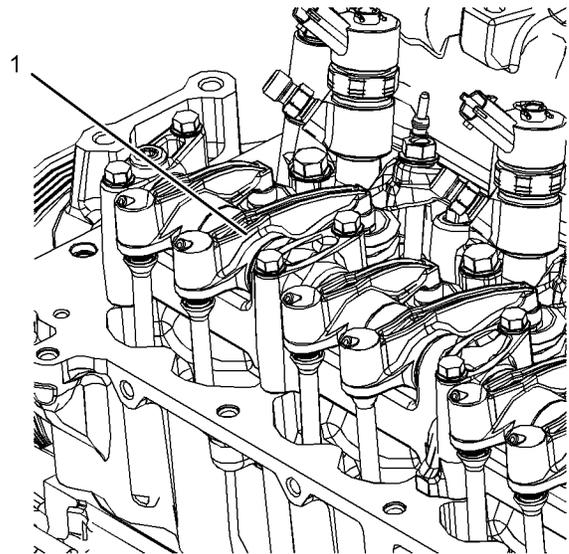


Illustration 60

g02948536

### Typical example

3. If there is an engine valve lash at any position the engine valve lash may be caused by a normal leakdown of the hydraulic lash adjuster. Push the affected rocker arm (1) against the pushrod. The rocker arm (1) should rotate as the pushrod is pushed up by the recovery of the hydraulic lifter. Once all motion has ceased test again for an engine valve lash. There should be no engine valve lash.
4. Use Tooling (A) to rotate the crankshaft in a clockwise direction. The crankshaft should be rotated 360 degrees.
5. Check the rocker arms for an engine valve lash.  
There should be no engine valve lash.
6. If there is an engine valve lash at any position the engine valve lash may be caused by a normal leakdown of the hydraulic lash adjuster. Push the affected rocker arm (1) against the pushrod. Monitor the rocker arm (1) for movement. The rocker arm (1) should rotate as the pushrod is pushed up by the recovery of the hydraulic lash adjuster. Once all motion has ceased test again for an engine valve lash. There should be no engine valve lash.

7. If an engine valve lash is found in any position, examine the valve mechanism components for excessive wear or damage. Examine the hydraulic lash adjusters for damage.

i04215789

## Valve Depth - Inspect

Table 8

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

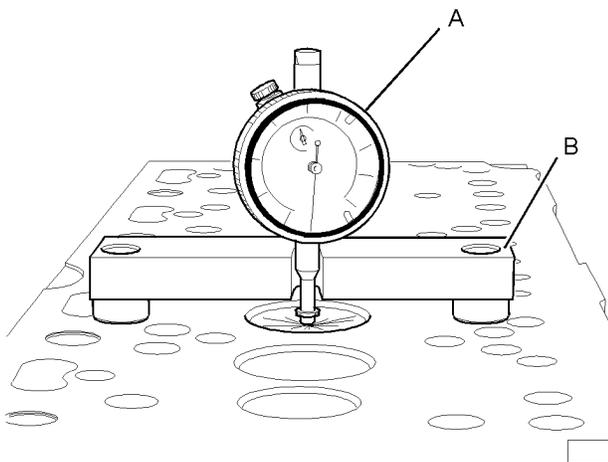


Illustration 61

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 Systems Operation, 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. For the minimum and maximum limits for a new engine for the inlet valves and the exhaust valves, refer to Specifications, "Cylinder Head".

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

For the wear limits for the inlet valves and exhaust valves, refer to Specifications, "Cylinder Head".

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 Systems Operation, 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.

i04483849

## Valve Guide - Inspect

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

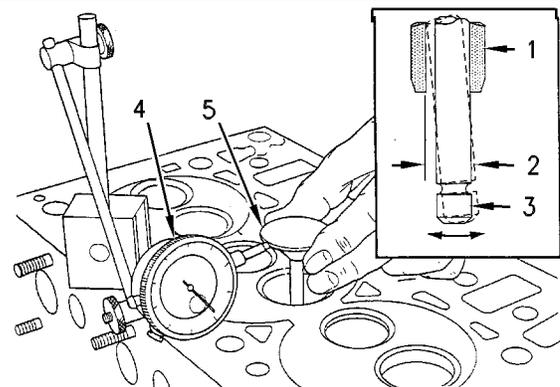


Illustration 62

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.

Air Inlet and Exhaust System

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3. Lift the edge of the valve head to a distance of 15 mm (0.591 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. Refer to Specifications, "Cylinder Head Valves" for the clearances.

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

## Engine Oil Pressure - Test

i04169630

### 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 a maximum engine speed of 2200 rpm and at normal operating temperature is 400 to 480 kPa (58.016 to 69.619 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.

i04484013

## Engine Oil Pump - Inspect

1. Remove the oil pump from the engine.
2. Clean the engine oil pump.

3. Look for cracks in the metal or other damage to the engine oil pump. If necessary, replace the engine oil pump.
4. Install the oil pump on the engine.
5. Remove the engine oil pressure relief valve from the engine.
6. Inspect the engine oil pressure relief valve for wear or for damage. If necessary, replace the engine oil pressure relief valve.

i04027269

## 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. Early wear will result.

Refer to Specifications for more information regarding component wear limits.

