

Systems Operation Testing and Adjusting

1206E-E70TTA Industrial Engine

BL (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 1206E-E70TTA engine. Due to individual applications, your engine may appear different from the illustrations.

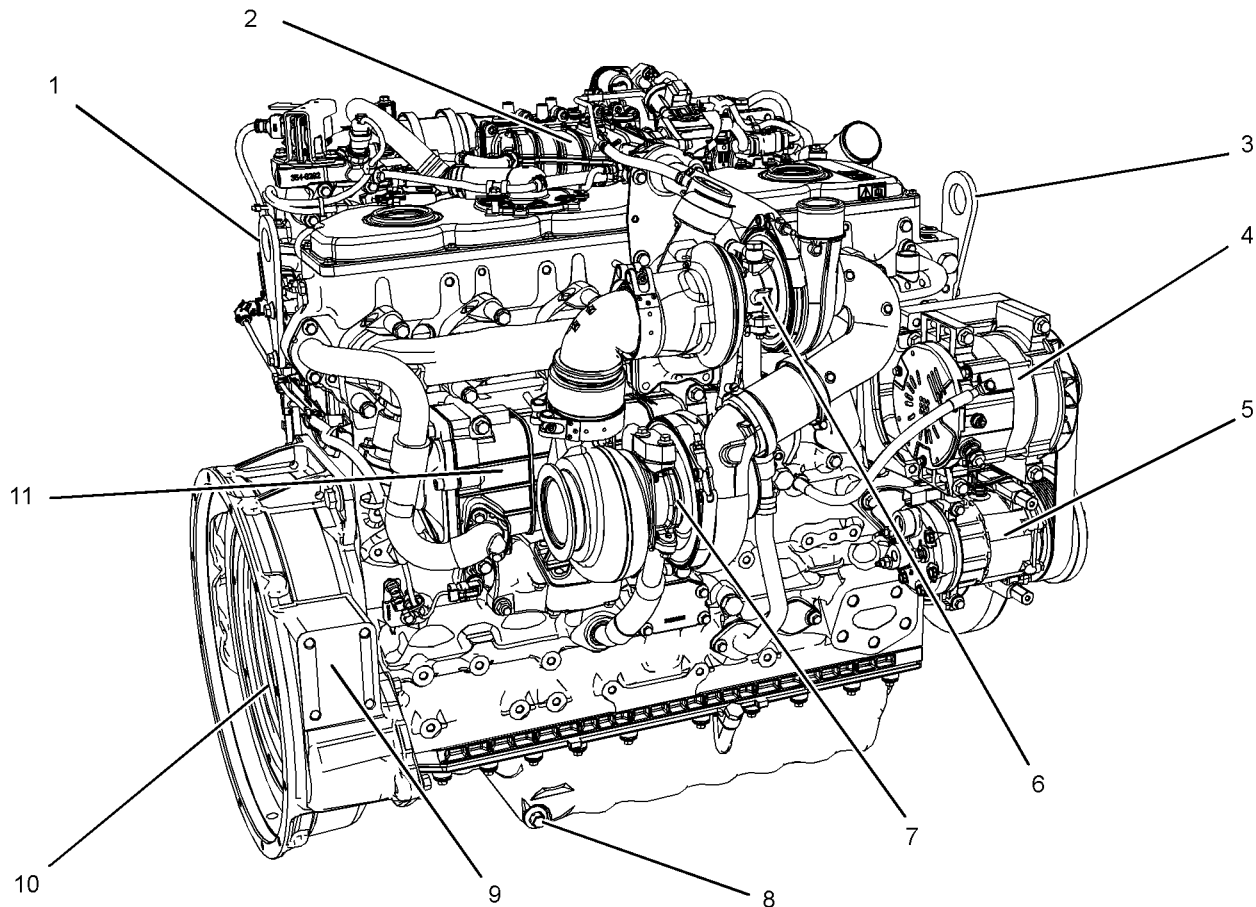


Illustration 1

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Typical example

- | | | |
|--------------------------------|--------------------------------|-------------------------------|
| (1) Rear lifting eye | (5) Refrigerant compressor | (9) Flywheel housing |
| (2) NOx Reduction System (NRS) | (6) High-pressure turbocharger | (10) Flywheel |
| (3) Front lifting eye | (7) Low-pressure turbocharger | (11) Exhaust gas cooler (NRS) |
| (4) Alternator | (8) Engine oil drain | |

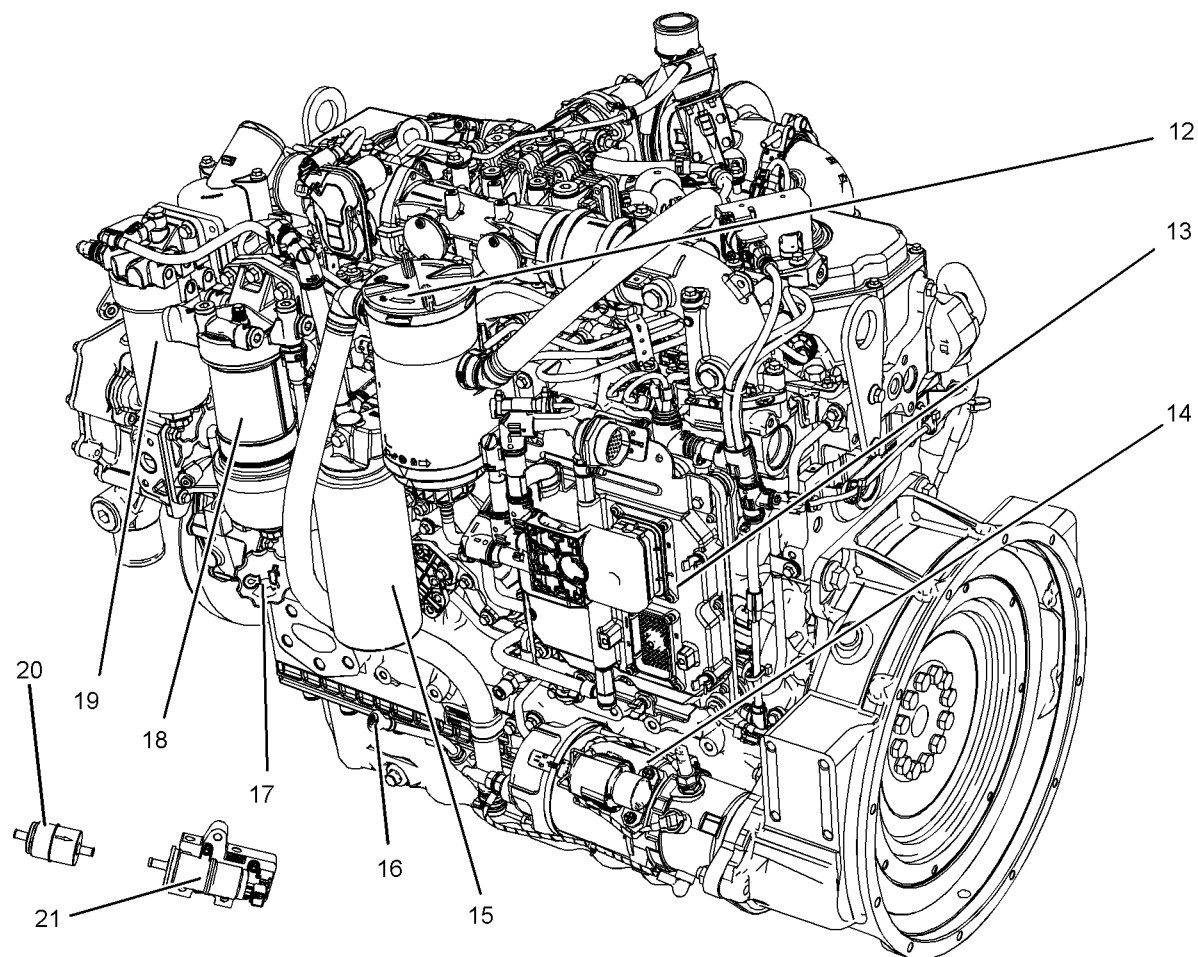


Illustration 2

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Typical example

(12) Crankcase breather
(13) Electronic control module (ECM)
(14) Starting motor
(15) Oil filter

(16) Oil gauge
(17) Oil filler
(18) Primary fuel filter
(19) Secondary fuel filter

(20) In-line fuel strainer
(21) Electric fuel priming pump

The location of the in-line fuel strainer (20) and the priming pump (21) will depend on the application.

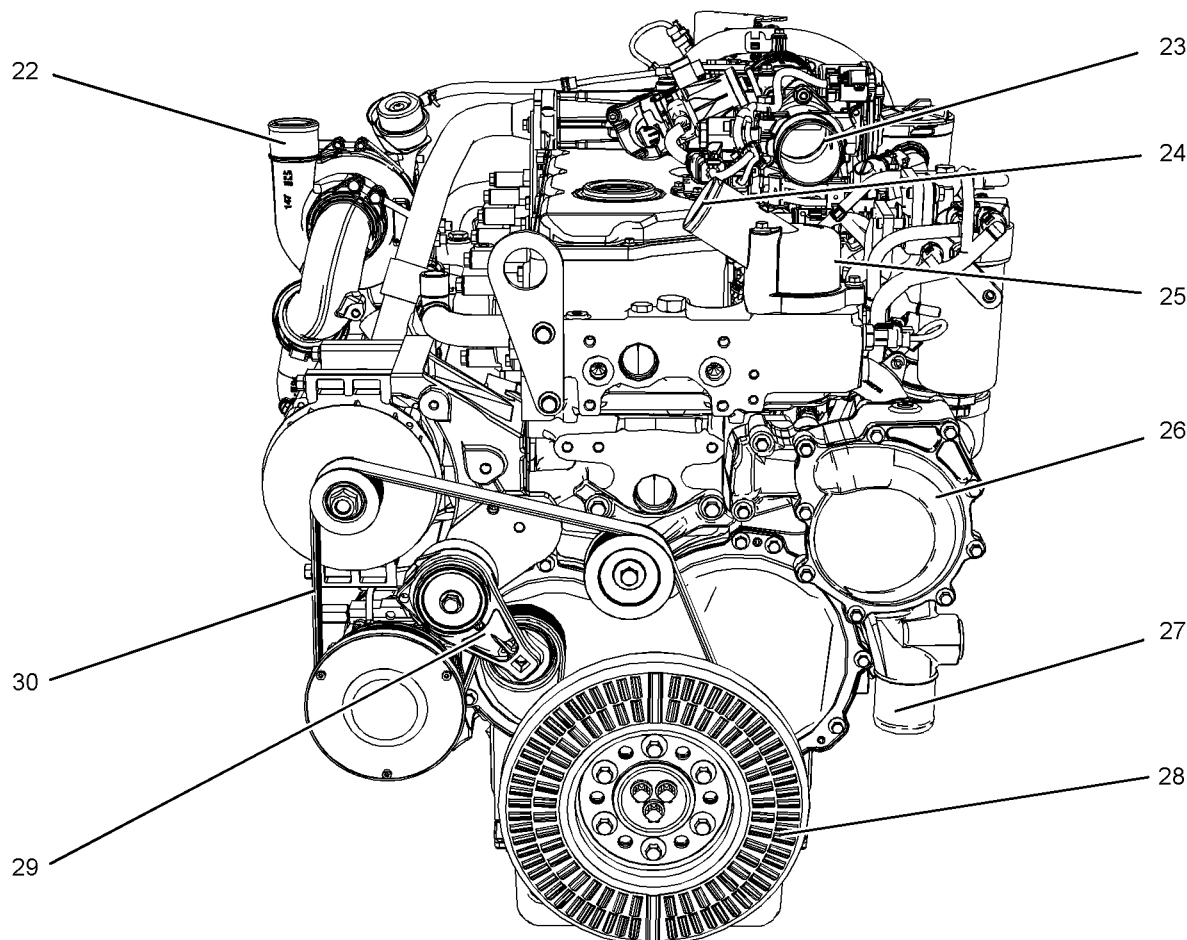


Illustration 3

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Typical example

(22) Outlet connection to the air to air charge cooler
(23) Connection for the air inlet
(24) Outlet connection for the coolant

(25) Housing for the water temperature regulator
(26) Water pump
(27) Inlet connection for the Coolant

(28) Vibration damper
(29) Belt tensioner
(30) Belt

The 1206E-E70TTA diesel engine is electronically controlled. The 1206E-E70TTA engine uses an Electronic Control Module (ECM) that receives signals from the fuel injection pump and other sensors in order to control the electronic unit injector. The fuel injection pump supplies fuel to the high-pressure manifold (Rail). The high-pressure manifold (Rail) distributes fuel to the electronic unit injectors.

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

Each cylinder has a piston cooling jet that is installed in the cylinder block. The piston cooling jet sprays engine oil onto the inner surface of the piston in order to cool the piston. The pistons have a Quiescent combustion chamber in the top of the piston in order to achieve clean exhaust emissions. The piston pin is off-center in order to reduce the noise level.

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

The crankshaft has seven main bearing journals. End play is controlled by thrust washers which are located on both sides of the number 6 main bearing.

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

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

- the camshaft gear
- the accessory drive gear (if equipped)
- the fuel injection pump gear
- the water pump gear

The camshaft runs at half the rpm of the crankshaft. The fuel injection pump runs at the same rpm 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 fuel is transferred to the fuel injection pump by an external electric transfer pump. The electric transfer pump draws fuel across a suction strainer that supplies fuel to the primary fuel filter and the secondary fuel filter. The fuel then travels to the fuel injection pump. A pressure regulator that is installed in the low-pressure fuel system controls the fuel pressure to the fuel injection pump. The pressure regulator regulates the fuel at an absolute pressure of 150 kPa (22 psi) when the engine is at idle speed.

The fuel injection pump increases the fuel to a maximum pressure of 200 MPa (29007 psi). The fuel injection pump delivers the fuel to the high-pressure manifold (Rail). The fuel injection pump is not serviceable. The engine uses speed sensors and the Electronic Control Module to control the engine speed.

For the specifications for the 1206E-E70TTA engine, refer to Specifications, "Engine Design".

Engine Operation

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Basic Engine

Introduction

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

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

Cylinder Block

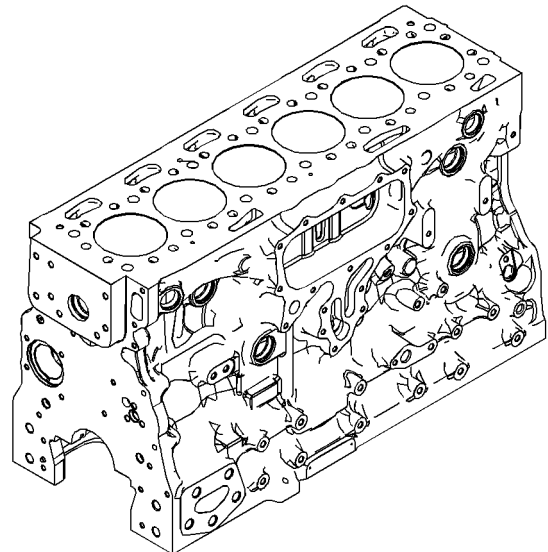


Illustration 4

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Typical example

The cast iron cylinder block for the 1206E-E70TTA engine has six cylinders which are arranged in-line. The cylinder block is made of cast iron in order to provide support for the full length of the cylinder bores. 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 seven main bearings which support the crankshaft. Thrust washers are installed on both sides of number 6 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 cast 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

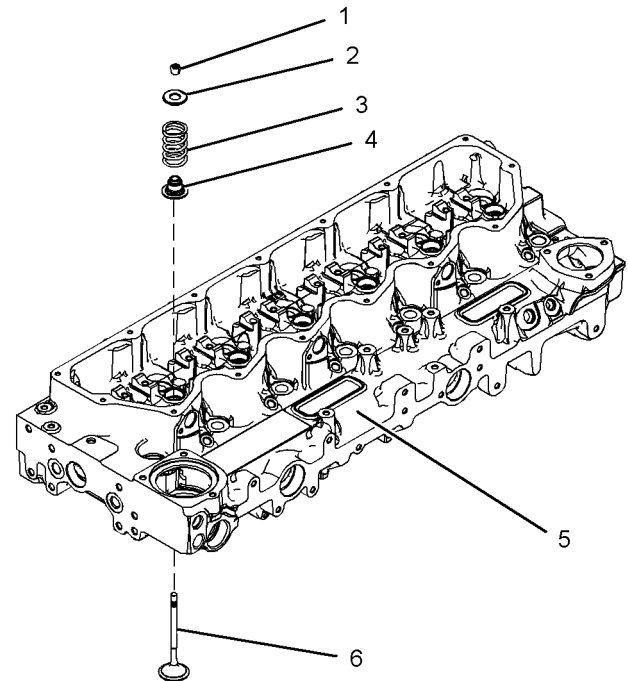


Illustration 5

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Typical example

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

The engine has a cast iron cylinder head (5). The inlet manifold is integral within the cylinder head. There are two inlet valves and two exhaust valves for each cylinder. Each pair of valves (6) are connected by a valve bridge that is controlled by a pushrod valve system. The ports for the inlet valves are on the left side of the cylinder head. The ports for the exhaust valves are on the right side of the cylinder head. The valve stems move in valve guides that are finished machined into the cylinder head. There is a renewable stem seal (4) that fits over the top of the valve guide. The valve seats are replaceable.

Pistons, Rings, and Connecting rods

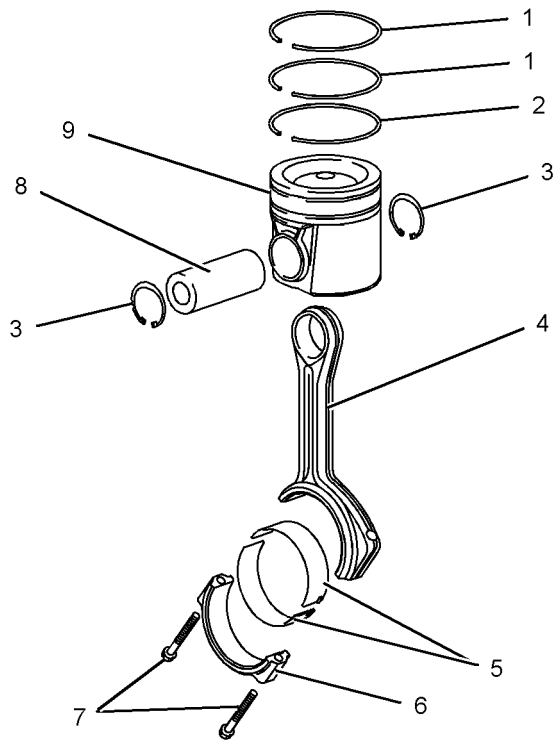


Illustration 6

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Typical example

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

The pistons 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 to reduce friction and improve fuel economy.

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. Two connecting rod bearings (5) are installed between the connecting rod (4) and the bearing cap (6). The bearing caps on fracture split connecting rods are retained with Torx 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

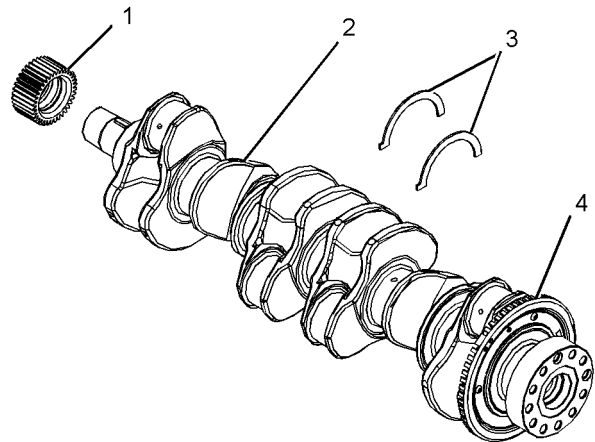


Illustration 7

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Typical example

- (1) Crankshaft gear
- (2) Crankshaft
- (3) Crankshaft thrust washers
- (4) Crankshaft timing ring

The crankshaft is a chromium molybdenum forging. The crankshaft has seven main journals. Thrust washers are installed on both sides of number 6 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
- The idler gear is driven by the crankshaft gear which turns the gear of the lubricating oil pump.