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.

i03577881

## **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

i05288851

## 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 3 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 Operation and Maintenance Manual, "Alternator and Fan Belts - Replace" 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.

i03577882

## 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 different atmospheric pressure ranges.
- 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.

## Cooling System

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.

i04169715

## 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 63. 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.

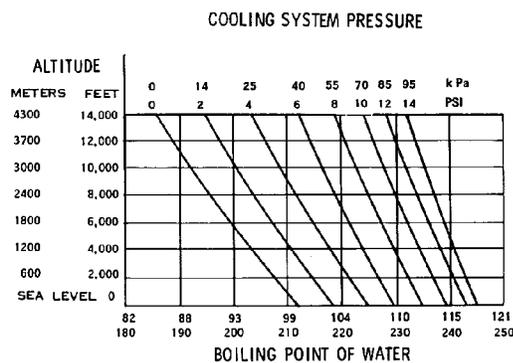


Illustration 63

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.

If the cooling system is equipped with a sight glass, the coolant should be to the correct level in the sight glass. On cooling systems without an indicator of the coolant level, fill the cooling system in order to be no more than 13 mm (0.5 inch) from the bottom of the filler pipe.

## 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.

### 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. The pressure cap should open within 95 to 110 kPa (13.7788 to 15.9544 psi). The pressure cap has a nominal pressure rating of 100 kPa (14.504 psi).
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 5 minutes.

- The dial indicator remains constant beyond 5 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.

i04338229

## Engine Oil Cooler - Inspect

### **⚠ WARNING**

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

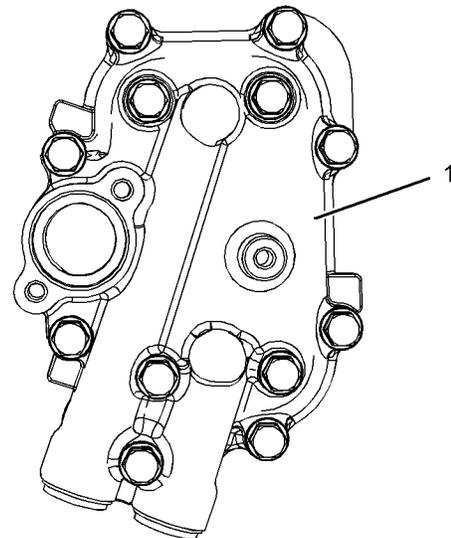


Illustration 64

g02494121

Typical example

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

1. Place a container under the oil cooler in order to collect any engine oil or coolant that drains from the oil cooler.
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 lubrication and 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.

i04338356

## 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. A normal condition is 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" for the correct procedures to remove and install the water pump.
3. Inspect the water pump shaft for unusual noise, excessive looseness and/or vibration of the bearings.

# Basic Engine

i04823065

## Position the Valve Mechanism Before Maintenance Procedures

**NOTICE**  
Ensure that this procedure is carried out before the rocker shaft is removed.

Table 9

Required Tools			
Tool	Part Number	Part Description	Qty
A <sup>(1)</sup>	27610291	Barring Device Housing	1
	27610289	Gear	1

(1) This Tool is used in the aperture for the electric starting motor.

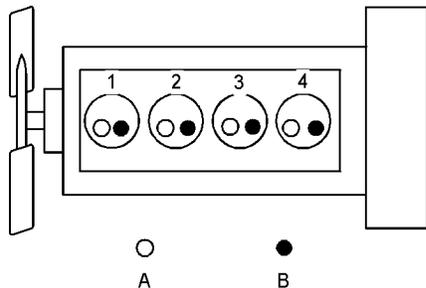


Illustration 65

g01353215

### Cylinder and valve location

- (A) Inlet valve
- (B) Exhaust valve

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

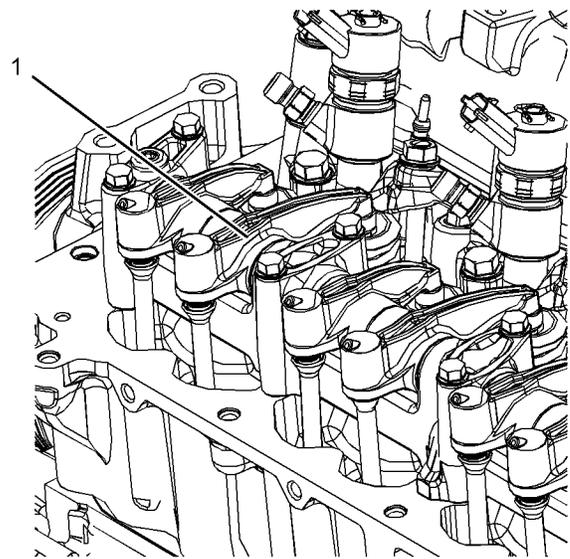


Illustration 66

g02948536

### Typical example

2. Select an exhaust rocker arm (1). The exhaust rocker arm (1) can be on any cylinder.
3. Use Tooling (A) to rotate the crankshaft in the normal direction of rotation until the hydraulic lash adjuster starts to open the exhaust valve. Continue to rotate the crankshaft until the valve has opened to the maximum extent. This is the safe position.