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

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

Vibration Damper

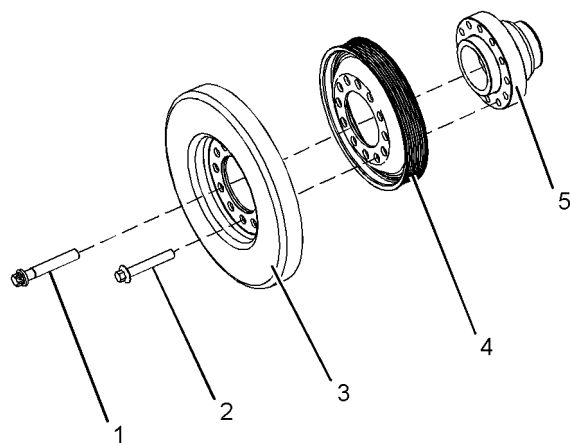


Illustration 8

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Typical example

- (1) Setscrews
- (2) Setscrews
- (3) Vibration damper
- (4) Crankshaft pulley
- (5) Crankshaft adapter

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

Gears and Timing Gear Case

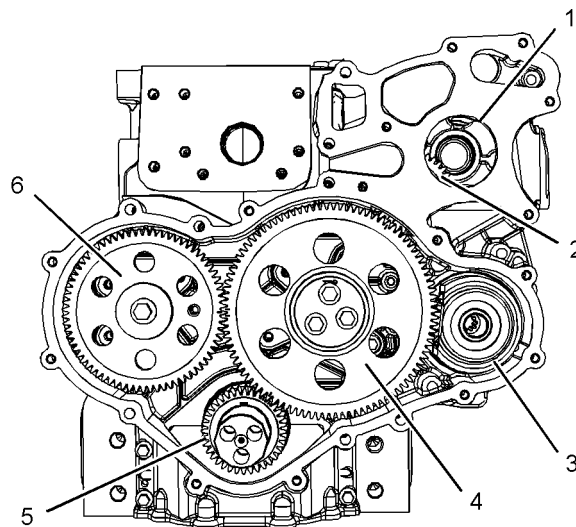


Illustration 9

g02212814

Typical example

- (1) Hole for the water pump gear
- (3) Position of the accessory drive gear

The crankshaft oil seal is mounted in the cover of the timing case. The timing case cover is made from sound-deadened steel or cast iron.

The timing gears are made of steel.

The crankshaft gear (5) drives an upper idler gear (4) and a lower idler gear. The upper idler gear (4) drives the camshaft gear (6) and the fuel injection pump gear (2). The lower idler gear drives the oil pump. The water pump drive gear is driven by the fuel injection pump gear.

The camshaft rotates at half the engine speed. The fuel injection pump rotates at 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

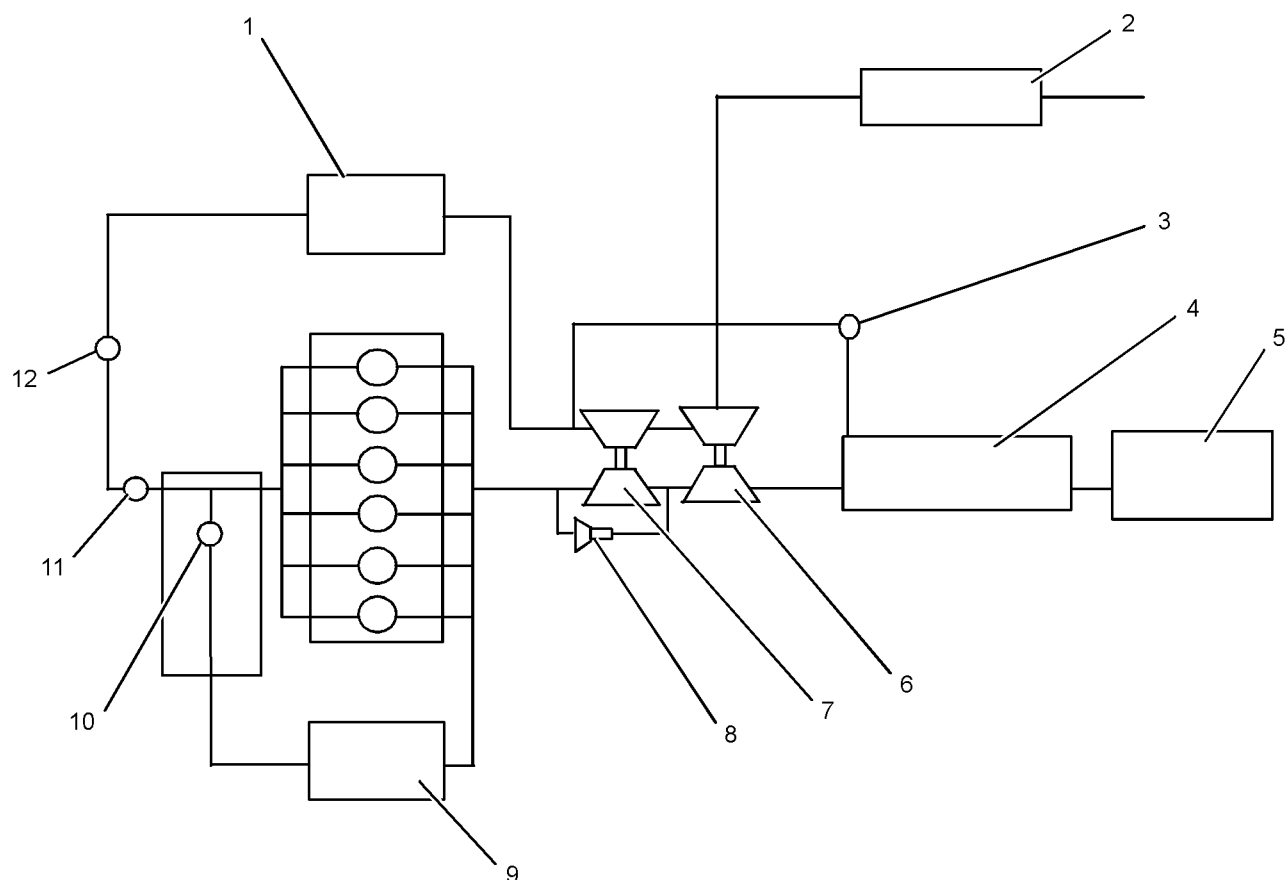


Illustration 10

g02349356

Air inlet and exhaust system

- | | | |
|--|---|-------------------------------|
| (1) Aftercooler core | (5) Diesel particulate filter and diesel oxidation catalyst | (9) Exhaust cooler (NRS) |
| (2) Air filter | (6) Low-pressure turbocharger | (10) Exhaust gas valve (NRS) |
| (3) Air control valve for the aftertreatment regeneration device | (7) High-pressure turbocharger | (11) Inlet gas throttle valve |
| (4) Aftertreatment regeneration device | (8) Wastegate actuator | (12) 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 gas cooler (NRS)
- Exhaust gas valve (NRS)
- Turbochargers
- Aftercooler
- Inlet manifold
- Cylinder head, injectors, and glow plugs
- Valves and valve system components
- Piston and cylinder
- Exhaust manifold
- Aftertreatment regeneration device
- Diesel oxidation catalyst
- Diesel particulate filter
- Inlet gas throttle valve

Air is drawn in through the air cleaner into the air inlet of the low-pressure turbocharger by the low-pressure turbocharger compressor wheel. The air is compressed to a pressure of about 150 kPa (22 psi) and heated to about 120° C (248° F). From the low-pressure turbocharger, the air passes to the high-pressure turbocharger. The air is compressed to a pressure of about 325 kPa (47 psi) and heated to about 240° C (464° 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 horsepower output
- Reduced NOx emission
- Reduced particulate emission

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

- Inlet
- Compression
- Power
- Exhaust

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

Note: If the cold starting system is operating, the glow plugs 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. The piston moving forward initiates the exhaust stroke. The exhaust valves open. The exhaust gases are forced through the open exhaust valves into the exhaust manifold.

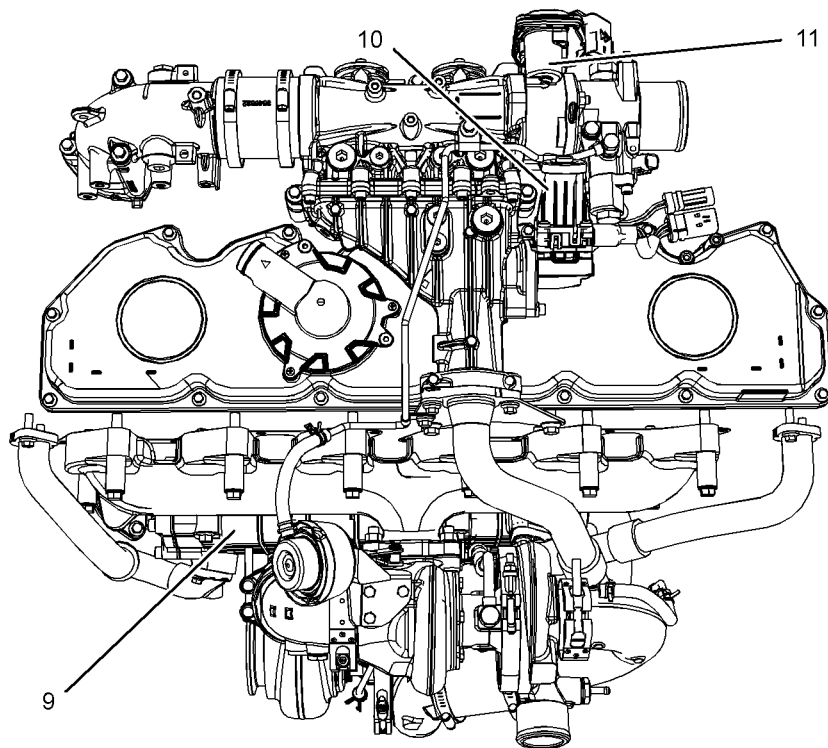


Illustration 11

g02297554

Typical example

The NOx Reduction System (NRS) operates with the transfer of the hot exhaust gas from the exhaust manifold to the exhaust cooler. The hot exhaust gas is cooled in the exhaust cooler (9). The now cooled exhaust gas passes through the assembly of the exhaust gas valve to an electronic controlled valve (10). The electronically controlled valve is electronically actuated.

The reed valves that are located in the exhaust gas valve (NRS) have two main functions. The first function is to prevent the reverse flow of charge air from the inlet side of the engine to the exhaust side of the engine. The second function of the reed valve is to obtain exhaust gas when the peak exhaust pressure is above the average inlet pressure.

As the electronically controlled valve (10) starts to open the flow of cooled exhaust gas from the exhaust cooler (9) mixes with the air flow from the charge air intercooler. The mixing of the cooled 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 cooled exhaust gas increases the electronically controlled valve opens further. The further opening of the valve increases the flow of cooled exhaust gas from the exhaust cooler. As the demand for cooled exhaust gas decreases, the electronically controlled valve closes. This decreases the flow of cooled exhaust gas from the exhaust cooler.

The electronically controlled exhaust gas valve and the inlet gas throttle valve (11) for the NOx Reduction System (NRS) are controlled by the ECM. In some instances, the engine will need to use the electronically controlled exhaust gas valve (10) and the inlet gas throttle valve (11) for the NOx Reduction System (NRS) in order to generate the required flow of exhaust gas. The inlet gas throttle valve for the NOx Reduction System (NRS) works by reducing the pressure in the inlet manifold in order to draw through extra exhaust gas.

Exhaust gases from the exhaust manifold enter the inlet of the high-pressure turbocharger in order to turn the high-pressure turbocharger turbine wheel. The turbine wheel is connected to a shaft that rotates. The exhaust gases travel from the high-pressure turbocharger through the duct on the turbine side into the turbine inlet of the low-pressure turbocharger in order to power the low-pressure turbocharger. The exhaust gases pass from the low-pressure turbocharger through the following components: exhaust outlet, Aftertreatment Regeneration Device (ARD), Diesel Oxidation Catalyst (DOC), Diesel Particulate Filter (DPF), and exhaust pipe.

Turbochargers

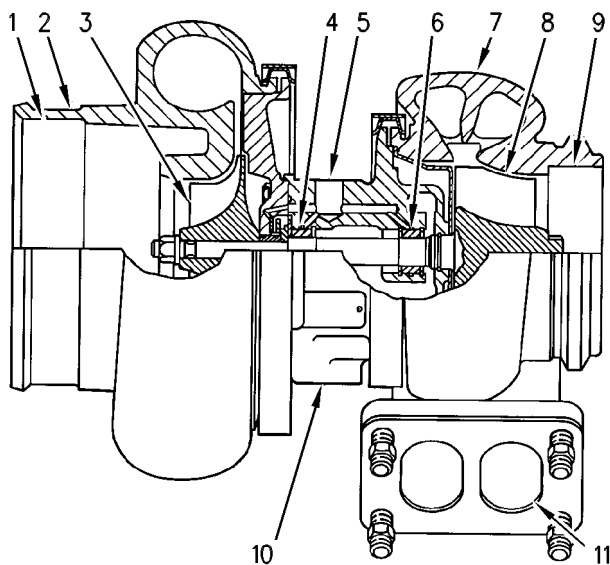


Illustration 12

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 high-pressure turbocharger is mounted on the outlet of the exhaust manifold. The low-pressure turbocharger is mounted on the side of the cylinder block. 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.

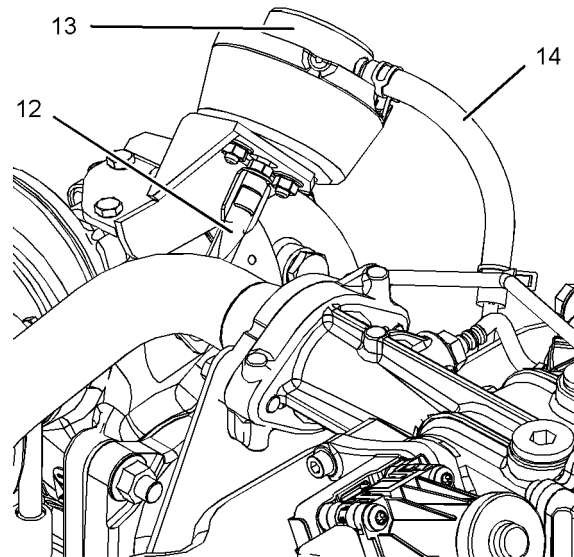


Illustration 13

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Typical example

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

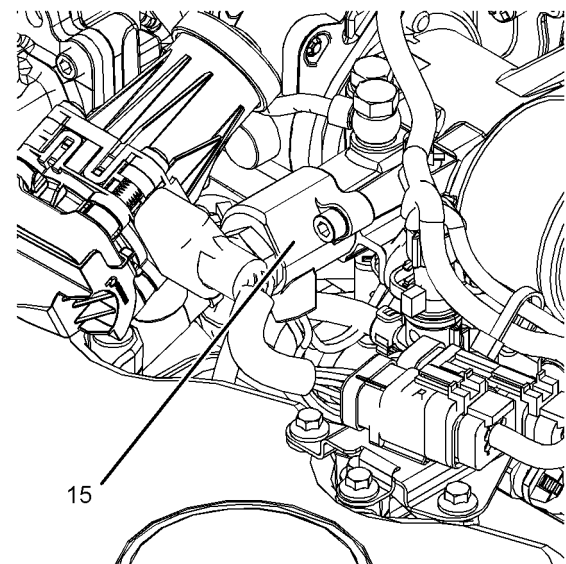


Illustration 14

g02299034

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. This produces more power.

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

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 higher boost pressure is needed for the engine performance, a signal is sent from the ECM to the wastegate regulator. The wastegate regulator reduces the pressure in the air inlet pipe (14) that acts upon the diaphragm within the wastegate actuator (13).

The spring within the wastegate actuator (13) forces the wastegate valve that is within the turbine housing to close via the actuating rod and lever. When the wastegate valve is closed, more exhaust gas is able to pass over the turbine wheel. This results in an increase in turbocharger speed and boost pressure generation.

When lower 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 (14) to act on the diaphragm within the wastegate actuator (13). The actuating rod (12) acts upon the actuating lever to open the valve in the wastegate. When the valve in the wastegate is opened, more exhaust gas from the engine is able to bypass the turbine wheel. The exhaust gases bypass the turbine wheel results 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

The engine crankcase breather is a filtered system. The crankcase breather system consists of two main elements, a primary separator in the valve mechanism cover and a filtered canister that is mounted on the cylinder head. The gases exit the engine through the valve mechanism cover. The gases then pass through the primary separator. The primary separator removes most of the liquid oil from the gas. The liquid oil is then returned to the engine.

The gas then passes through the filter element before exiting to atmosphere in an open breather system or back to the induction system in a closed breather system via the breather vent pipe.

Any liquid oil that is captured by the filter drains from the bottom of the canister. The liquid oil is returned by the drain pipe that runs from the bottom of the canister back to the crankcase. A valve connects the drain pipe to the crankcase. This valve prevents the bypass of gas past the filter and oil from passing up the drain pipe.

A pressure relief valve is located in the rear of the canister in the integral mounting bracket. Under normal operation of the engine, this valve will not operate. If part of the system becomes blocked the valve will open at a pressure of 8.5 kPa (1.2 psi). The open valve will allow gas to bypass the filter and the pipes for venting.

The filter element can be accessed from either the top of the canister by removing the top cap or from the bottom of the canister by removing the bottom cap. Refer to Operation and Maintenance Manual, "Engine Crankcase Breather Element - Replace" for the correct procedure.

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.

Valve System Components

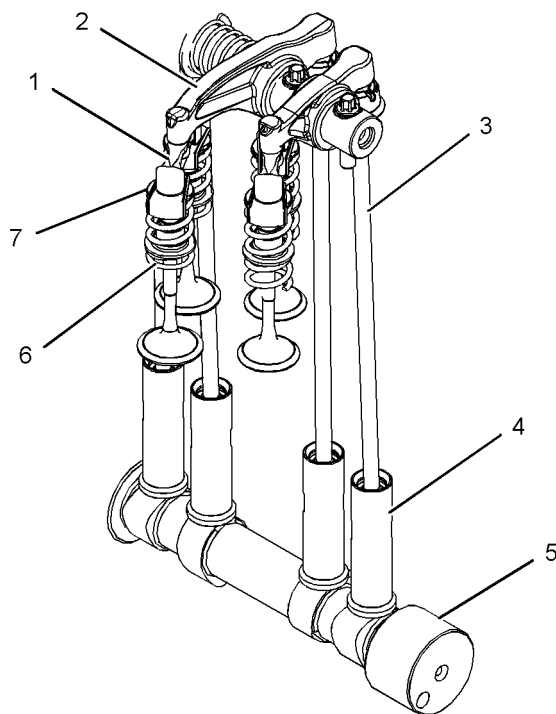


Illustration 15

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Valve system components

- (1) Bridge
- (2) Rocker arm
- (3) Pushrod
- (4) Hydraulic lifter
- (5) Camshaft
- (6) Spring
- (7) Valve

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

The crankshaft gear drives the camshaft gear through an idler gear. The camshaft (5) must be timed to the crankshaft in order to get the correct relation between the piston movement and the valve movement.

The camshaft (5) has two camshaft lobes for each cylinder. The lobes operate either a pair of inlet valves or a pair of exhaust valves. As the camshaft turns, lobes on the camshaft cause the lifter (4) to move the pushrod (3) up and down.

The lifter (4) incorporates a hydraulic lash adjuster which removes valve lash from the valve mechanism. The lifter (4) 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 lifter (4) through a non-return valve. The engine lubricating oil increases the length of the lifter (4) until all valve lash is removed. If the engine is stationary for a prolonged period the valve springs will cause the lifter (4) 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 lifter (4) increases in length and removes the valve lash. When load is removed from a lifter (4) during service work by the removal of the rocker shaft the lifter (4) 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.