**Note:** Make temporary marks on the front pulley and the front housing once the engine is in the safe position.

### NOTICE

Ensure that the crankshaft is located in the safe position before the rocker shaft assembly is installed.

i03635080

## 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.

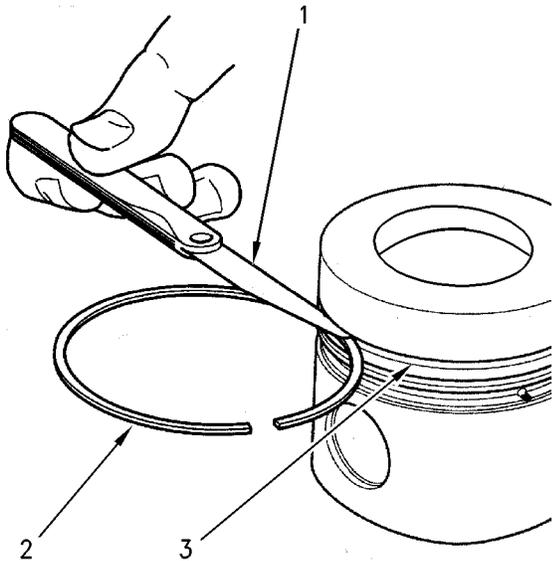


Illustration 67

g00905732

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

2. Install 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) for the intermediate ring and the oil control ring. Refer to Specifications, "Piston and Rings" for the dimensions.

## Inspect the Piston Ring End Gap

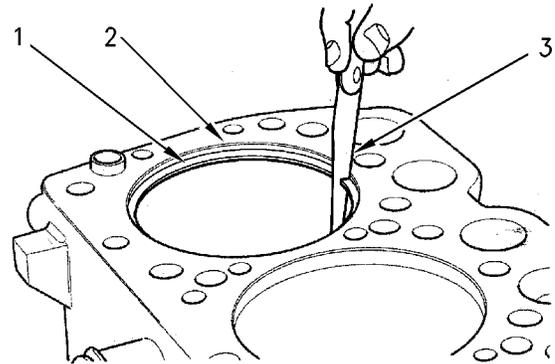


Illustration 68

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.

i04175235

## Connecting Rod - Inspect

If the crankshaft or the cylinder block are replaced, the piston height for all cylinders must be measured. Refer to Specifications, "Piston and Rings" for the correct piston height.

Inspect the connecting rod for wear or for damage. Refer to Specifications, "Connecting Rod" for the correct dimensions.

**Note:** When the piston pin is installed, always install new retaining rings on each end of the piston pin.

i05391913

## Cylinder Block - Inspect

1. Clean all of the coolant passages and the oil passages.
2. Check the cylinder block for cracks and damage.

3. 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.

i04338889

## 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).

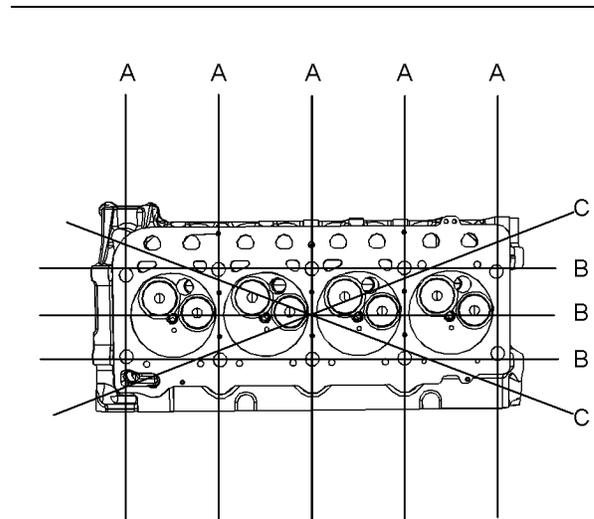


Illustration 69

g02490336

### 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 more information.

i04156372

## Piston Height - Inspect

Table 10

Required Tools			
Tool	Part Number	Part Description	Qty
A	21825617	Dial Gauge	1
B	21825496	Dial gauge holder	1

## Basic Engine

If the height of the piston above the cylinder block is not within the tolerance that is given in Specifications, "Piston and Rings", the bearing for the piston pin must be checked. Refer to Systems Operation, 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.