Upward movement of the pushrod against rocker arm (2) results in a downward movement that acts on the valve bridge (1). This action opens a pair of valves (7) which compresses the valve springs (6). When the camshaft (5) has rotated to the peak of the lobe, the valves are fully open. When the camshaft (5) rotates further, the two valve springs (6) under compression start to expand. The valve stems are under tension of the springs. The stems are pushed upward in order to maintain contact with the valve bridge (1). The continued rotation of the camshaft causes the rocker arm (2), the pushrods (3) and the lifters (4) to move downward until the lifter reaches the bottom of the lobe. The valves (7) are now closed. The cycle is repeated for all the valves on each cylinder.

i04027280

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.

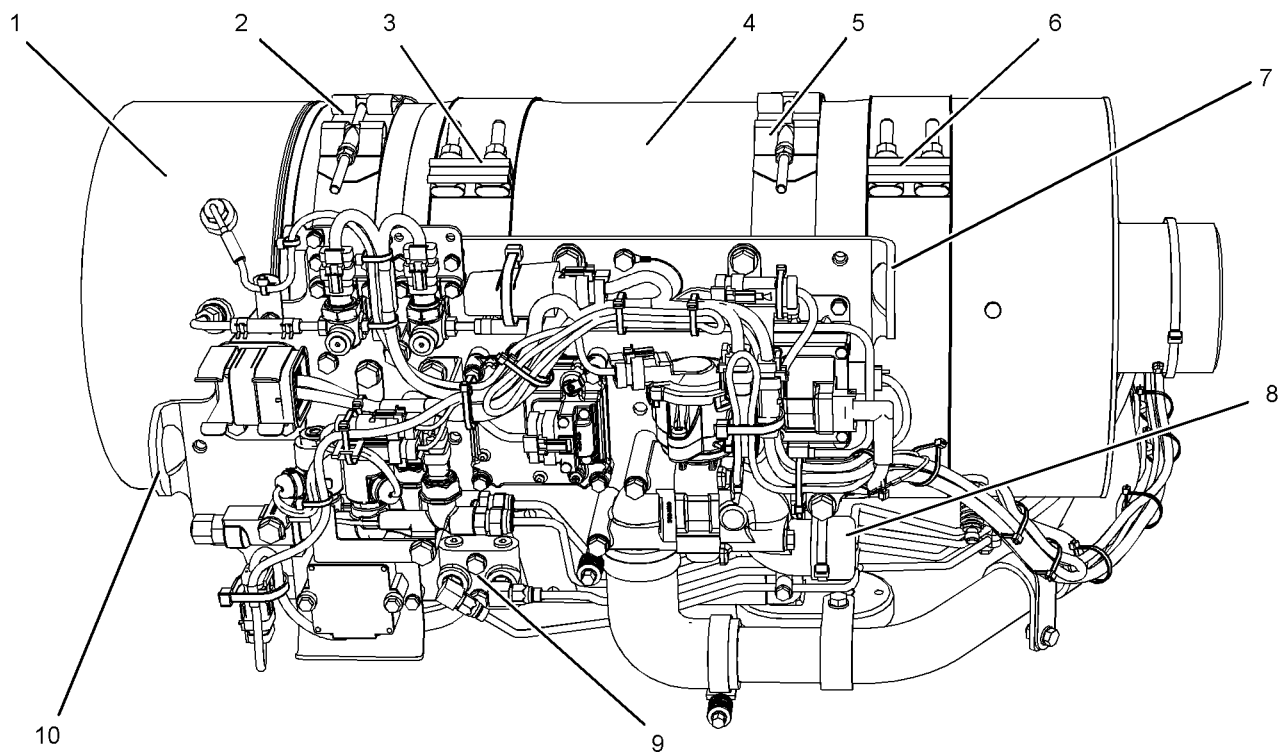


Illustration 16

g02162626

Typical example

- | | | |
|-------------------------------------|--|------------------|
| (1) Diesel Oxidation Catalyst (DOC) | (6) Torca clamp | (10) Lifting eye |
| (2) Securing clamp | (7) Lifting eye | |
| (3) Torca clamp | (8) Air inlet for Aftertreatment Regeneration Device (ARD) | |
| (4) Diesel Particulate Filter (DPF) | (9) Connections for coolant manifold | |
| (5) Securing clamp | | |

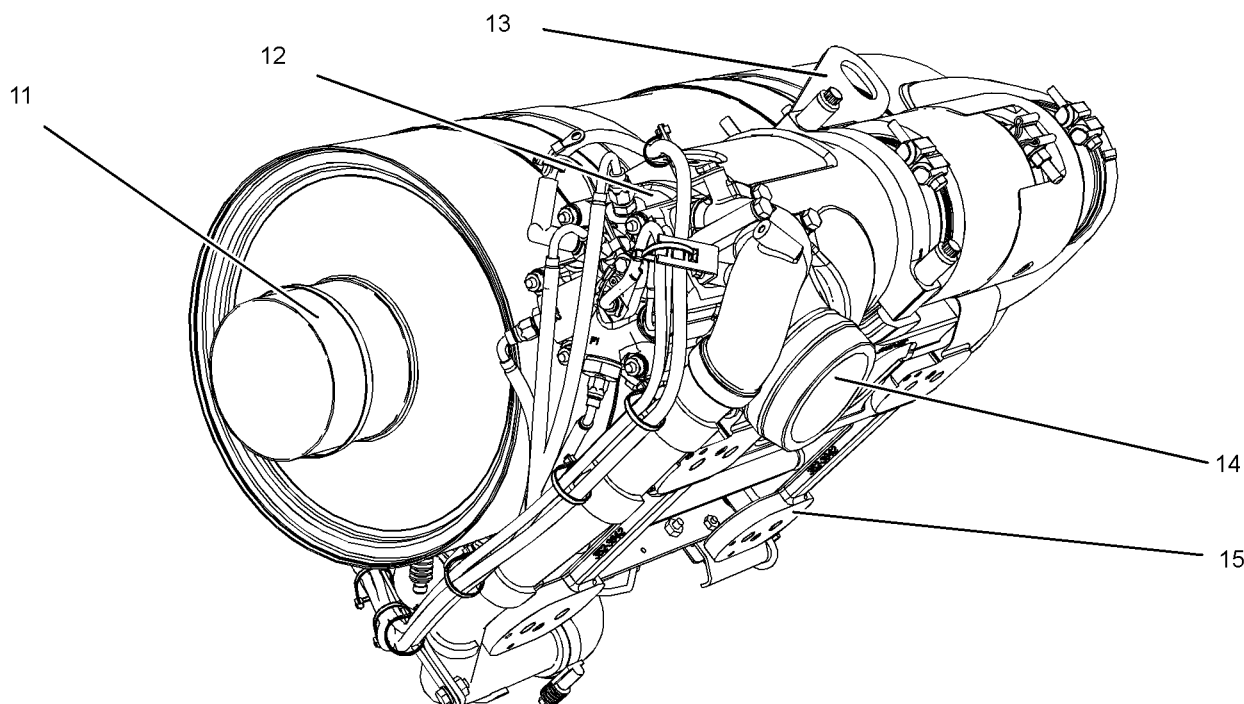


Illustration 17

g02162641

Typical example

- | | |
|---|----------------------|
| (11) Outlet to exhaust system | (13) Lifting eye |
| (12) Aftertreatment Regeneration Device (ARD) | (14) Exhaust Inlet |
| | (15) Mounting cradle |

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

- Aftertreatment Regeneration Device (ARD)
- 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. This 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 Aftertreatment Regeneration Device (ARD) increases the exhaust gas temperature to a sufficient level. The soot that is collected in the DPF is oxidized to carbon dioxide.

A flexible exhaust pipe connects the engine to the Clean Emissions Module (CEM). Refer to Disassembly and Assembly for the correct procedure to install the flexible exhaust pipe.

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.

The rate of accumulation of ash is slow. The filter is designed to contain all the ash that is produced until the defined service interval.

The soot that is collected must be removed at regular intervals. Removal of the soot is achieved by elevating the exhaust gas temperature by burning fuel in the ARD for a short time period. If the exhaust gas temperature is high enough, the ARD oxidizes the soot into carbon dioxide, which then passes through the filter and into the atmosphere. The ARD may automatically switch ON and OFF. The ARD may be manually controlled by the operator. The ARD is controlled by the sensor for the soot level. The sensor for the level of soot will ensure that the level of soot in the filter is kept within limits. This is referred to as a regeneration of the filter.

In order to regenerate the DPF at the right time, the engine ECM must know how much soot is in the DPF. Measurement of soot is accomplished through the following means:

- Delta pressure measurement across the DPF

- Radio frequency measurement across the DPF
- Calculated model based on developed engine out soot measurements

The information gathered from these three inputs is then converted into a percentage of soot output that is viewable through electronic soot level gauges. These gauges can be found in the cab of most applications as well as various operator displays that are used with most engines. The soot level may be displayed as a graphical bar, or as an actual percentage. Soot level can also be viewed through the electronic service tool.

The frequency of regeneration will depend on the operating conditions of the engine. The frequency of regeneration will depend on the ambient conditions of the operation of the engine. Regeneration will be most frequent if the application operates with a high transient content or the atmospheric temperature or the altitude is high.

Soot Level Outputs

The soot level percentage that is generated by the engine ECM is used in determining:

- When to activate the DPF lamp
- When to activate the action lamp (for high soot load events)
- When to activate the action alarm (for high soot load events) (if equipped)
- When to activate the forced engine low idle strategy
- When to activate the forced engine shutdown strategy
- Operator initiated regeneration lockout
- When a force switch regeneration is allowed
- When a low speed regeneration is allowed
- When a high speed regeneration is allowed

DPF Lamp – The DPF lamp will be illuminated at a 90 percent soot level on engines.

Action Lamp – The action lamp will be illuminated at a 100 percent soot level for engines. The DPF lamp will remain on with the action lamp.

Action Alarm – The action alarm will be activated at a 116 percent soot level for engines.

Forced low idle strategy – The forced low idle strategy will be activated after the soot level has been at 116 percent for 5 minutes. At this time, the engine will automatically drop to the programmed low idle speed. The only method to unlock the low idle speed is to cycle the key switch or perform a regeneration.

Regeneration lockout – Regeneration will be locked out from the operator once the soot level percent has been at 116 percent for 10 minutes. Regeneration can only be performed by using the “Manual DPF Regeneration” service procedure within the electronic service tool.

Forced engine shutdown strategy – The forced engine shutdown strategy will be activated when the soot level reaches 140 percent soot level. The engine will initially idle for 30 seconds before completely shutting down. The DPF can no longer be regenerated and must be replaced.

Force Switch Regeneration – Regeneration initiated by the force switch is allowed once soot level is greater than 15 percent.

Low Speed Regeneration – Low speed regeneration will be allowed once soot level is greater than 30 percent.

High Speed Regeneration – High speed regeneration will be allowed once soot level is greater than 60 percent.

Regeneration Types and Operating Criteria

Automatic Regenerations

There are two types of automatic regeneration. These regenerations are referred to as low speed regeneration and high speed regeneration. Low speed regeneration and high speed regeneration must meet certain criteria before the regeneration will automatically activate. This criteria is outlined below. Both low speed regeneration and high speed regeneration can be configured through the electronic service tool.

Low Speed Regeneration

Low speed regeneration occurs when the application is in a stationary or non-working condition. Low speed regenerations allow for the most precise control of fuel and airflow. Low speed regenerations require the least amount of fuel to be used as well as having the lowest duration times. The parameters listed below must be met to activate the low speed regeneration.

Engine Speed – Engine speed must be within the low idle speed setting and 1500 rpm. If engine speed exits this window for 1 second, the regeneration will terminate.

Fuel Delivery – Delivered fuel volume must be within 10 and 80 cubic millimeters of fuel. If fuel delivery exits this window for 1 to 2 seconds, the regeneration will terminate.

Readiness indicators – The ECM will monitor a number of different parameters that are communicated through the CAN datalink from other ECMs on the machine (if equipped). These parameters are referred to as regeneration readiness indicators. Examples of these parameters are: parking brake on or off, hydraulic lock on or off, vehicle speed, throttle position, and operator seat switch. These parameters are used in determining the best opportunity to perform a low speed regeneration. As the ECM processes the data from these inputs, the ECM is able to predict when the machine will likely be in a non-working condition. During this non-working condition the ECM will attempt to perform a significant amount of regeneration. The regen readiness parameters are not viewable in the electronic service tool.

Engine Speed Control During Low Speed Regeneration – If the engine speed is below 975 rpm when a regeneration is activated, the ECM will elevate engine speed between 1000 and 1400 rpm. This change depends on the application. This change in speed allows for the proper amount of air flow required to maintain an optimal DPF inlet temperature for regeneration. The elevated engine speed may remain for up to 1 minute after a regeneration has stopped.

High Speed Regeneration

High speed regeneration typically occurs when the engine is in normal operating mode. High speed regenerations consume more fuel and take a longer time to complete compared to low speed regenerations. This longer time is due to maintaining lower desired DPF inlet temperatures to avoid damaging the DPF from extreme changes in temperature. High speed regeneration has two distinct operating regions. These operating regions are determined by the soot level. The first region is between 60 and 75 percent soot level, the second region is between 75 and 90 percent soot level. The 60 to 75 percent region has a tighter engine operating mode in which high speed regeneration can occur. The 75 to 90 percent region opens the engine operating mode to allow for the highest opportunity to perform a high speed regeneration. The parameters listed below outline the operating criteria that are monitored to activate and sustain high speed regeneration.

Note: All of the parameters listed below are independently developed for each application. All applications may not meet the exact criteria outlined below.

Engine speed (60-75% soot level) – Engine speed is typically between 1350 and 2200 rpm. Engine speed should not change more than 200 rpm per second.

Engine speed (75-90% soot level) – Engine speed is typically between 975 and 2350 rpm. Engine speed should not change more than 400 rpm per second.

Fuel Delivery (60-75% soot level) – Fuel delivery is typically within 30 cubic millimeters of the upper limit defined by the engine power rating. As the engine speed increases the window for allowed fuel delivery increases.

Fuel Delivery (75-90% soot level) – Fuel delivery is typically within 10 cubic millimeters and the upper limit defined by the engine power rating. In this soot level range, the upper fuel limit is the maximum allowed fuel at each rpm.

Combustion Air Inlet Pressure (60-75% soot level) – The combustion air inlet pressure should not change more than 65 kPa (9.4 psi) per second.

Combustion Air Inlet Pressure (75-90% soot level) – The combustion air inlet pressure should not change more than 80 kPa (11.6 psi) per second.

Engine Speed Control during High Speed Regeneration

Most aspects of high speed regeneration are transparent. If the engine is in normal working mode and the throttle is released, the low idle will be limited to 1000 rpm. Limiting the engine speed to 1000 rpm will maintain the regeneration. If the engine speed must be brought to the programmed low idle speed, pressing the disable regen switch will stop the regeneration. The engine will return engine speed to the programmed low idle speed.

Manual Regenerations

Manual regeneration is accomplished by pressing the force regeneration switch. Refer to the Operation and Maintenance Manual for correct location of switch. For some applications, the engine must be operating in the low speed regeneration region outlined above. Also soot level must be greater than the amount listed for forced switch regeneration in the soot level outputs section listed above.

Fuel System for the Clean Emissions Module

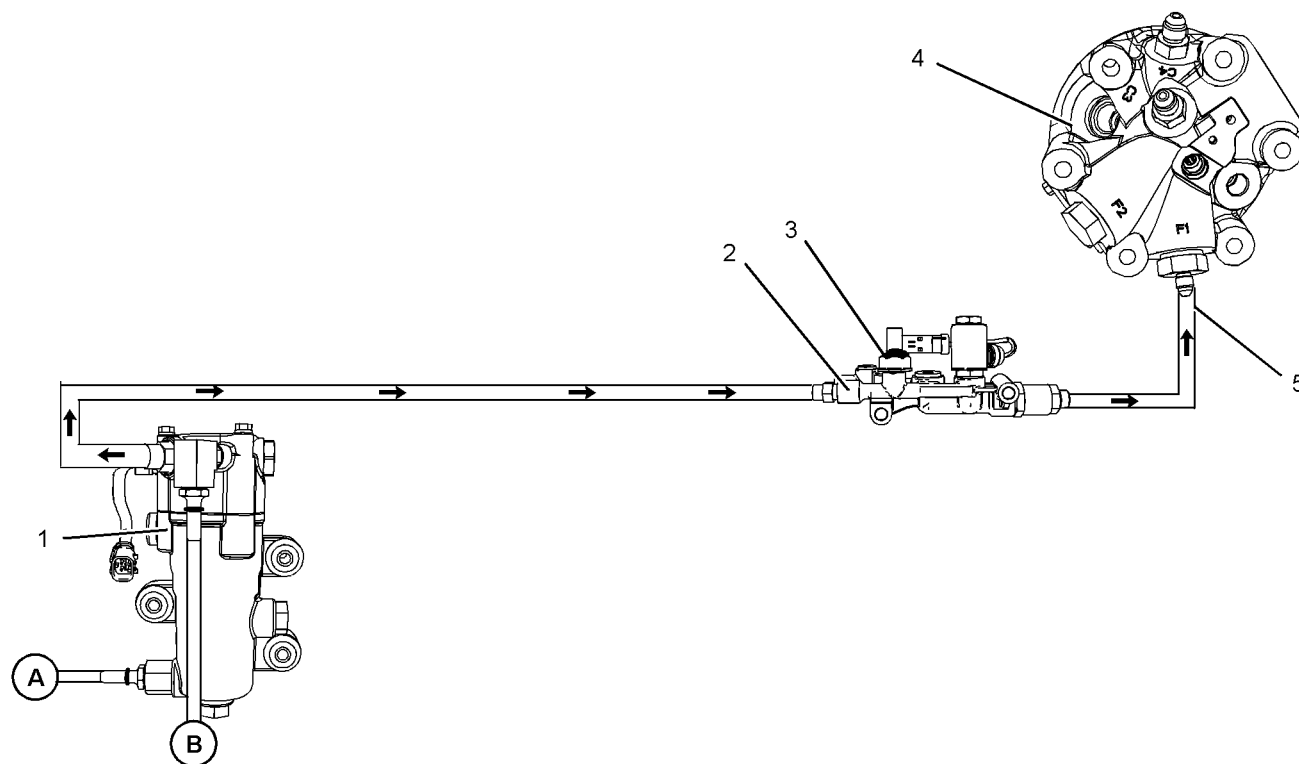


Illustration 18

g02301233

Typical example

(A) Fuel from primary fuel filter
 (1) Fuel pump for the ARD
 (2) Fuel control manifold (ARD)

(3) Fuel pressure sensor
 (4) ARD head
 (5) Fuel line

(B) Fuel return to secondary fuel filter

Fuel flows from the primary fuel filter/water separator to the ARD fuel pump (1). The ARD fuel pump (1) provides fuel for ARD head (4).

Fuel pressure sensor (3) send a signal to the ECM. The signal indicates the fuel pressure inside the fuel control manifold (ARD) (2). The fuel is sent directly to the ARD head (4) from the fuel control manifold (ARD) (2).

Excess fuel from the fuel pump for the ARD (1) is then returned to the secondary fuel filter.