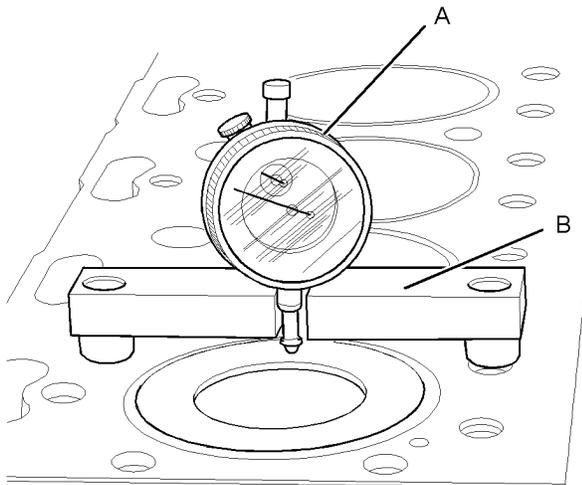


Illustration 70

g01201898

Typical example

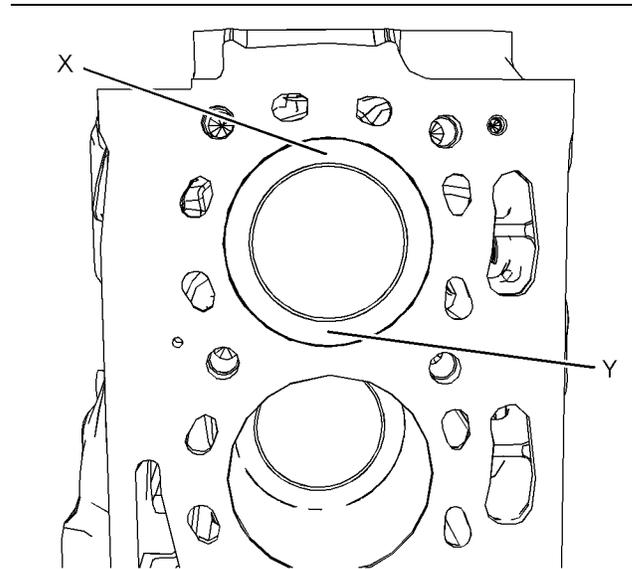


Illustration 71

g02351060

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. The piston height should be measured at positions (X) or (Y). 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".

i03635082

## Flywheel - Inspect

Table 11

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

## Alignment of the Flywheel Face

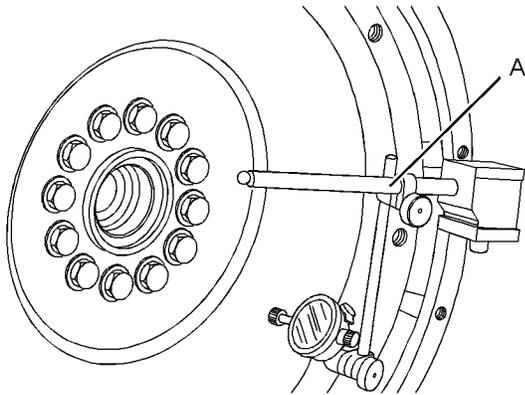


Illustration 72

g01332565

Typical example

1. Install Tooling (A) in illustration 72 , 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 play.

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

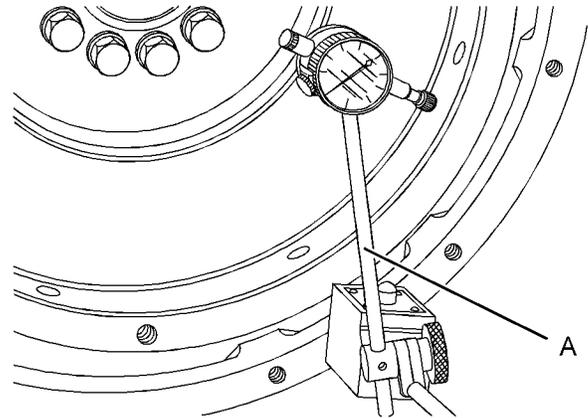


Illustration 73

g01321858

Typical example

1. Install Tooling (A) in illustration 73 , 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 12

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.

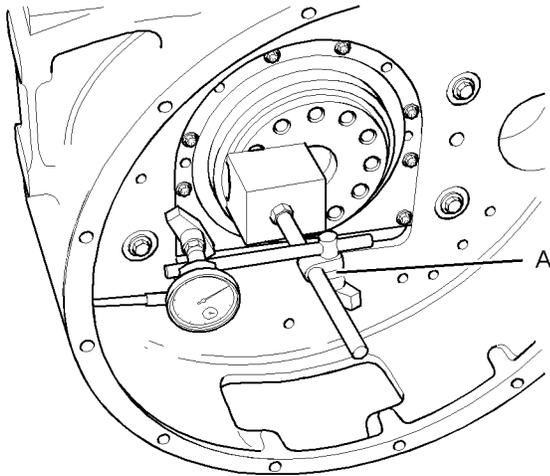


Illustration 74 g01199468

Typical example

1. Install Tooling (A). See illustration 74 .
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 13 .

**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.

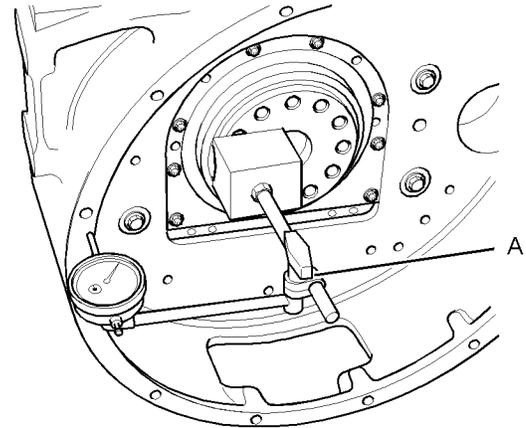


Illustration 75 g01199467

Typical example

1. Install Tooling (A). See illustration 75 .
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 13 .

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

Table 13

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)

i04175270

## Gear Group - Inspect

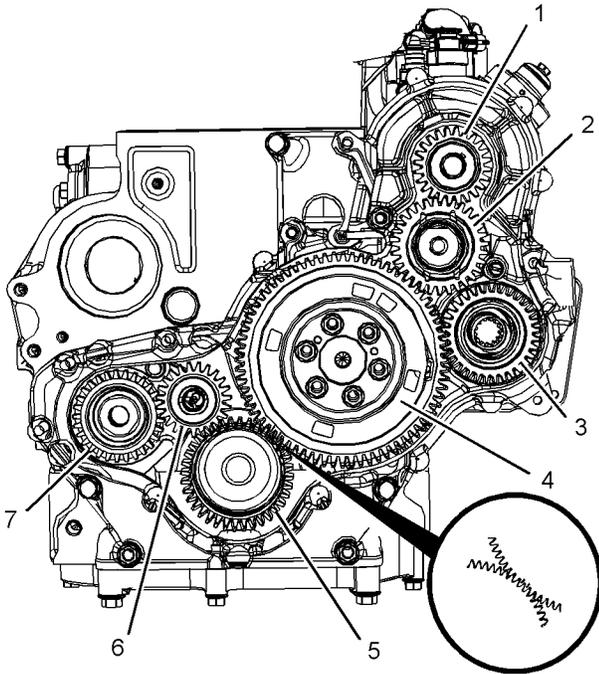


Illustration 76

g02859779

### Typical example

- (3) Accessory drive gear (if equipped)  
(7) Oil 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 remove the gears. Refer to the Disassembly and Assembly, “Gear Group (Front) - Install” in order to install the gears.

1. Inspect the gears for wear or for damage. If the gears are worn or damaged, use new parts for replacement.
2. Measure the clearance between the crankshaft gear (5) and the camshaft gear (4). Refer to Specifications, “Gear Group (Front)” for the clearance measurement.
3. Measure the clearance between the idler gear (6) for the oil pump and the crankshaft gear (5). Refer to Specifications, “Gear Group (Front)” for the clearance measurement.

4. Measure the backlash between the fuel injection pump gear (1) 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.

i04338214

## Crankshaft Pulley - Check

The crankshaft pulley is installed on the front of the crankshaft.

Replace the crankshaft pulley if any of the following conditions exist:

- There is movement of the crankshaft pulley.
- 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 crankshaft pulley for cracks or for wear and for damage.

Use the following steps in order to check the alignment and the runout of the crankshaft pulley:

1. Remove any debris from the front face of the crankshaft pulley. Remove any debris from the circumference of the crankshaft pulley.
2. Mount the dial indicator on the front cover. Use the dial indicator to measure the outer face of the crankshaft pulley. 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 for damage. If the pulley is damaged, use new parts for replacement.

5. Move the dial indicator so that the dial indicator will measure the circumference of the crankshaft pulley. 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 crankshaft pulley. 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 for damage. If the pulley is damaged, use new parts for replacement.

# Electrical System

i03635721

## Alternator - Test

Inspect the alternator for any visible faults. The faults could be the following items.

- Frayed wires or damaged wires
- Loose connections or damaged connections
- Loose alternator pulley
- Loose alternator or damaged alternator

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.

a. Turn the keyswitch to the ON position but do not start the engine.

b. The system voltage matches the specification. Go to step 2.

c. The system voltage is less than the specification. Check if the battery is in good condition. Refer to Systems Operation, Testing and Adjusting, “Battery - Test” for the correct procedure. Go to step 5.a if the battery is in good condition.

2. 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.

a. Start the engine and run the engine at least 75% of full throttle. Record the voltage on the multimeter.

b. The voltage should be higher than the voltage in step 1.b. The voltage is less than the maximum voltage listed for the alternator. The alternator is partially charging. Go to step 3. The voltage is more than the maximum voltage listed for the alternator. There is overcharging of the alternator. Check the alternator wiring. Refer to Systems Operation, Testing and Adjusting, “Charging System - Test” for the correct procedure.

c. The value of the voltage is less than the voltage in step 1.b. Go to step 6.