Air System for the Clean Emissions Module

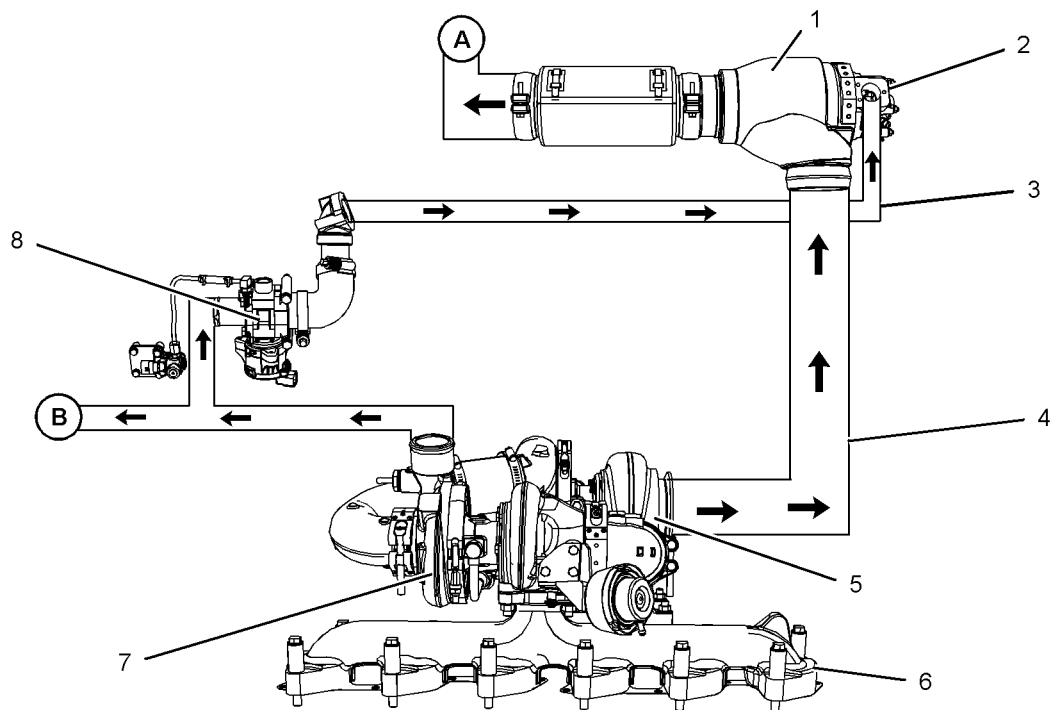


Illustration 19

g02303496

Typical example

- | | | |
|---------------------------------|--------------------------------|-----------------------------------|
| (1) ARD body | (5) Low-pressure turbocharger | (A) Exhaust air to DOC and DPF |
| (2) ARD head | (6) Exhaust manifold | (B) Compressed air to aftercooler |
| (3) Line for the combustion air | (7) High-pressure turbocharger | |
| (4) Exhaust from turbocharger | (8) ARD combustion air valve | |

Exhaust Air

Exhaust air flows from the turbine housing to the ARD body. The exhaust air then flows through the Diesel Oxidation Catalyst (DOC) and the DPF.

Combustion Air

Pressurized air from the turbocharger flows to the combustion air valve. The combustion air valve controls the amount of air that is supplied to the ARD Head. The combustion air is used with the supplied fuel and the spark plug to create the flame.

Cooling System

Two lines circulate coolant in the ARD head. The coolant is used to extend the life of the O-ring for the ARD nozzle.

Electronic Controls

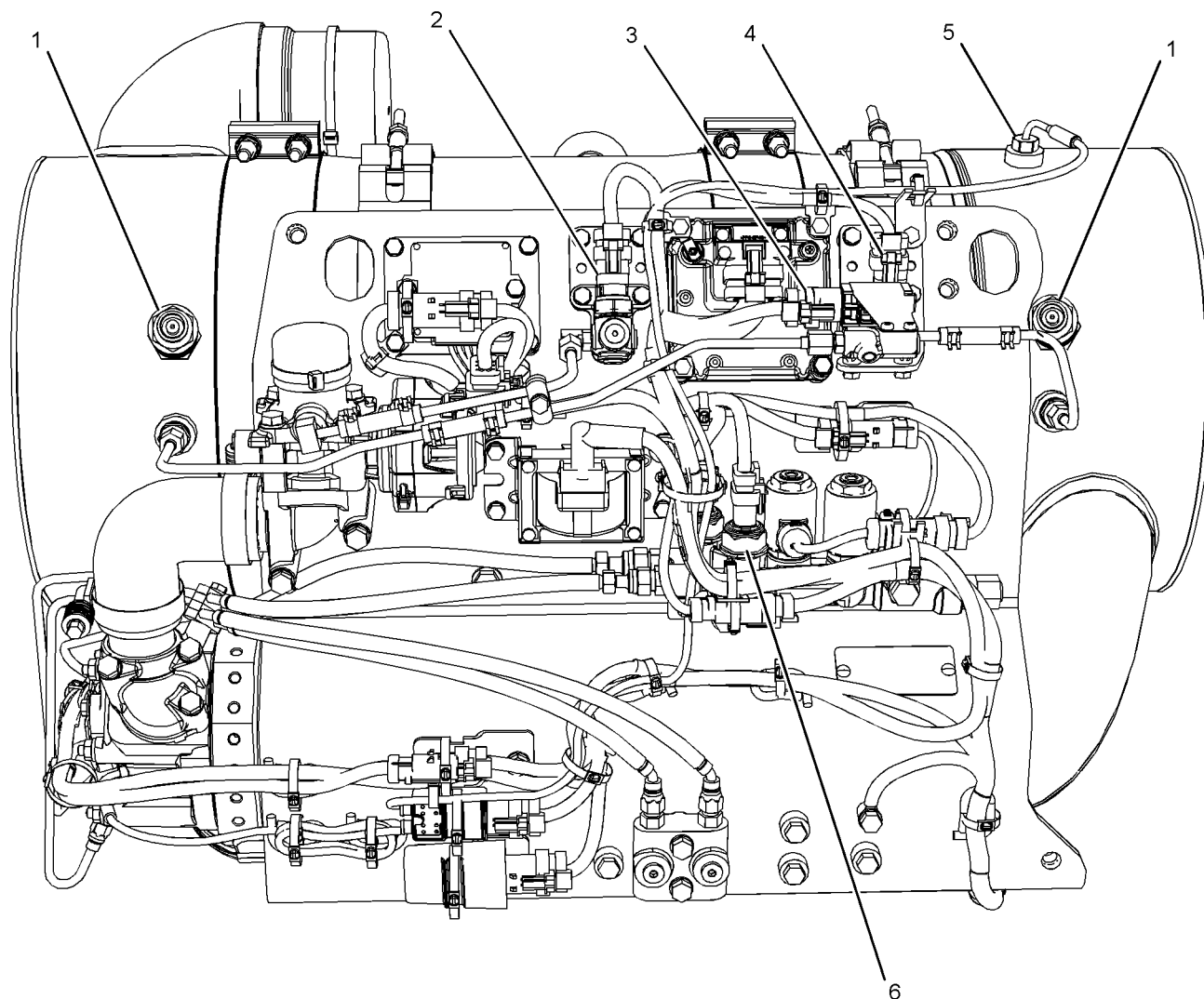


Illustration 20

g02304673

Typical example

(1) Soot Sensors
(2) Combustion air inlet pressure sensor

(3) DPF differential pressure sensor
(4) DPF inlet pressure sensor

(5) DPF inlet temperature sensor
(6) Fuel pressure sensor

All electronic devices on the CEM are controlled by the engine ECM. The ECM sends signals in order to complete the following functions: sending fuel pressure to the ARD head, the ignition, and the actuation of the heated nozzle.

Sensors

Absolute Pressure Sensor (combustion air valve) – This sensor determines the pressure of the combustion air in the combustion air valve.

Absolute Pressure Sensor (Exhaust Gas) – This sensor measures the pressure of the exhaust gases as they enter the DOC.

Inlet Temperature Sensor – This sensor determines the temperature of the air that is entering the DOC and the DPF.

Soot Sensors – The Soot Sensors use a radio frequency to determine the amount of soot in the DPF. The Soot Sensors use a coaxial cable in order to send a signal to a control box that is mounted on the machine. The control box conditions the signal. Then, the control box sends a value to the engine ECM, which converts the value to a soot level.

Fuel Pressure Sensor – The sensor determines the pressure of the fuel that is being supplied to the ARD Head.

Flame Detection Temperature Sensor – This sensor determines if a flame is present.

Heated Nozzle

The orifice for the fuel creates a high amount of atomization of the fuel for ignition and operation.

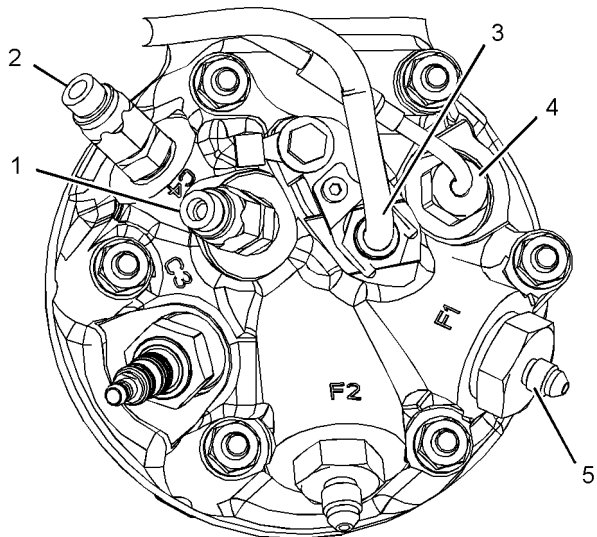


Illustration 21

g02304633

Typical example

- (1) Coolant inlet
- (2) Coolant outlet
- (3) Heated Nozzle
- (4) Flame detection temperature sensor
- (5) Fuel fitting

The heating element in the nozzle periodically cleans the nozzle when the ECM sends a command. The interval of the cleaning is determined by the hours of operation on the engine.

Ignition System for the Clean Emissions Module

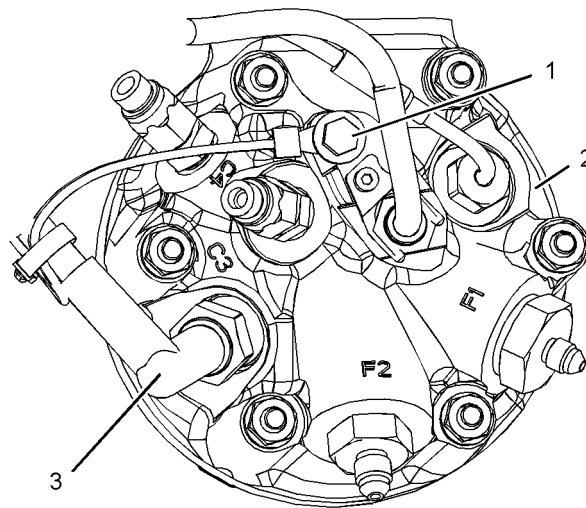


Illustration 22

g02304634

Typical example

- (1) Ground point on the ARD combustion head
- (2) ARD head
- (3) Ignition wire

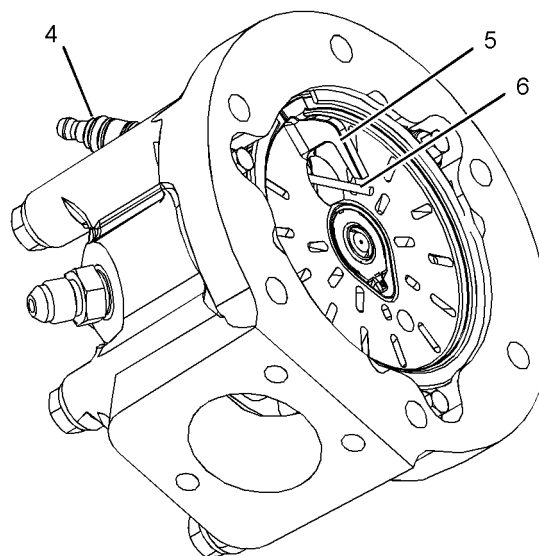


Illustration 23

g02303173

Typical example

- (4) Spark plug
- (5) Ground probe
- (6) Spark plug electrode

The ARD ignition system has two circuits. The primary circuit is between the ECM and the ignition coil. The secondary circuit is between the ignition coil and the ARD combustion head. The current flow through the primary circuit indicates the condition of the primary circuit and of the secondary circuit. The ECM monitors the current flow through the primary circuit. In this way, the ECM is able to detect problems with the primary circuit and the secondary circuit.

The ECM creates an ignition pulse 40 times each second whenever the engine speed is greater than 500 rpm. Wiring sends the signal to the primary side of the ignition coil. The ignition coil is located on the panel for the electronics on the Clean Emissions Module (CEM).

The ignition coil converts the ignition pulse into a high voltage signal. Ignition wire connects the ignition coil output to the spark plug. The spark plug is threaded into the ARD combustion head. The spark jumps between the spark plug electrode and ground probe inside the ARD combustion head. The spark ignites the air/fuel mixture.

The ground wire ensures that the secondary ignition circuit is complete between the ARD combustion head and the ignition coil. The ground wire runs inside the insulation that is wrapped around ignition wire. The ground wire is connected to two ground points. One ground point is on the ARD combustion head. One ground point is on the panel for the electronics near the ignition transformer.

i04094269

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

Coolant Flow

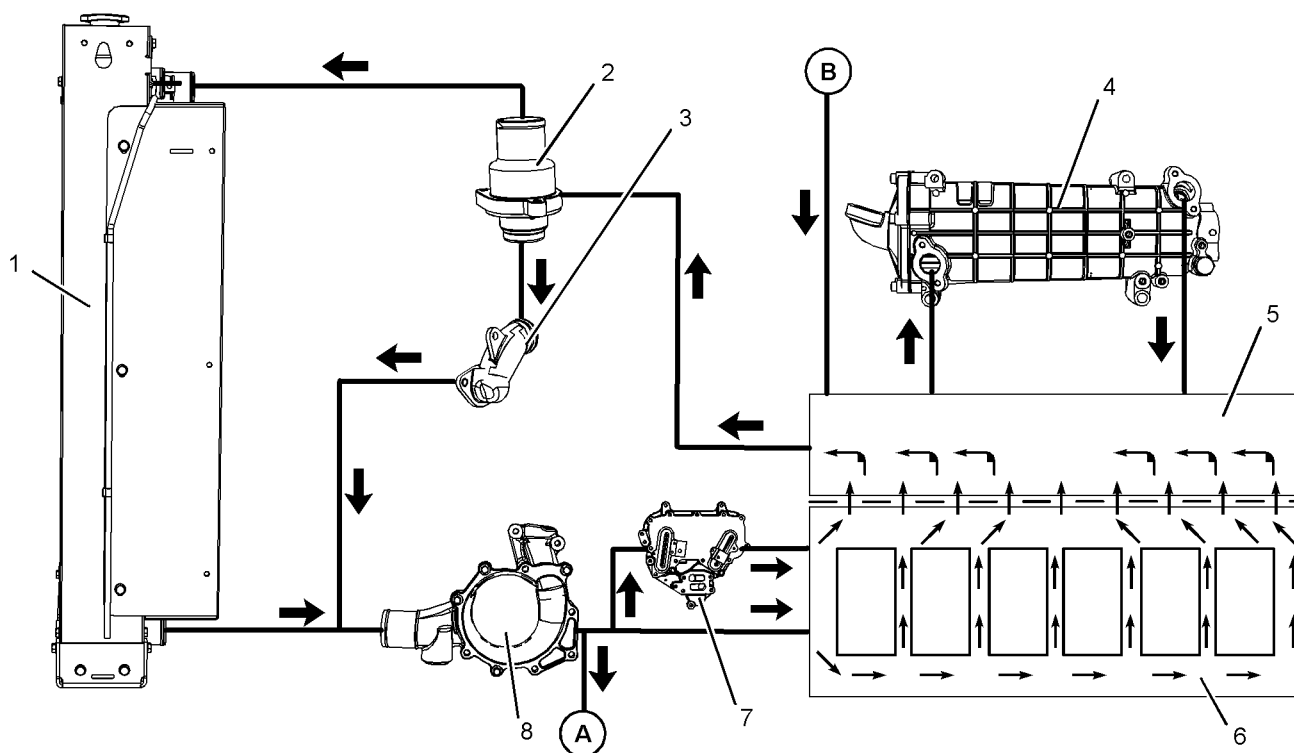


Illustration 24

g02301833

Typical example

(A) Coolant flow to Clean Emissions Module (CEM)
(1) Radiator
(2) Water temperature regulator and housing
(3) Bypass for the water temperature regulator

(4) Exhaust gas cooler (NRS)
(5) Cylinder head
(6) Cylinder block
(7) Engine oil cooler
(8) Water pump

(B) Coolant return from Clean Emissions Module (CEM)

The coolant flows from the bottom of the radiator (1) to the centrifugal water pump (8). The water pump (8) is installed on the front of the timing case. The water pump (8) is driven by a gear. The gear of the fuel injection pump drives the water pump gear.

The water pump (8) 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 (8) pumps the coolant through a passage in the timing case to the front of the cylinder block (6).

The coolant enters a passage in the left side of the cylinder block (6). Some coolant enters the cylinder block. Some coolant passes over the element of the oil cooler (7). The coolant then enters the block (6). Coolant flows around the outside of the cylinders then flows from the cylinder block into the cylinder head (5).

Some coolant flows through a cavity in the front of the cylinder head (5). Some coolant is diverted into the exhaust gas cooler (4) by a coolant pipe in the rear of the cylinder head (5). The coolant then flows out of the exhaust gas cooler (4) to the cavity in the cylinder head (5).

The coolant then flows into the housing of the water temperature regulator (2). If the water temperature regulator (2) is closed, the coolant goes directly through a bypass (3) 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).

Coolant flows from the top of the water pump (8) to the Clean Emissions Module (CEM). In the CEM, the coolant then flows to the ARD head. The coolant flows from the ARD head back to the top of the cylinder head (5).

i04091629

Lubrication System

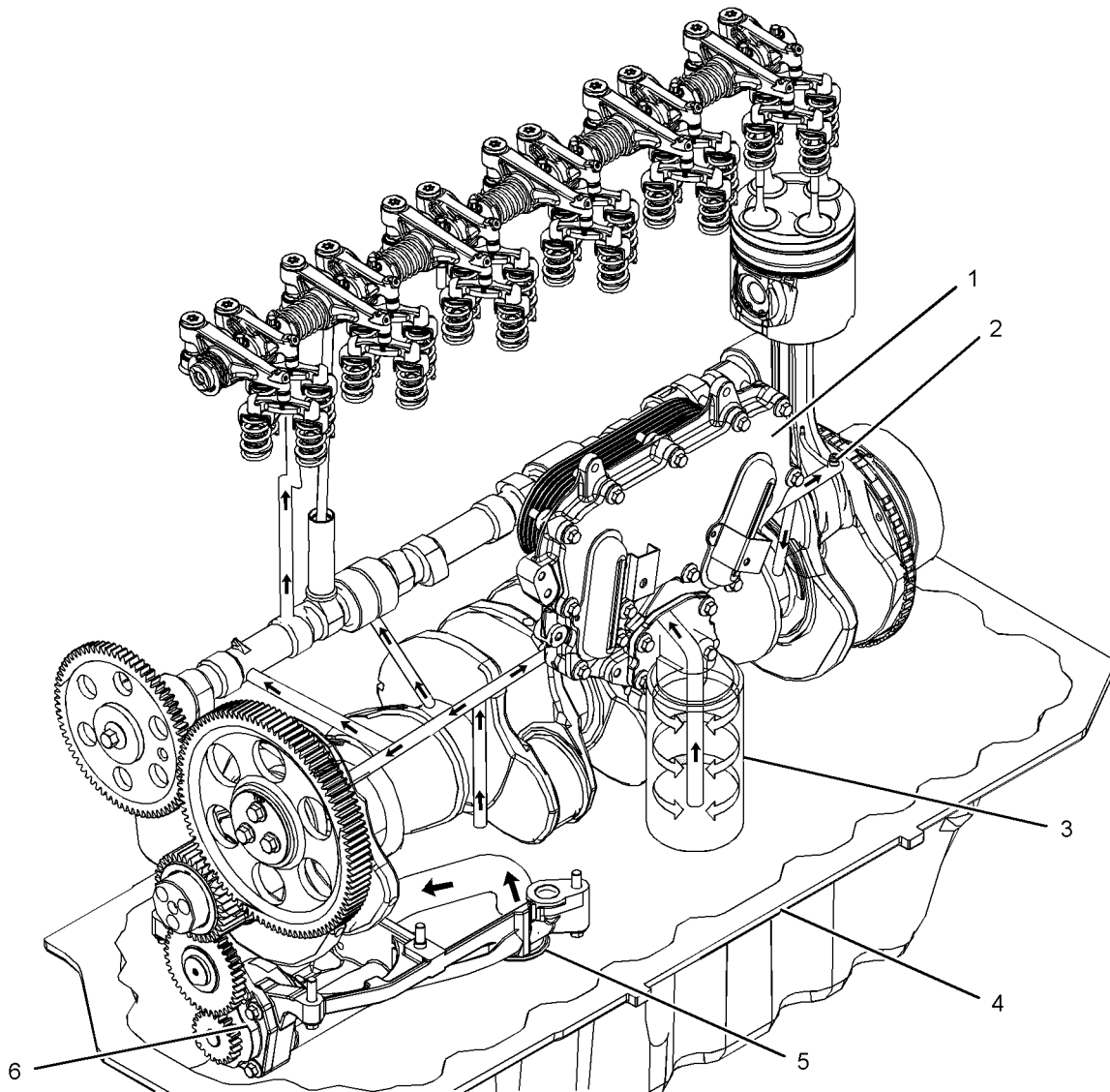


Illustration 25
Typical example

g02299093

Oil pressure for the engine lubrication system is provided by an engine mounted oil pump (6). The engine oil pump (6) is located on the bottom of the cylinder block and within the oil pan (4). Lubricating oil from the oil pan (4) flows through a strainer (5) and a pipe to the inlet side of the engine oil pump (6). The engine oil pump (6) is driven from the crankshaft through an idler gear.