**Note:** Severely discharged batteries can cause low system voltage. This can occur even while the engine is running above idle, and the alternator is working properly. Correct low engine idle is important. All alternators that are installed on this engine are self-excited. The alternators must exceed the turn on speed before charging will begin.

3. Ensure that the batteries are not fully charged.

a. Fully charged batteries have open circuit voltage above 12.5 V on 12 V systems or 25 V on 24 V systems.

b. If the batteries are fully charged then crank the engine for 30 seconds. This reduces the battery voltage.

c. Connect a current probe or an ammeter to a digital multimeter. The multimeter must have a peak hold feature. Ensure that the probe is zeroed. Clamp the probe around the output wire “B+”.

d. Set the multimeter to “peak hold” or “max mode”.

e. Turn on all electrical accessories.

f. Start the engine and run the engine at least 75% of full throttle. The peak current will appear on the multimeter.

g. The current is at least 90% of the peak output of the alternator. Go to step 4 or step 5.

h. The current is less than 90% of the peak alternator output. Go to step 6.

**Note:** This test procedure is for applications with a main disconnect switch.

4. Turn off all accessories. Turn the keyswitch to the OFF position.

a. Connect a current probe or an ammeter to a digital multimeter. Ensure that the probe is zeroed. Clamp the current probe or an ammeter around the ground cable. Clamp the tool with the positive side away from the battery. Record the value of the electrical current.

b. The current value is below 2 amperes. Go to step 4.d.

c. The current value is above 2 amperes. Go to step 7.

## Electrical System

- d. Turn the disconnect switch to the ON position. Connect an ammeter across the disconnect switch terminals. Connect the red lead to the terminal on the frame side. Connect the black lead to the terminal on the battery. If a multimeter is used for the test use the ten amp connections to avoid damage.
- e. Turn the disconnect switch to the OFF position. Record the value of the electrical current.
- f. The current is below 0.05 amperes. The charging system is currently good. The fault is possibly an intermittent draw in the system. The batteries may be faulty. Check that no accessories were on during the test.

**Note:** The standard acceptable draw is 0.05 amperes. A current that is greater than this value usually indicates a problem. However, some large machines with multiple control modules have a higher acceptable limit.

- g. The current value is above 0.05 amperes. There is a current draw in the system. Go to step 7.
5. Turn off all accessories. Turn the keyswitch to the OFF position.
  - a. Connect a current probe or an ammeter to a digital multimeter. Ensure that the probe is zeroed. Clamp the current probe or an ammeter around the ground cable. Clamp the tool with the positive side away from the battery. Record the value of the electrical current.
  - b. The current value is below 2 amperes. Go to step 4.d.
  - c. The current value is above 2 amperes. Go to step 7.
  - d. Remove the ground cable from the battery terminal. For systems with four batteries or 12 V systems with two batteries, disconnect the ground cables from both negative batteries.
  - e. Connect an ammeter between the disconnected battery ground cable and one of the negative battery terminals. Connect the red lead to the cable. Connect the black lead to the terminal on the battery. If a multimeter is used for the test use the ten amp connections to avoid damage.
  - f. The current is below 0.05 amperes. The charging system is currently good. The fault is possibly an intermittent draw in the system. The batteries may be faulty. Check that no accessories were on during the test.

**Note:** The standard acceptable draw is 0.05 amperes. A current value above this figure usually indicates a problem. However, some large machines with multiple control modules have a higher acceptable limit.

- g. The current value is above 0.05 amperes. There is a current draw in the system. Go to step 7.
6. Check the condition of the poly v-belt and alternator pulley.
  - a. If the poly v-belt is oily, clean the pulleys. Replace the poly v-belt. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install" for the correct procedure. Inspect the poly v-belt for wear or for cracks. Refer to Systems Operation, Testing and Adjusting, "V-Belt - Test". If the poly v-belt is wet, dry the poly v-belt and the pulleys. Retest the system.
  - b. Inspect the nut on the alternator pulley. Ensure that the nut is not loose. If the nut is loose, tighten the nut to the correct torque. Refer to Specifications, "Alternator" for the correct torque.
  - c. If no faults are found from the procedures in step 6.a and step 6.b, inspect the charging system. Refer to Systems Operation, Testing and Adjusting, "Charging System - Test" for the correct procedure.
7. Turn the keyswitch to the OFF position.
  - a. Connect a current probe or an ammeter to a digital multimeter. Ensure that the probe is zeroed. Clamp the current probe or an ammeter around the "B+" cable. Clamp the tool with the positive side away from the battery. Record the value of the electrical current.
  - b. The current is less than two amperes. Go to step 7.d.
  - c. The current is more than two amperes. There is an internal problem with the alternator. Replace the alternator. Refer to Disassembly and Assembly, "Alternator - Remove and Install" for the correct procedure.
  - d. Disconnect the wire for "B+" terminal from the alternator. Connect the red lead of the multimeter to the wire for the "B+" terminal. Connect the black lead of the multimeter to the "B+" terminal on the alternator. Set the multimeter to ten amp. Record the value of the electrical current.

- e. The current is below 0.015 amperes. The alternator is operating correctly. There is an electrical load on the machine. Go to step 8.
  - f. The current is above 0.015 amperes. There is an internal fault with the alternator. Replace the alternator. Refer to Disassembly and Assembly, "Alternator - Remove and Install" for the correct procedure.
8. Turn off all electrical accessories. Turn the keyswitch to the OFF position.
- a. Connect a current probe or an ammeter to a digital multimeter. Ensure that the probe is zeroed. Clamp the current probe or an ammeter to the main ground cable. Clamp the tool with the positive side away from the battery.
  - b. Monitor the current and remove the fuses and circuit breakers one at a time. Check the current after each fuses or each of the circuit breakers are removed. After removing a fuse and checking the current, replace the fuse. Start with the main fuses and proceed to the smaller circuits.
  - c. If removing a fuse causes a current drop, then the problem is within that circuit.
  - d. Check if any components on the circuit are on.
  - e. If all components are switched off, disconnect electrical components on that circuit one at a time and monitor the current.
  - f. After all components on the circuit have been disconnected, check the current. If the problem still exists, check the wiring for corrosion. Check if there is a short to ground.

**Note:** The standard current is 0.05 amperes. A current value above this figure usually indicates a problem. However, some large machines with multiple control modules have a higher acceptable limit.

i01899136

## Battery - Test

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

### WARNING

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

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

### NOTICE

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

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

i06260318

## 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 28 mL (1 oz) 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

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  $28 \pm 1$  V on a 24 V system and  $14 \pm 0.5$  V on a 12 V 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 Specifications, "Alternator".

i04371153

## V-Belt - Test

### NOTICE

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

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

- Check the poly v-belt for cracks, splits, glazing, grease, displacement of the cord and evidence of fluid contamination.

The poly v-belt must be replaced if the following conditions are present.

- The poly v-belt has a crack in more than one rib.
- More than one section of the poly v-belt is displaced in one rib of a maximum length of 50.8 mm (2 inch).

To replace the poly v-belt, refer to Operation and Maintenance Manual, "Alternator and Fan Belts - Replace".

i03923009

## Electric Starting System - Test

### General Information

Power which is available during cranking varies according to the temperature and condition of the batteries. Table 14 shows the voltages which are expected from a battery at the various temperature ranges.

Table 14

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

Table 15 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. The voltage drop for new machines is less than the voltage shown in table 15 .

Table 15

Maximum Acceptable Voltage Drop In The Starting Motor Circuit During Cranking		
Circuit	12 V System	24 V System
Battery post "-" to the starting motor terminal "-"	0.7 V	1.4 V
Drop across the disconnect switch	0.5 V	1.0 V
Battery post "+" to the terminal of the starting motor solenoid "+"	8 to 10 V	16 to 20 V
Solenoid terminal "Bat" to the solenoid terminal "Mtr"	0.4 V	0.8 V

Voltage drops that are greater than the amounts in table 15 are caused most often by the following conditions:

- Loose connections
- Corroded connections
- Faulty switch contacts

### Diagnosis Procedures

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.