The engine oil pump (6) has an inner rotor with six lobes. The inner rotor is mounted to a shaft which also carries the drive gear. The engine oil pump (6) also has an outer annulus with seven lobes. The axis of rotation of the annulus is offset relative to the rotor. The distance between the lobes of the rotor and the annulus increases on the right-hand side when the rotor is rotated. The increasing space between the lobes of the rotor and the annulus causes a reduction in pressure. This reduction in oil pressure causes oil to flow from the oil pan (4), through the oil strainer (5) and into the oil pump (6).

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

The oil flows from the oil pump (6) through holes in the cylinder block to a plate type oil cooler (1). The plate type oil cooler (1) is located on the left-hand side of the engine.

From the oil cooler (1), the oil returns through a drilling in the cylinder block to the filter head.

The oil flows from the oil filter (3) through a passage to the oil gallery. The oil gallery is drilled through the total length of the left side of the cylinder block. If the oil filter (3) is on the right side of the engine, the oil flows through a pipe assembly. The pipe assembly is mounted to the lower face of the cylinder block.

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

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

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

The turbocharger is lubricated by oil via a drilled passage through the cylinder block. An external line from the engine block supplies oil to the turbocharger. The oil then flows through a line to the oil pan (4).

Piston cooling jets (2) are installed in the engine. The piston cooling jets (2) are supplied with the oil from the oil gallery. The piston cooling jets (2) spray lubricating oil on the underside of the pistons in order to cool the pistons.

i04027375

Electrical System

The electrical system is a negative ground system.

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

Starting Motor

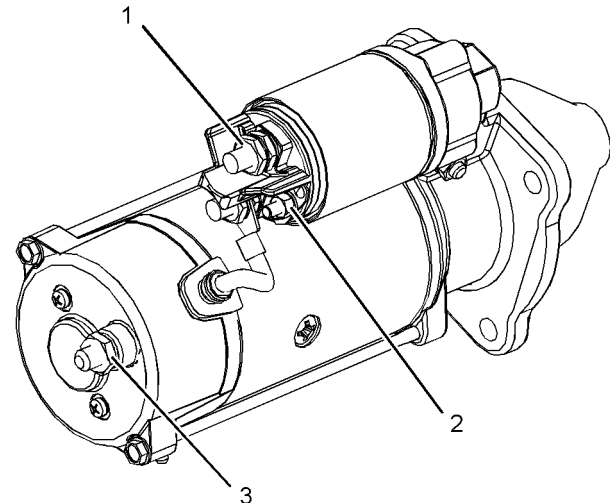


Illustration 26

g01964824

Typical example

12 Volt 4 kW Starting Motor

- (1) Terminal 30 for connection of the battery cable
- (2) Terminal 50 for connection of ignition switch
- (3) Terminal 31 for connection of the ground

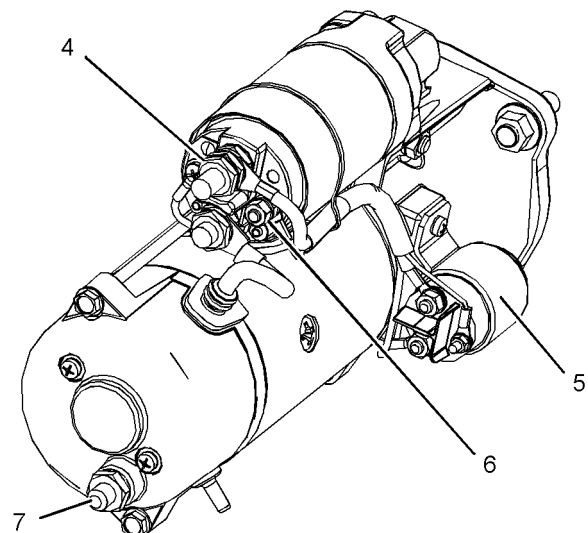


Illustration 27

g01964833

Typical example

24 Volt 5.5 kW Starting Motor

- (4) Terminal 30 for connection of the battery cable
- (5) Integrated Magnetic Switch (IMS)
- (6) Terminal 50 for connection of ignition switch
- (7) Terminal 31 for connection of the ground

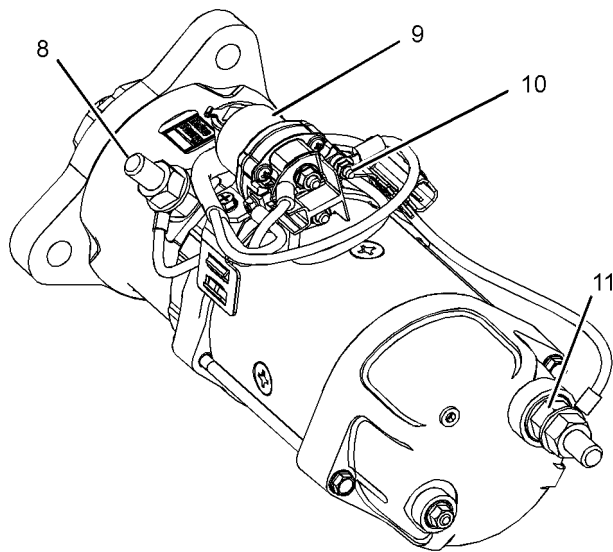


Illustration 28

g01964823

Typical example

24 Volt 8 kW Starting Motor

- (8) Terminal 30 for connection of the battery cable
 (9) Integrated Magnetic Switch (IMS)
 (10) Terminal 50 for connection of ignition switch
 (11) Terminal 31 for connection of the ground

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

The starting motor consists of the main armature and a solenoid. The solenoid is a relay with two windings Pull-In (PI) and Hold-In (HI). Upon activation of ignition switch, both windings move the iron core by electromagnets. The linkage from the iron core acts to move the pinion toward the flywheel ring gear for engagement. Upon complete engagement, the solenoid completes the high current circuit that supplies electric power to the main armature in order to provide rotation. During cranking of the engine, only the Hold-In (HI) winding is active.

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 starting motor has an overrunning clutch to prevent damage to the starting motor and mechanical transmissions as the engine speed increases.

Certain higher powered starting motors are designed with an Integrated Magnetic Switch (IMS). The Integrated Magnetic Switch (IMS) is activated by the ignition switch. The solenoid circuit then engages the starting motor. The benefit of Integrated Magnetic Switch (IMS) is a lower current in the ignition circuit that will allow the engine ECM to control ignition without the use of a relay.

Alternator

The electrical outputs of the alternator have the following characteristics:

- Three-phase
- Full-wave
- Rectified

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

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

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

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

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

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

i04103311

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.

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".

i04026049

Fuel Injection

Introduction

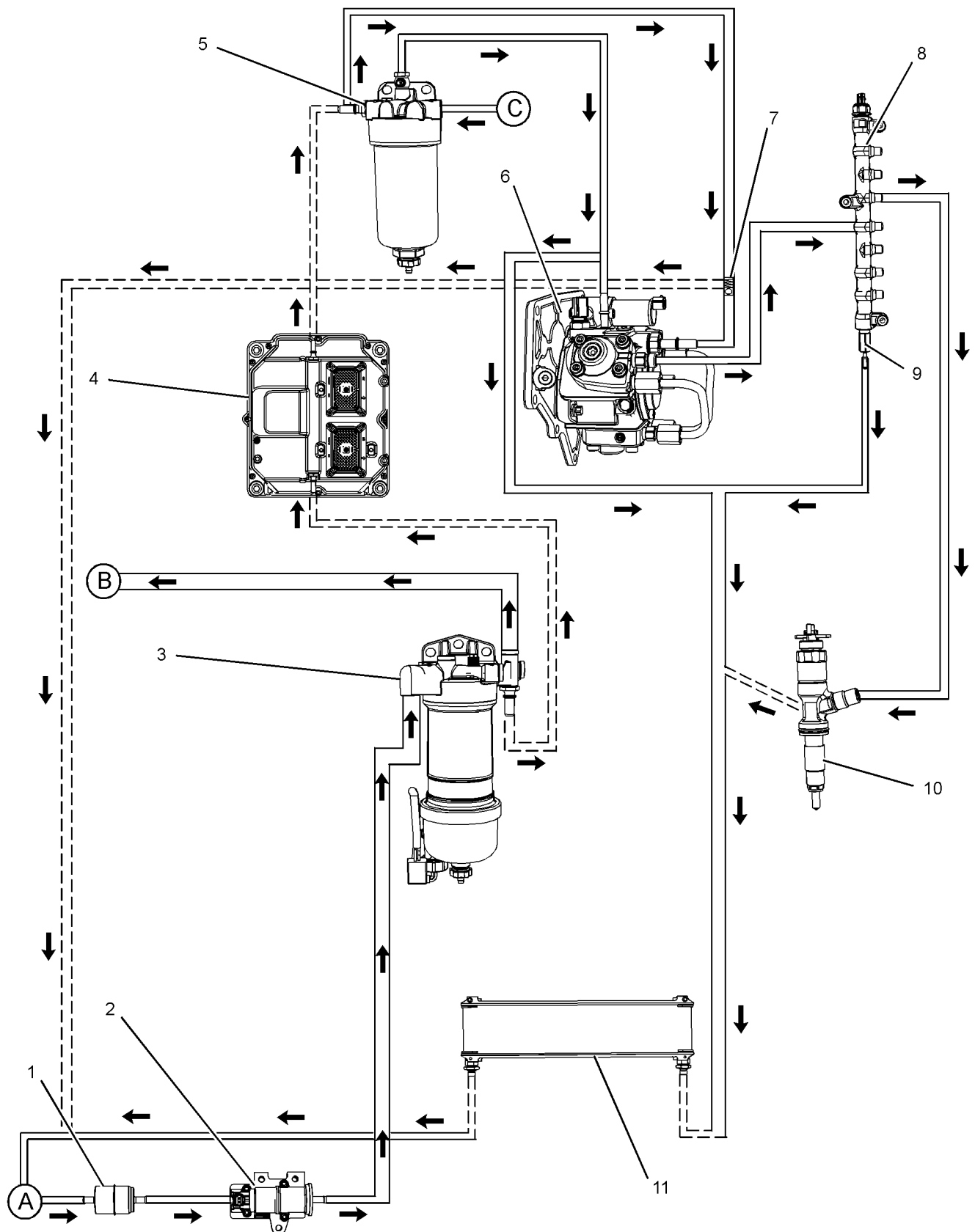


Illustration 29
Typical example

- | | | |
|------------------------------|-------------------------------|-----------------------------|
| (1) Fuel strainer | (6) Fuel Injection Pump | (11) Fuel cooler (optional) |
| (2) Electric transfer pump | (7) Inlet pressure regulator | (A) Fuel tank |
| (3) Primary fuel filter | (8) Fuel manifold (rail) | (B) To CEM |
| (4) ECM that is fuel cooled. | (9) Pressure relief valve | (C) Return from CEM |
| (5) Secondary fuel filter | (10) Electronic unit injector | |

Note: For more information regarding the fuel system for the engine aftertreatment system, refer to Systems Operation, Testing and Adjusting, “Clean Emissions Module”.

Fuel is drawn from the fuel tank through a fuel strainer to an external electric transfer pump. The fuel then flows to the 10 micron primary fuel filter and a water separator.

The fuel may flow to the engine aftertreatment system or the fuel may flow to a fuel cooled ECM. The fuel then flows to a 4 micron secondary fuel filter.

The fuel flows from the secondary fuel filter to a pressure regulator. A pressure regulator that is installed in the low-pressure fuel system controls the fuel pressure to the fuel injection pump. The pressure regulator regulates the fuel at an absolute pressure of 150 kPa (22 psi) when the engine is at idle speed.

From the pressure regulator, the fuel flows to the fuel injection pump. The fuel is pumped at an increased pressure of 200 MPa (29000 psi) to the 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 an optional fuel cooler on the way back to the fuel tank.

High Pressure Fuel System

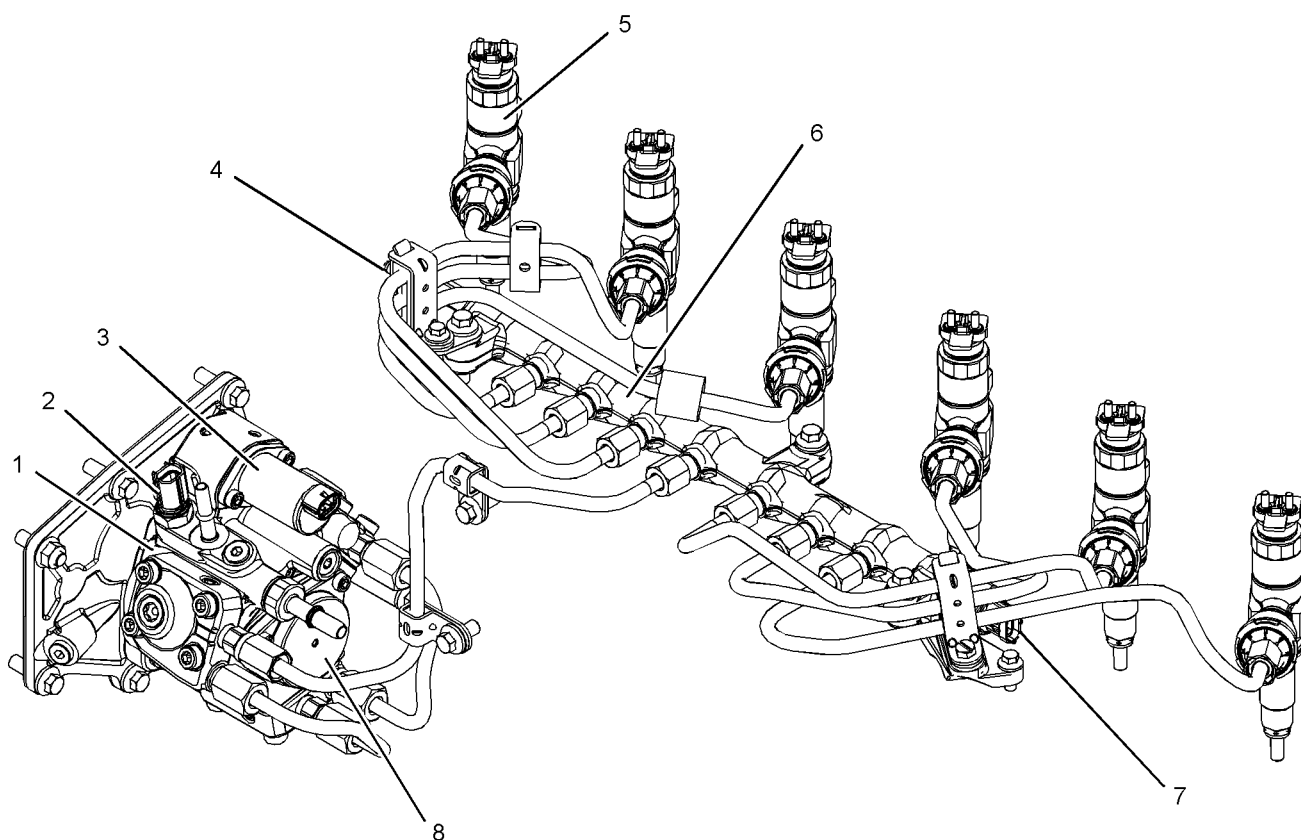


Illustration 30

g02216334

Typical example

(1) Fuel injection pump
 (2) Fuel temperature sensor
 (3) Suction control valve for the fuel injection pump

(4) Pressure relief valve
 (5) Electronic unit injector
 (6) Fuel manifold (rail)
 (7) Fuel pressure sensor

(8) Fuel transfer pump

The fuel injection pump (1) feeds fuel to the high-pressure fuel manifold (rail) (6). The fuel is at a pressure of 200 MPa (29000 psi). A pressure sensor (7) in the high-pressure fuel manifold (rail) (6) monitors the fuel pressure in the high-pressure fuel manifold (rail) (6). The ECM controls a suction control valve (3) in the fuel injection pump (1) in order to maintain the actual pressure in the high-pressure fuel manifold (6) at the desired level. The high-pressure fuel is continuously available at each injector. The ECM determines the correct time for activation of the correct electronic unit injector (5) which allows fuel to be injected into the cylinder. The leakoff fuel from each injector passes into a drilling which runs along the inside of the cylinder head. A pipe is connected to the rear of the cylinder head in order to return the leakoff fuel to the fuel tank.

Components of the Fuel Injection System

The fuel injection system has the following mechanical components:

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

- Fuel pressure sensor
- Fuel temperature 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.
- The ECM 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

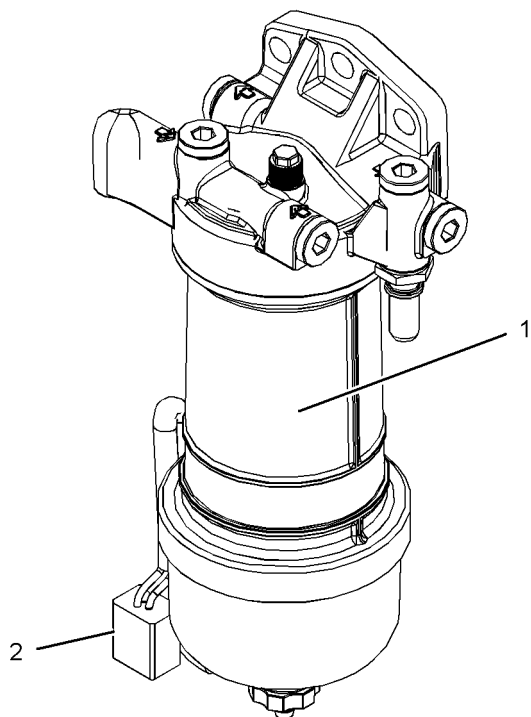


Illustration 31

g02214535

Typical example

The primary filter/water separator (1) is located between the electric lift pump and the secondary fuel filter. 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 (2).

Secondary Fuel Filter

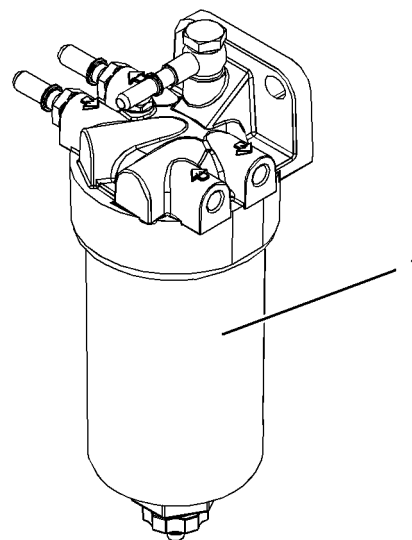


Illustration 32

g02214536

Typical example

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

Fuel Pump Assembly

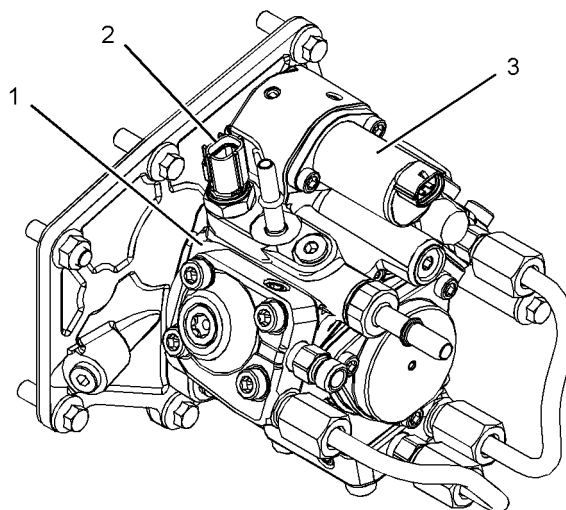


Illustration 33

g02216343

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 engine speed. The fuel injection pump (1) has three plungers that are driven by a camshaft. The fuel injection pump (1) delivers a volume of fuel three times for each revolution. The stroke of the plungers are fixed.

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 (3) for the fuel injection pump (1) 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 (1) allows fuel to return to the tank continuously.

The fuel temperature sensor (2) measures the temperature of the fuel. The ECM receives the signal from the fuel temperature sensor (2). The ECM calculates the volume of fuel.

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

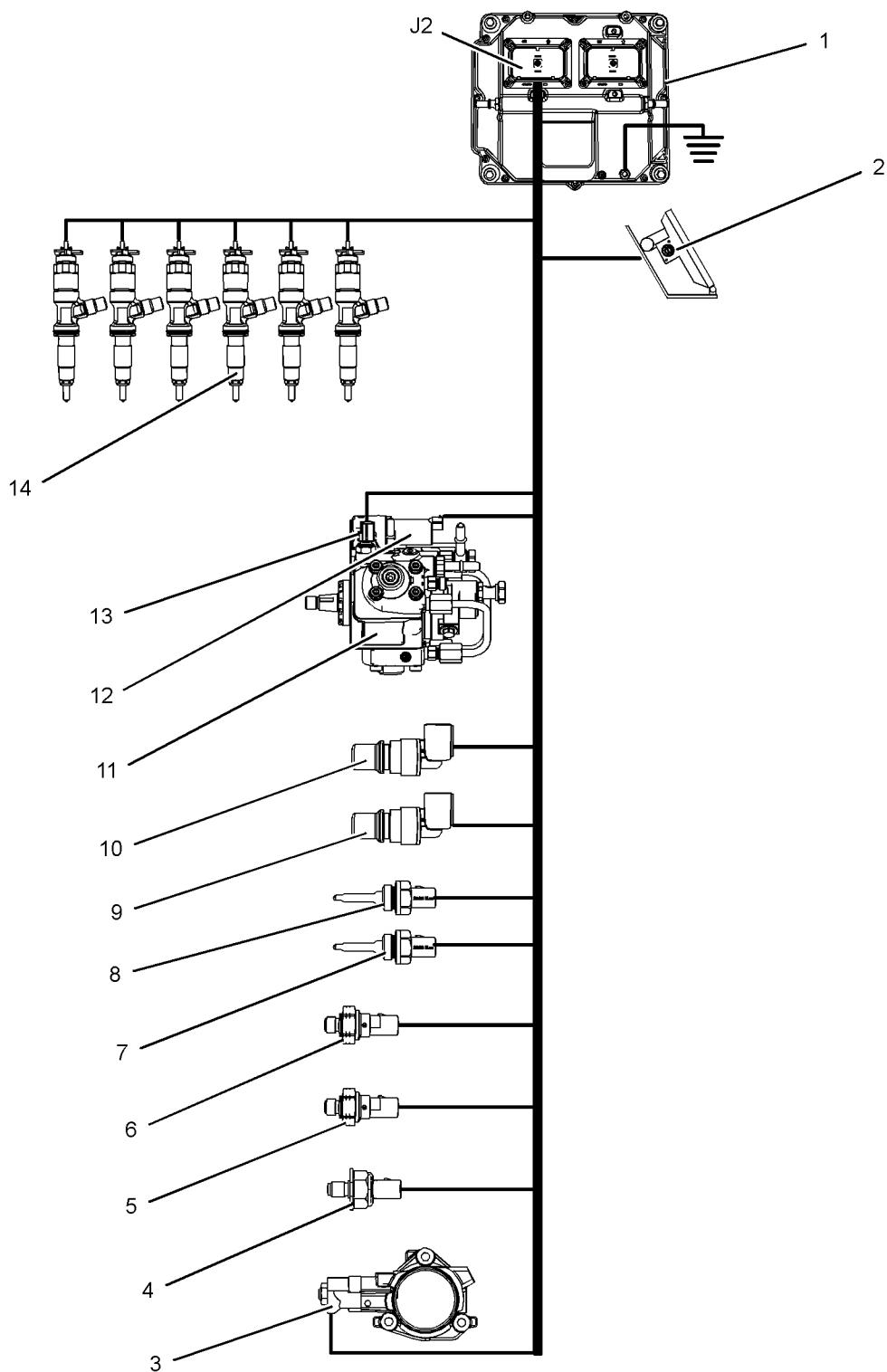


Illustration 34

g02210619

Typical example of the electrical control system for the fuel system

- | | | |
|-------------------------------------|---|--|
| (1) Electronic Control Module (ECM) | (6) Atmospheric pressure sensor | (11) Fuel injection pump |
| (2) Throttle position sensor | (7) Coolant temperature sensor | (12) Suction control valve for the fuel injection pump |
| (3) Wastegate regulator | (8) Inlet manifold air temperature sensor | (13) Fuel temperature sensor |
| (4) Fuel rail pressure sensor | (9) Secondary speed/timing sensor | (14) Electronic unit injectors |
| (5) Inlet manifold pressure sensor | (10) Primary speed/timing sensor | |

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 proportional to 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

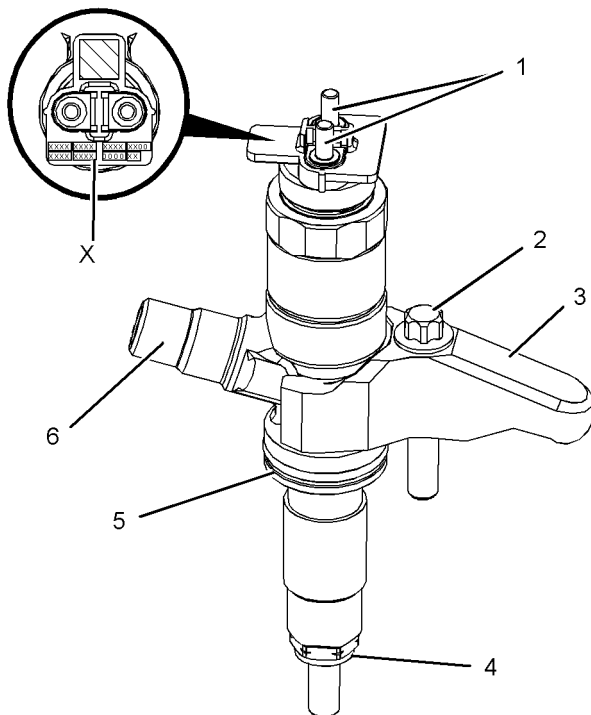


Illustration 35

g02290433

Typical example

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

Note: If a replacement electronic unit injector is installed, the correct injector code must be programmed into the electronic control module. Refer to Troubleshooting, "Injector Code - Calibrate" for more information. The code that is required is located at Position (X). Record Code (X) before the electronic unit injector is installed.

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

When the ECM sends a signal to the injector solenoid, a valve inside the injector opens. The valve allows the high-pressure fuel from the fuel manifold to enter the injector. Fuel is also diverted via the leak-off route to cool and lubricate injector. The pressure of the fuel pushes the needle valve and a spring. The difference in pressure around the needle valve becomes too great, this causes the pressure to lift the needle and start injecting.

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

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

When the needle valve opens, fuel under high pressure will flow through nozzle orifices into the cylinder. The fuel is injected into the cylinder through the orifices in the nozzle as a very fine spray.

When the signal to the injector ends, the valve closes. The fuel in the injector changes to a low pressure. When the pressure drops the needle valve will close and the injection cycle stops.

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

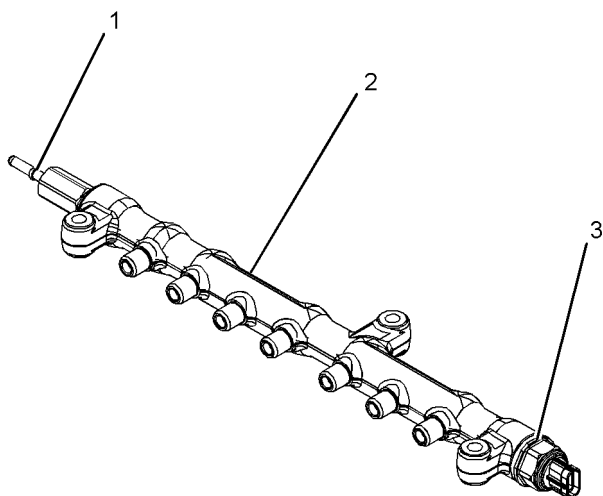


Illustration 36

g01911496

Typical example

The fuel manifold (2) stores high-pressure fuel from the fuel injection pump. The high-pressure fuel will flow to the injectors.

The fuel pressure sensor (3) measures the fuel pressure in the fuel manifold (2).

The pressure relief valve (1) will prevent the fuel pressure from getting too high.

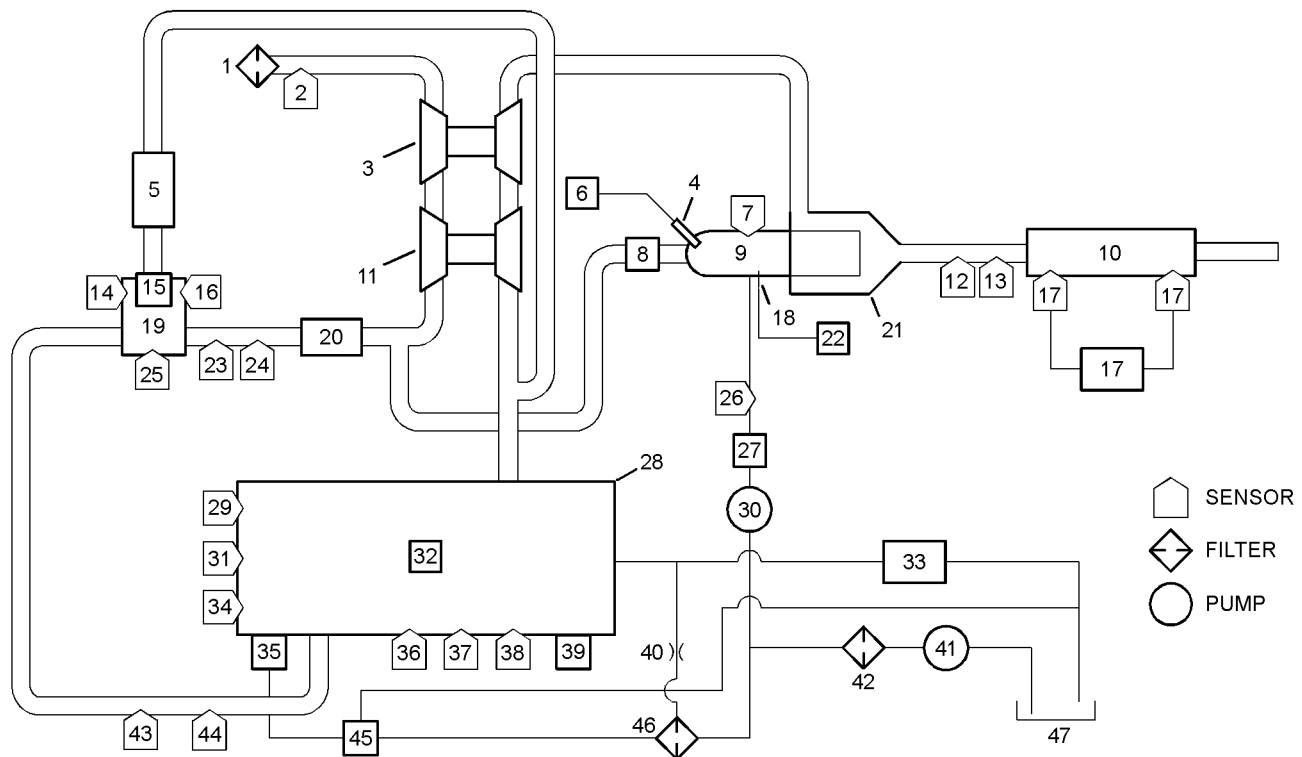
The fuel pressure sensor must be replaced with the fuel manifold (rail). The pressure relief valve can be serviced as a separate component.

i04103749

Electronic Control System

Introduction

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



g02351556

Illustration 37

Typical example of the control system layout

- | | | |
|--|--|--|
| (1) Air cleaner | (17) Soot sensor | (32) Electronic unit injectors |
| (2) Air inlet temperature sensor | (18) Heater wire for the (ARD) fuel nozzle | (33) Fuel cooler |
| (3) Low-pressure turbocharger | (19) Exhaust gas valve for the NOx Reduction System (NRS) | (34) Camshaft speed/timing sensor |
| (4) Spark plug | (20) Air-to-air aftercooler | (35) Fuel injection pump and fuel temperature sensor |
| (5) Exhaust gas cooler (NRS) | (21) Aftertreatment Regeneration Device (ARD) body | (36) Fuel pressure sensor |
| (6) Ignition coil | (22) Heater wire relay | (37) Oil pressure sensor |
| (7) Flame detection temperature sensor | (23) Intake throttle valve | (38) Atmospheric pressure sensor |
| (8) ARD combustion air valve | (24) Wastegate regulator | (39) ECM |
| (9) ARD combustion head | (25) Differential pressure sensor for the NOx Reduction System (NRS) | (40) Secondary fuel filter air purge restrictor |
| (10) Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF) | (26) Fuel pressure sensor | (41) Fuel transfer pump |
| (11) High-pressure turbocharger | (27) Fuel control valve | (42) Primary fuel filter |
| (12) Inlet pressure sensor for the DPF | (28) Engine | (43) Inlet manifold pressure sensor |
| (13) Inlet temperature sensor for the DPF | (29) Coolant temperature sensor | (44) Inlet manifold air temperature sensor |
| (14) Temperature sensor for the NOx Reduction System (NRS) | (30) Aftertreatment Regeneration Device (ARD) fuel pump | (45) Transfer pump inlet regulator |
| (15) Exhaust gas valve (NRS) | (31) Crankshaft speed/timing sensor | (46) Secondary fuel filter |
| (16) Inlet pressure sensor for the NOx Reduction System (NRS) | | (47) Fuel tank |

The electronic control system has the following components:

- ECM
- Pressure sensors
- Temperature sensors
- Crankshaft speed/timing sensor
- Camshaft speed/timing sensor
- The suction control valve for the fuel injection pump
- Wastegate regulator
- Electronic unit injectors
- Soot sensors
- Valve for the NOx Reduction System (NRS)
- Pilot fuel control valve
- Ignition coil
- ARD combustion air valve

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.

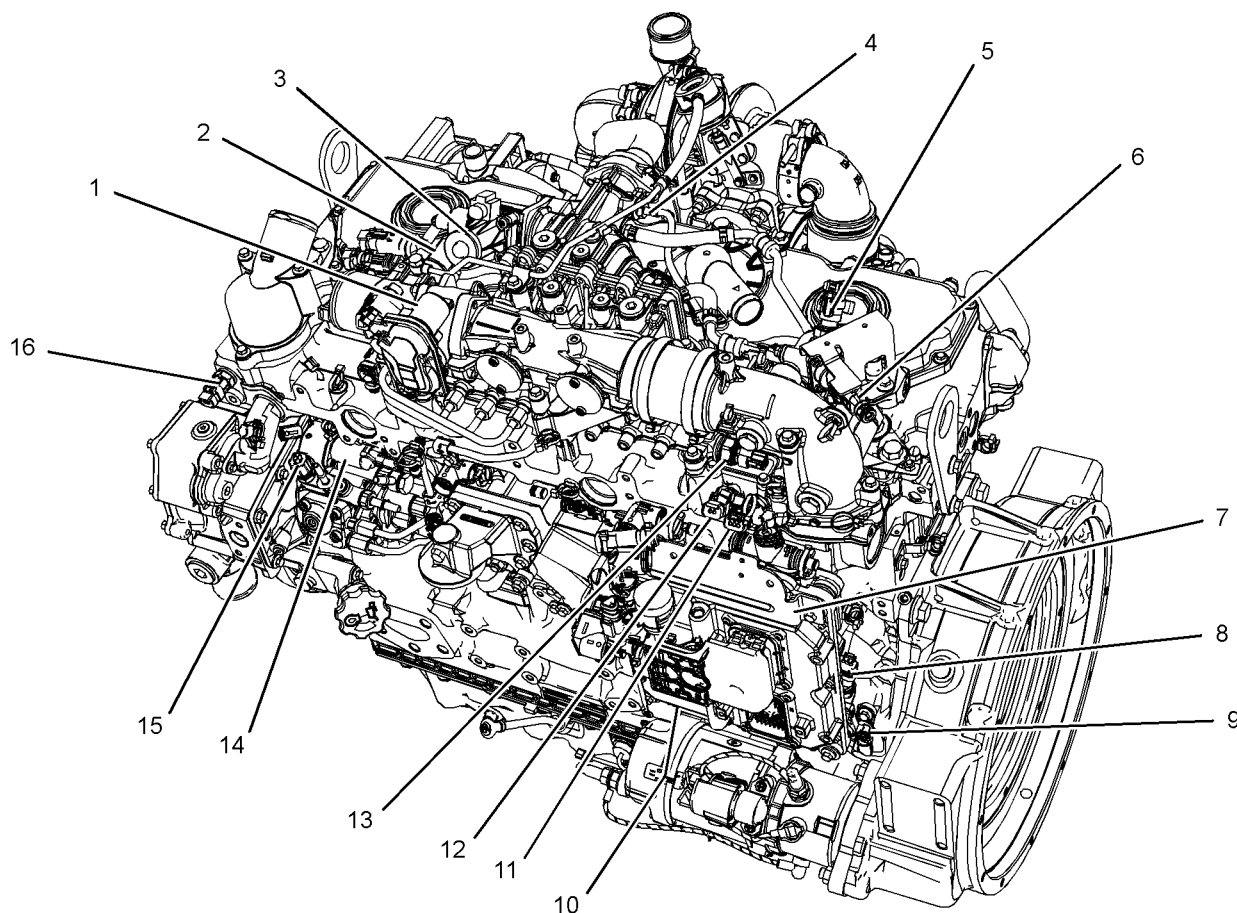


Illustration 38

g02311573

- | | | |
|--|---|--|
| (1) Intake throttle valve for the NOx Reduction System (NRS) | (6) Differential pressure sensor for the NOx Reduction System (NRS) | (14) Suction control valve for the fuel injection pump |
| (2) Wastegate regulator | (7) Electronic control module (ECM) | (15) Fuel temperature sensor |
| (3) Exhaust gas valve for the NOx Reduction System (NRS) | (8) Atmospheric pressure sensor | (16) Coolant temperature sensor |
| (4) Temperature sensor for the NOx Reduction System (NRS) | (9) Crankshaft speed/timing sensor | |
| (5) Inlet pressure sensor for the NOx Reduction System (NRS) | (10) Engine oil pressure sensor | |
| | (11) Boost pressure sensor | |
| | (12) Inlet manifold temperature sensor | |
| | (13) Fuel pressure sensor | |

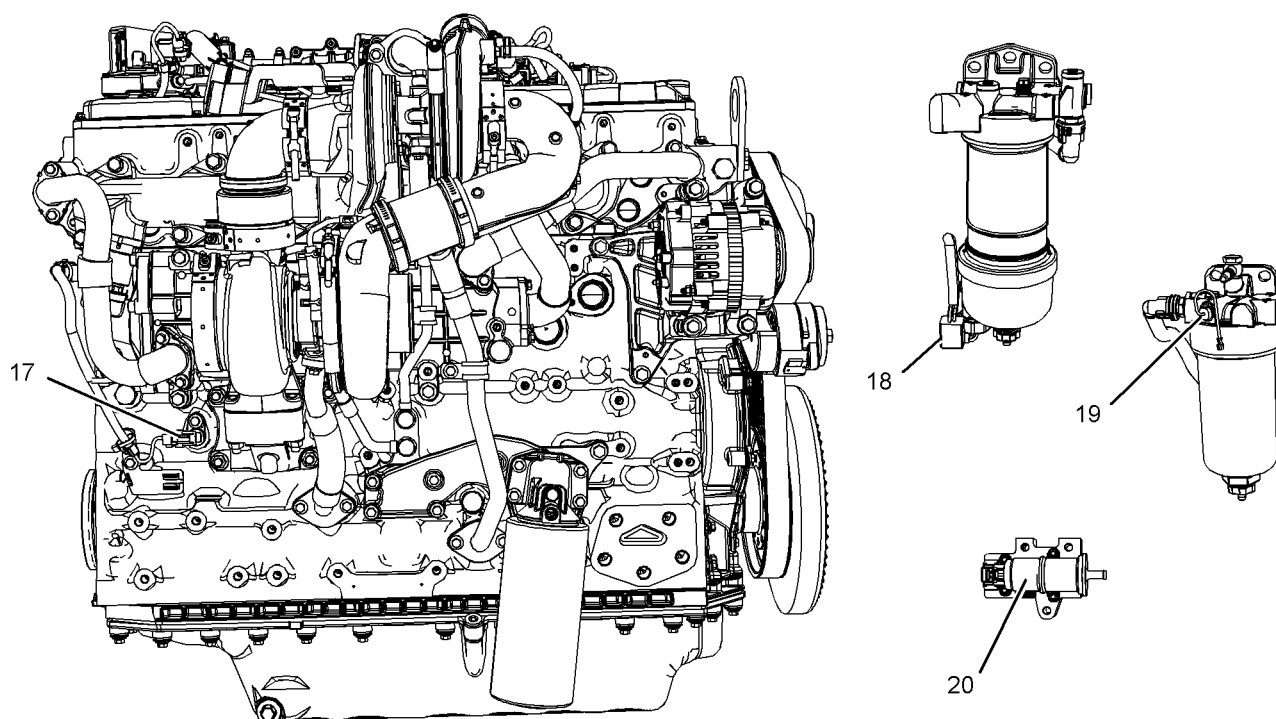


Illustration 39

g02311337

The location of the fuel filters will depend on the application.