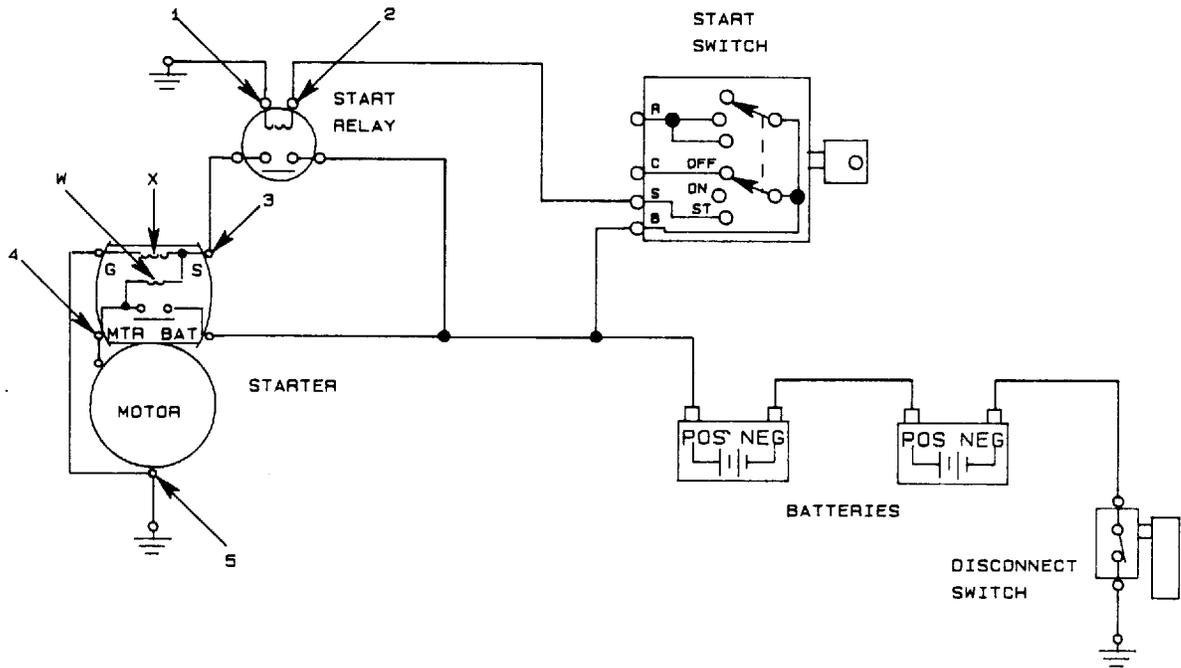


Illustration 77

g00584419

Typical 24 V starting circuit

- (1) Test point
- (2) Test point
- (3) Test point
- (4) Test point
- (5) Test point
- (X) Hold-in coil
- (W) Pull-in coil

**Diagnosis Procedure for 12 V 4 kW Starting Motor**

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

1. Perform a visual check on the starting motor and the circuit. Record any appropriate observations.
  - Ensure that all cables and connections are clean and tight.
  - Ensure that any lead wires are not shorted.
2. 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 14 , then go to step 3.
- b. The battery voltage is less than the voltage in table 14 . Test the battery. Refer to Systems Operation, Testing, and Adjusting, "Battery -

Test" for the correct procedure.

**Note:** Low battery voltage can be caused by the condition of the battery or a shorted starting motor.

3. Measure the current that is sent to the T31 terminal on the starting motor solenoid from the positive post of the battery with a suitable ammeter. The maximum current that flows to the T31 terminal should be equal to 1000 amp or the maximum current that flows to the solenoid should be less than 1000 amp.

If the current is too great, a problem exists in the starting motor. Replace the starting motor.

**Note:** If the following conditions exist, do not perform the test in step 3 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 14 .
- The large starting motor cables get hot.

4. Measure the starting motor voltage from test point (4) to test point (5) with a suitable multimeter.
  - 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 14 , then the battery and the starting motor cable that goes to the starting motor are within specifications. Go to step 6.
  - c. The starting motor voltage is less than the voltage specified in table 14 . The voltage drop between the battery and the starting motor is too great. Go to step 5.
5. 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 15 .
  - b. Voltage drops are equal to the voltage drops that are given in table 15 or the voltage drops are less than the voltage drops that are given in table 15 . Go to step 6 in order to check the engine.
  - c. The voltage drops are greater than the voltage drops that are given in table 15 . The faulty component should be repaired or replaced.
6. 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 7.
7. 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.

## Diagnosis Procedure for 24 V 5.5 kW Starting Motor

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

1. Perform a visual check of the starting motor and the circuit. Record any appropriate observations.
  - Ensure that all cables and connections are clean and tight.
  - Ensure that any lead wires are not shorted.
2. 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 14 , then go to step 3.
- b. The battery voltage is less than the voltage in table 14 . Test the battery. Refer to Systems Operation, Testing, and Adjusting, "Battery - Test" for the correct procedure.

**Note:** Low battery voltage can be caused by the condition of the battery or a shorted starting motor.

3. Measure the current that is sent to the T31 terminal on the starting motor solenoid from the positive post of the battery with a suitable ammeter. The maximum current that flows to the T31 terminal should be equal to 600 amp or the maximum current that flows to the solenoid should be less than 600 amp.

If the current is too great, a problem exists in the starting motor. Replace the starting motor.

**Note:** If the following conditions exist, do not perform the test in step 3 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 14 .
- The large starting motor cables get hot.

4. Measure the starting motor voltage from test point (4) to test point (5) with a suitable multimeter.
  - 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 14 , then the battery

and the starting motor cable that goes to the starting motor are within specifications. Go to step 6.

- c. The starting motor voltage is less than the voltage specified in table 14 . The voltage drop between the battery and the starting motor is too great. Go to step 5.

**5. 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 15 .
- b. Voltage drops are equal to the voltage drops that are given in table 15 or the voltage drops are less than the voltage drops that are given in table 15 . Go to step 6 in order to check the engine.
- c. The voltage drops are greater than the voltage drops that are given in table 15 . The faulty component should be repaired or replaced.

**6. 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 7.

**7. Attempt to crank the starting motor.**

- a. The starting motor cranks slowly.

Remove the starting motor for repair or replacement.

- b. The starting motor does not crank.

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

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

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