- (17) Camshaft speed/timing sensor
(18) Water in fuel switch

- (19) Differential pressure Switch for the
secondary fuel filter

- (20) Electric fuel transfer pump

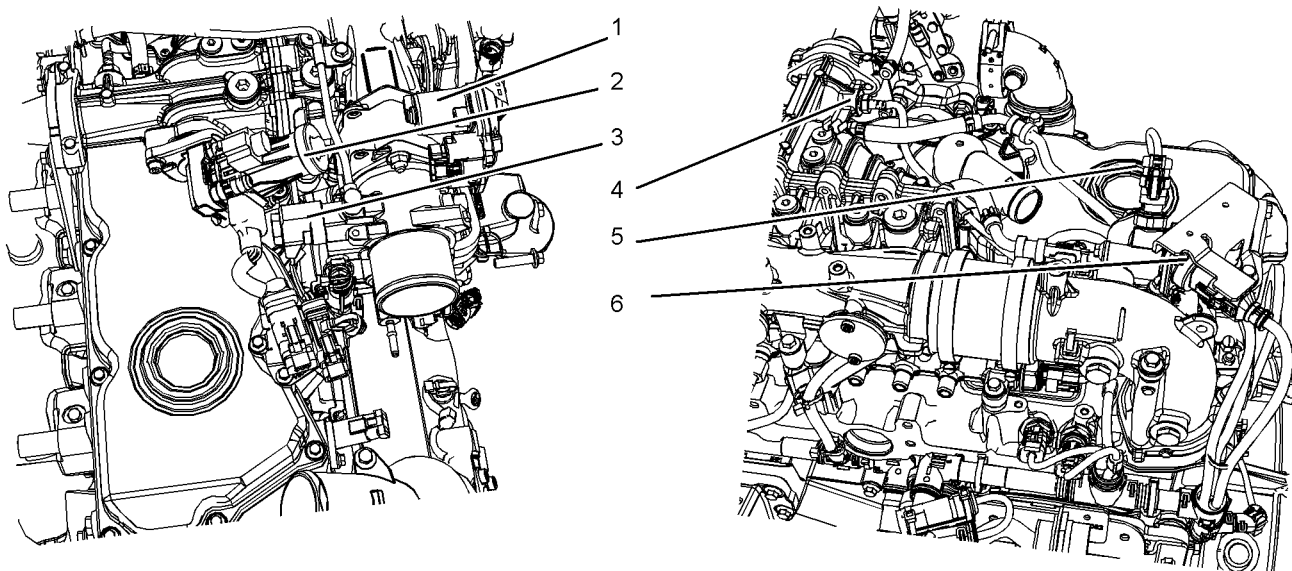


Illustration 40

g02311338

- (1) Intake throttle valve for the NOx
Reduction System (NRS)
(2) Wastegate regulator

- (3) Exhaust gas valve for the NOx Reduction
System (NRS)
(4) Temperature sensor for the NOx
Reduction System (NRS)

- (5) Inlet pressure sensor for the NOx
Reduction System (NRS)
(6) Differential pressure sensor for the NOx
Reduction System (NRS)

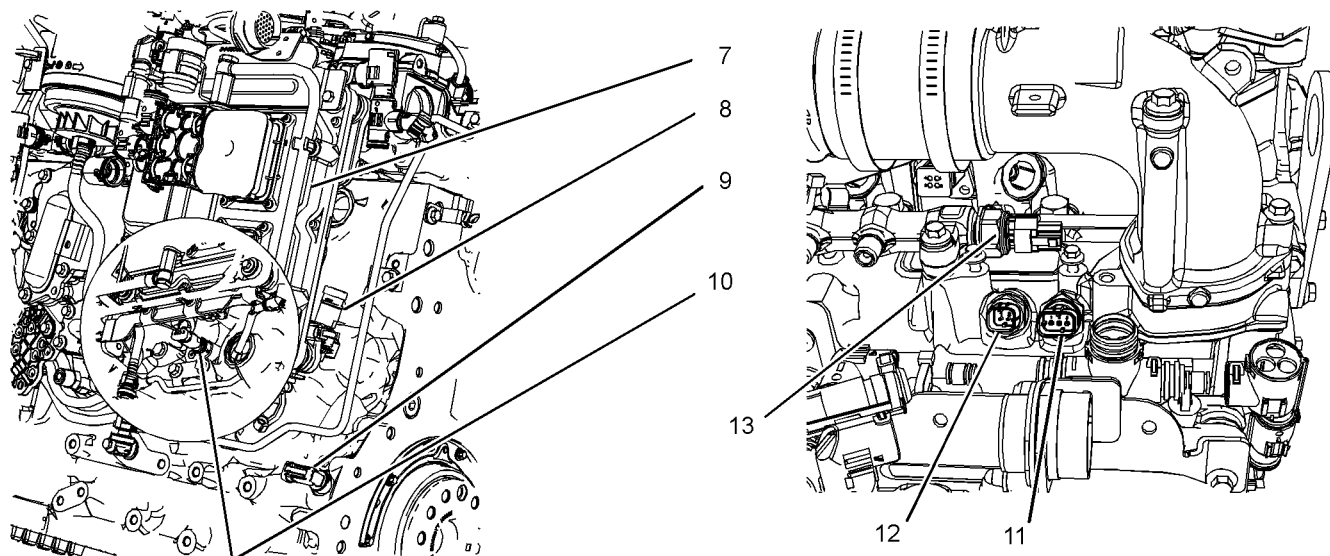


Illustration 41

g02311339

- (7) Electronic control module (ECM)
- (8) Atmospheric pressure sensor
- (9) Crankshaft speed/timing sensor

- (10) Engine oil pressure sensor
- (11) Boost pressure sensor
- (12) Inlet manifold temperature sensor

- (13) Fuel pressure sensor

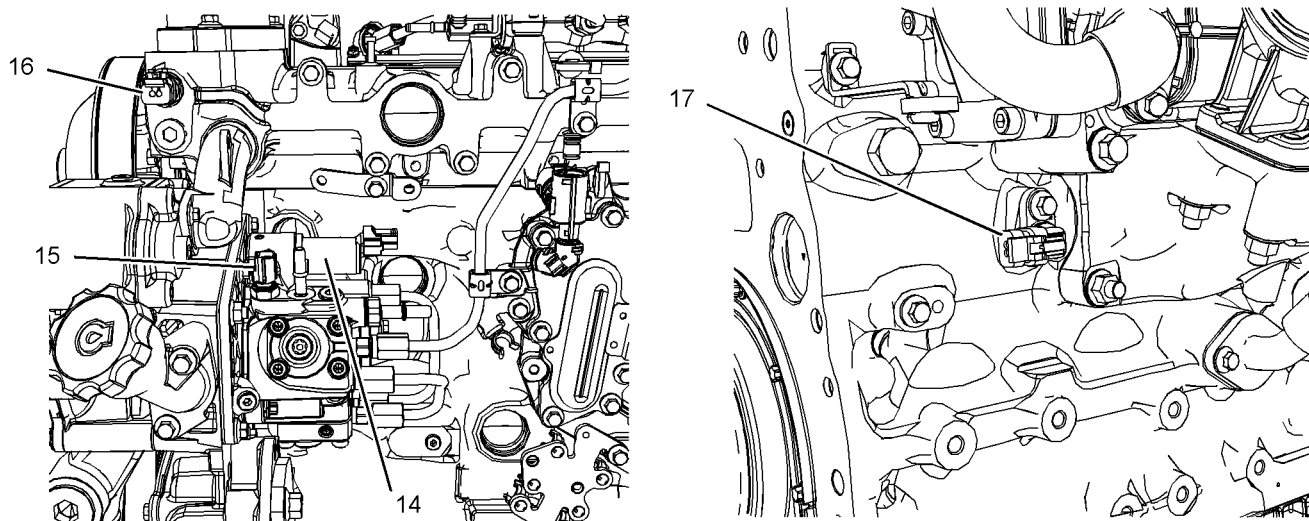


Illustration 42

g02311341

- (14) Suction control valve for the fuel injection pump

- (15) Fuel temperature sensor
- (16) Coolant temperature sensor

- (17) Camshaft speed/timing sensor

Sensor Locations for the Clean Emissions Module

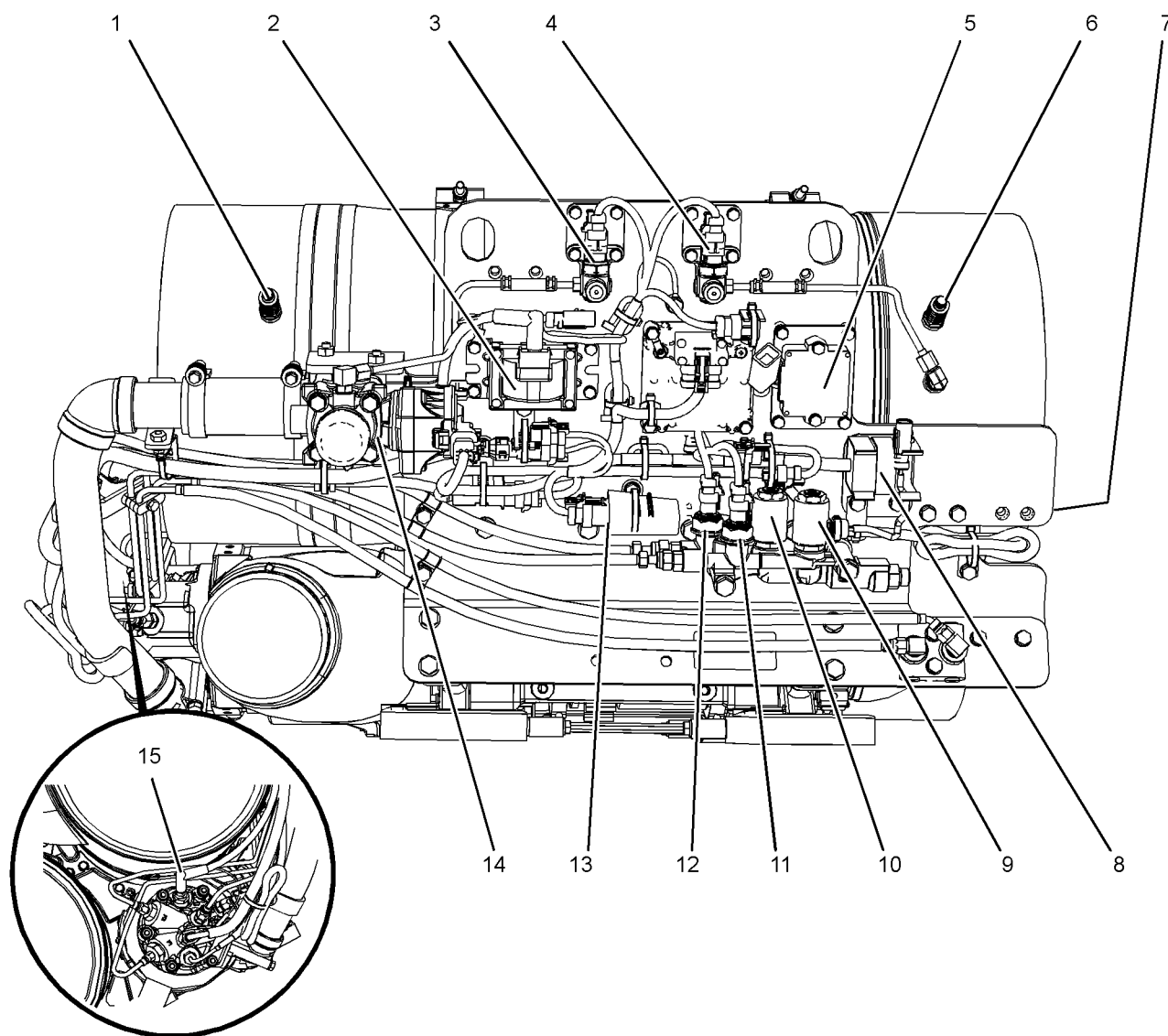


Illustration 43

g02311956

Typical example

- | | | |
|--|--|-------------------------------------|
| (1) Soot sensing antenna | (6) Soot sensing antenna | (10) ARD pilot fuel control valve |
| (2) Ignition coil for spark plug | (7) Inlet temperature sensor for the DPF (not shown) | (12) ARD pilot fuel pressure sensor |
| (3) ARD air pressure sensor | (8) Harness connector | (13) Aftertreatment ID module |
| (4) Intake pressure sensor for the DPF | (9) ARD main fuel control valve | (14) ARD combustion air valve |
| (5) Heater relay for the ARD fuel injector | | (15) Spark plug |

ECM

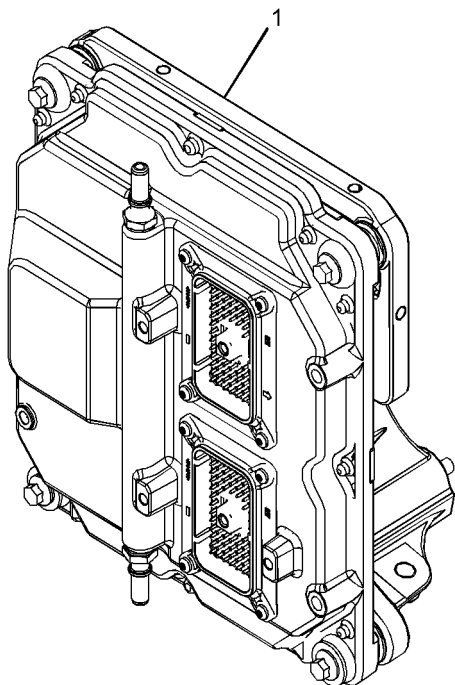


Illustration 44
Typical example

g01926054

The Electronic Control Module (ECM) (1) functions as a governor and a computer for the fuel system.

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

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

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

The programmable software contains all the fuel setting information. The information determines the engine performance.

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

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

Engine Speed

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 in order 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

At start-up, the ECM determines the top center position of the number 1 cylinder from the secondary speed/timing sensor in the fuel injection pump. The ECM decides when fuel injection should occur relative to the top center position. The ECM optimizes engine performance by control of each of the electronic unit injectors so that the required amount of fuel is injected at the precise point of the engine's cycle. The electronic unit injectors are supplied high pressure fuel from the fuel 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 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 in order to control the engine's exhaust emissions. When the ECM senses a higher intake manifold air pressure, the ECM increases the FRC Limit. A higher intake manifold air pressure indicates that there is more air in the cylinder. When the ECM increases the FRC Limit, the ECM allows more fuel into the cylinder.

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

These limits are in the programmable software and these limits cannot be changed.

The ECM controls the following characteristics:

- Boost pressure
- Operation of the NOx reduction system
- Regeneration

Diagnostic Codes

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

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

Event Codes

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

Passwords

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

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

Speed/Timing Sensors

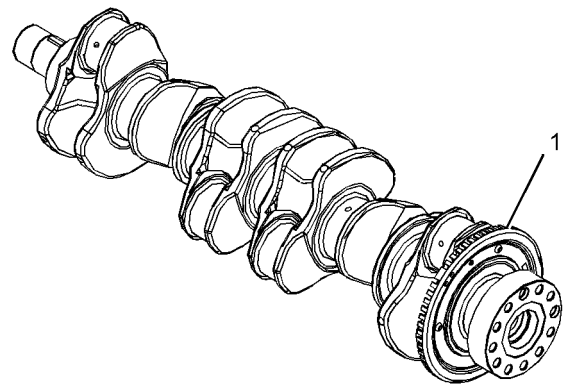


Illustration 45

g01926057

Typical example

The primary speed/timing sensor is located on the left-hand side of the cylinder block close to the flywheel housing. The primary speed/timing sensor generates a signal by detecting the movement of the teeth that are located 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.

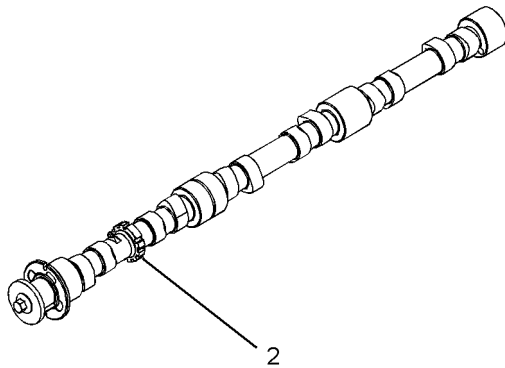


Illustration 46
Typical example

g02328496

The secondary speed/timing sensor is located on the right-hand side of the cylinder block toward the rear of the engine. The secondary speed/timing sensor generates a signal that is related to the camshaft position. The secondary speed/timing sensor detects the movement of the teeth on the timing ring (2) for the camshaft. 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. The secondary speed/timing sensor is required for starting purposes.

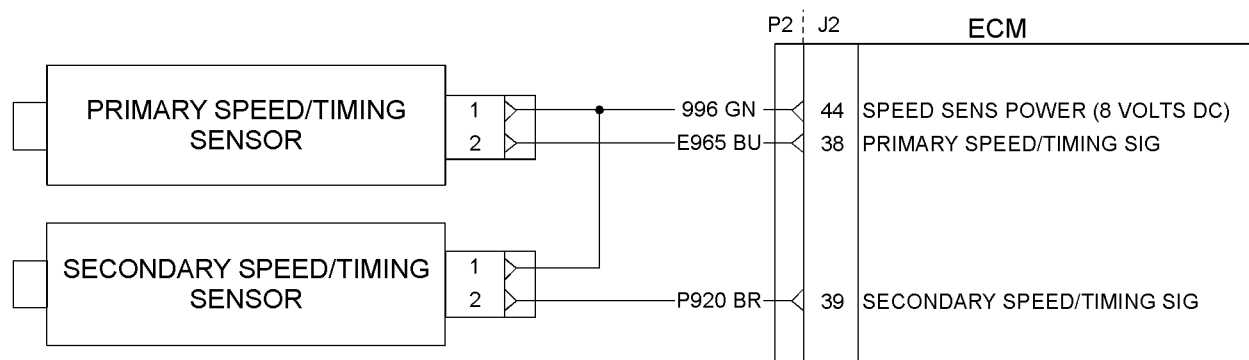


Illustration 47

g01878676

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

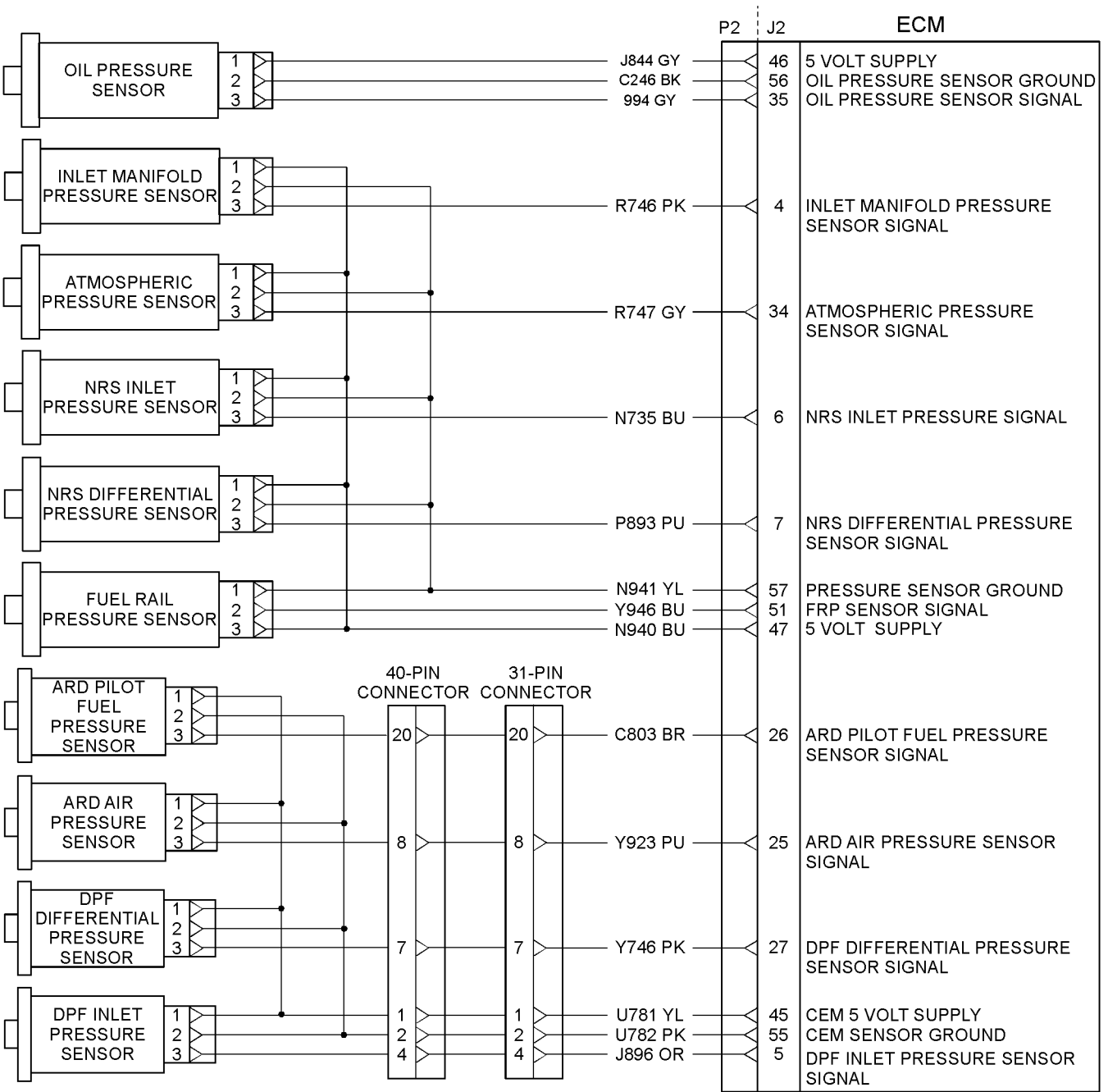


Illustration 48
Schematic for the pressure sensors

g02292253

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

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

The operating range of the boost pressure sensors is 39 to 400 kPa (6 to 58 psi).

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

The operating range for the engine oil pressure sensor 55 to 1200 kPa (8 to 174 psi)

Temperature Sensors

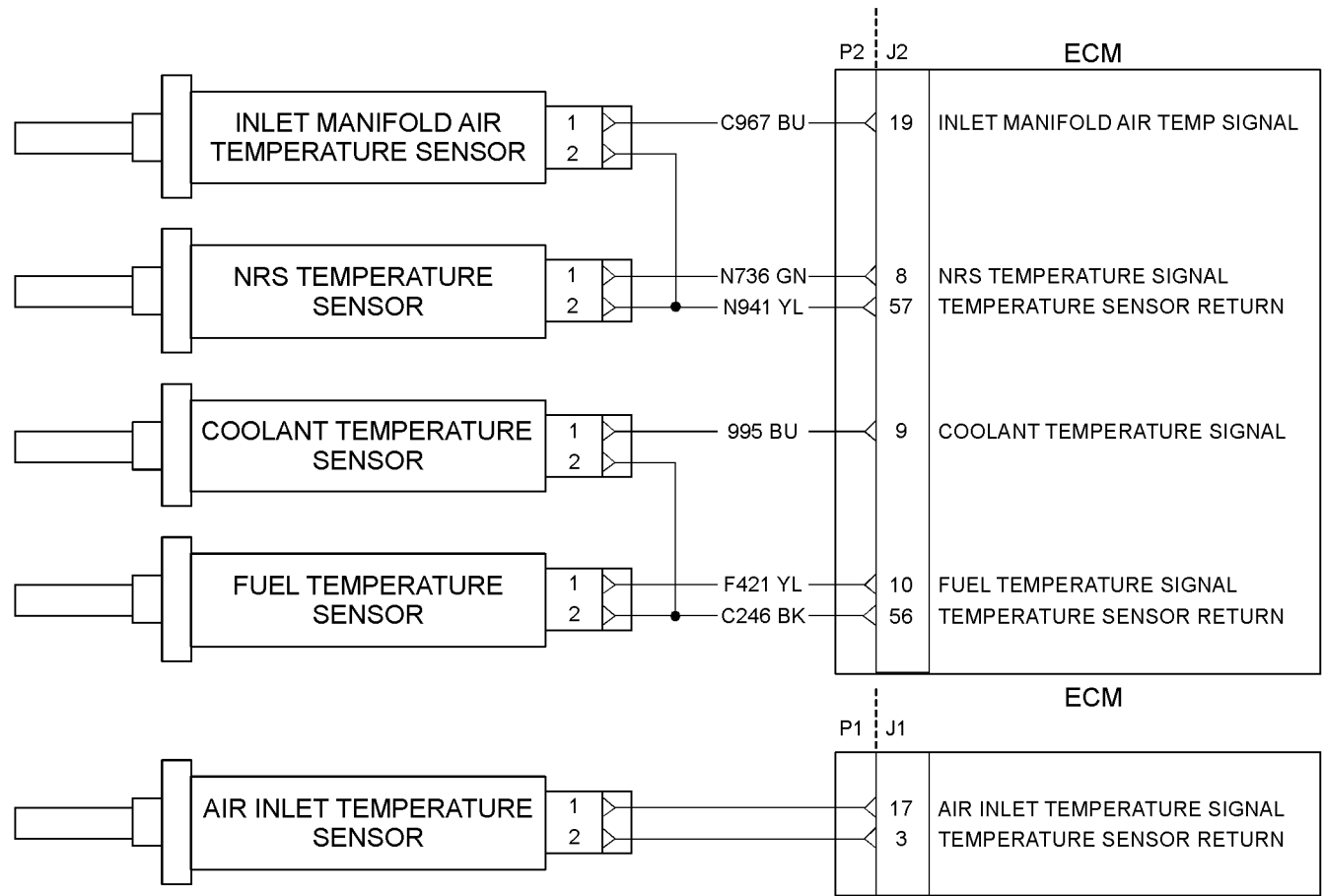


Illustration 49
Schematic for the engine temperature sensors

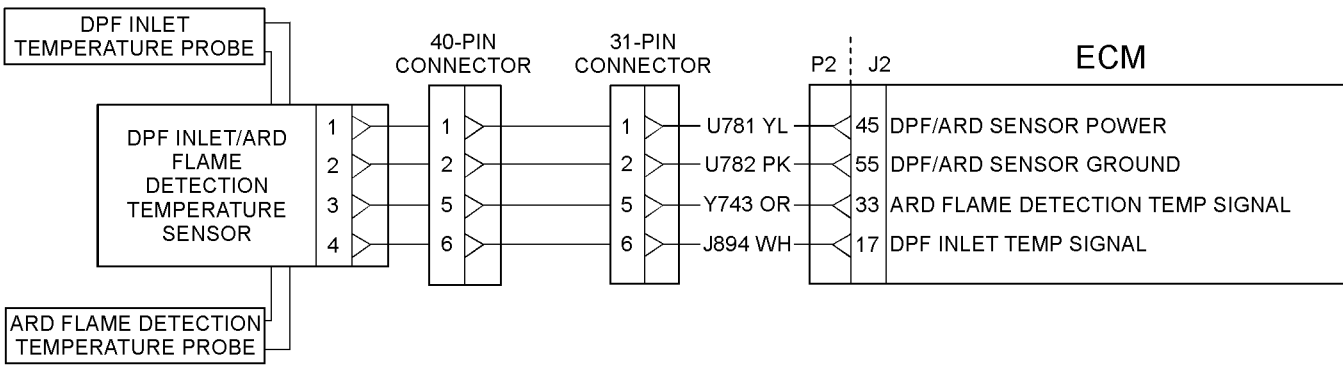


Illustration 50
Schematic for the temperature sensors for the engine aftertreatment system

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

- Fuel delivery

- Injection timing

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

The operating range for the fuel temperature sensor -40° to 120°C (-40° to 248°F)

The sensors are also used for engine monitoring.

Position Sensors

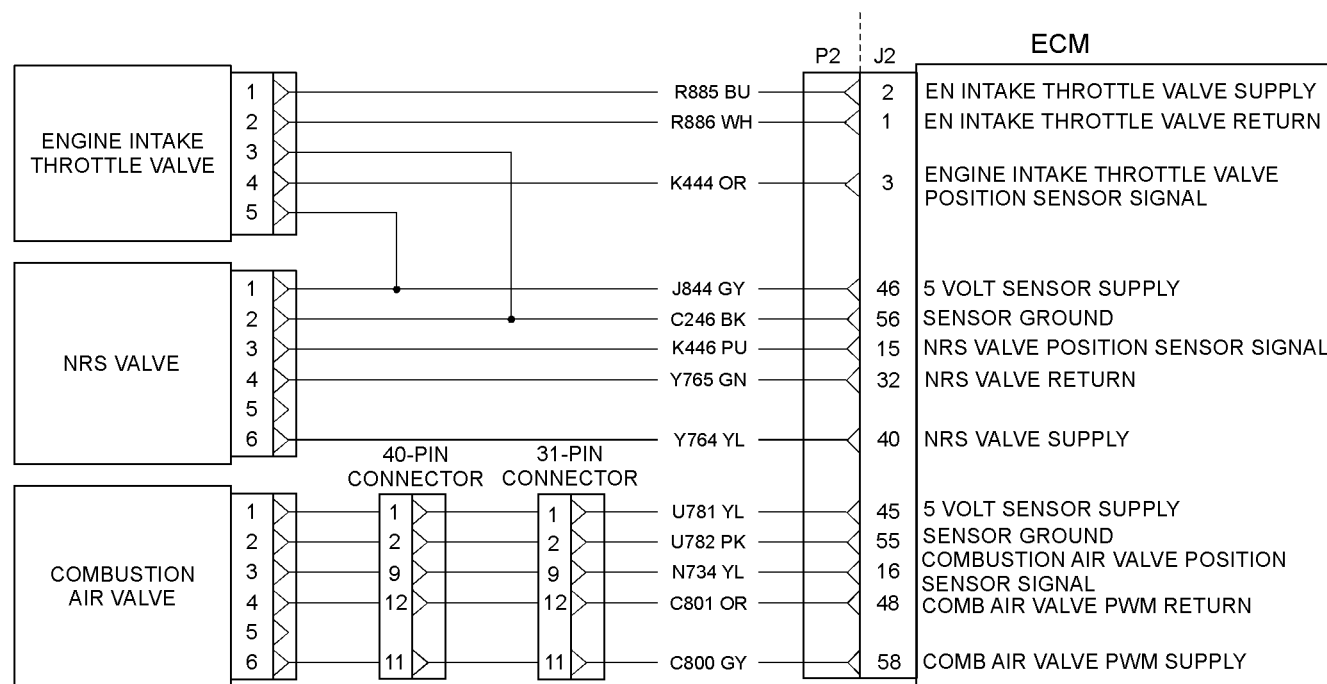


Illustration 51

g02292259

A typical example of a schematic of the position sensors

i04084272

The glow plugs are powered directly from the battery.

Power Sources

Introduction

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

- All sensors on the engine and the clean emissions module
- The suction control valve for the fuel injection pump
- The solenoid for the wastegate
- Diagnostic connector
- Electronic unit injectors
- ARD fuel pump
- ARD ignition circuit
- ARD nozzle heater

ECM Power Supply

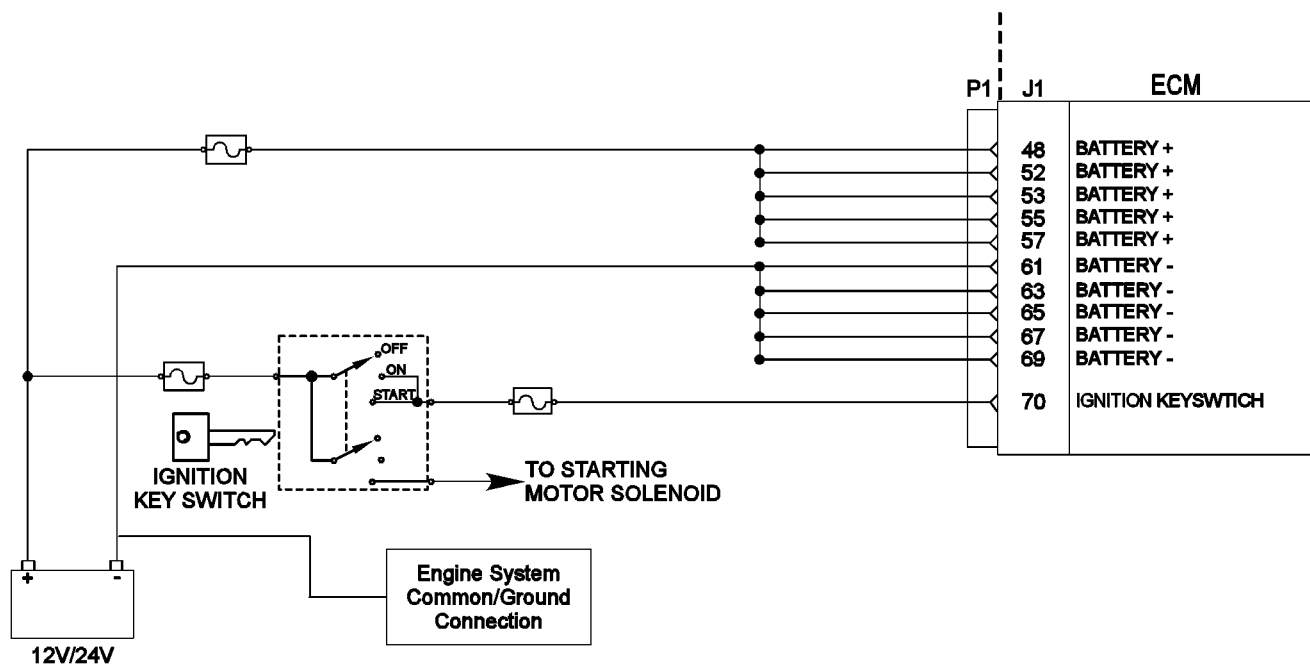


Illustration 52

g01908416

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 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

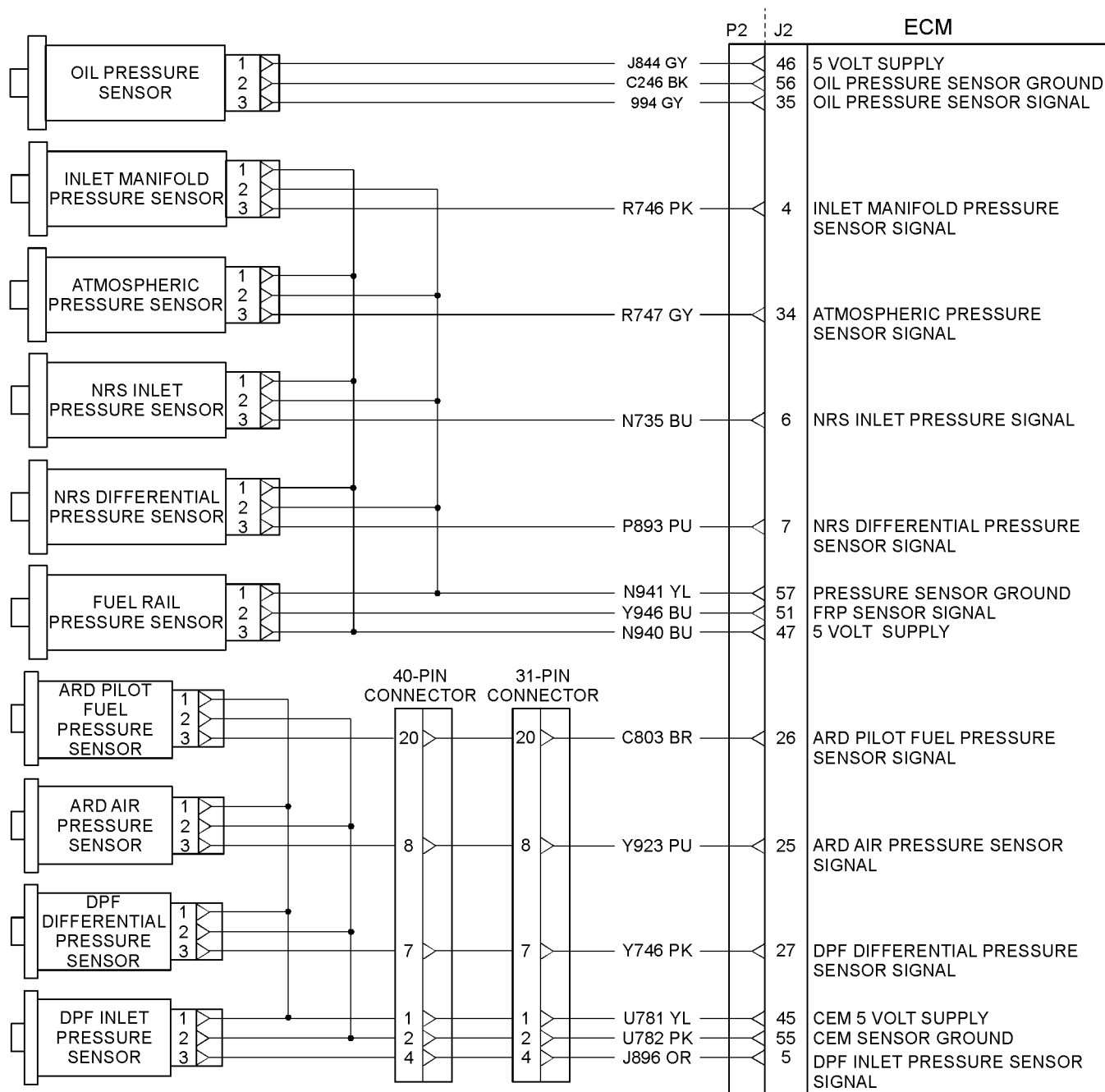


Illustration 53
Schematic for pressure sensors

g02292253

The ECM supplies 5 VDC 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

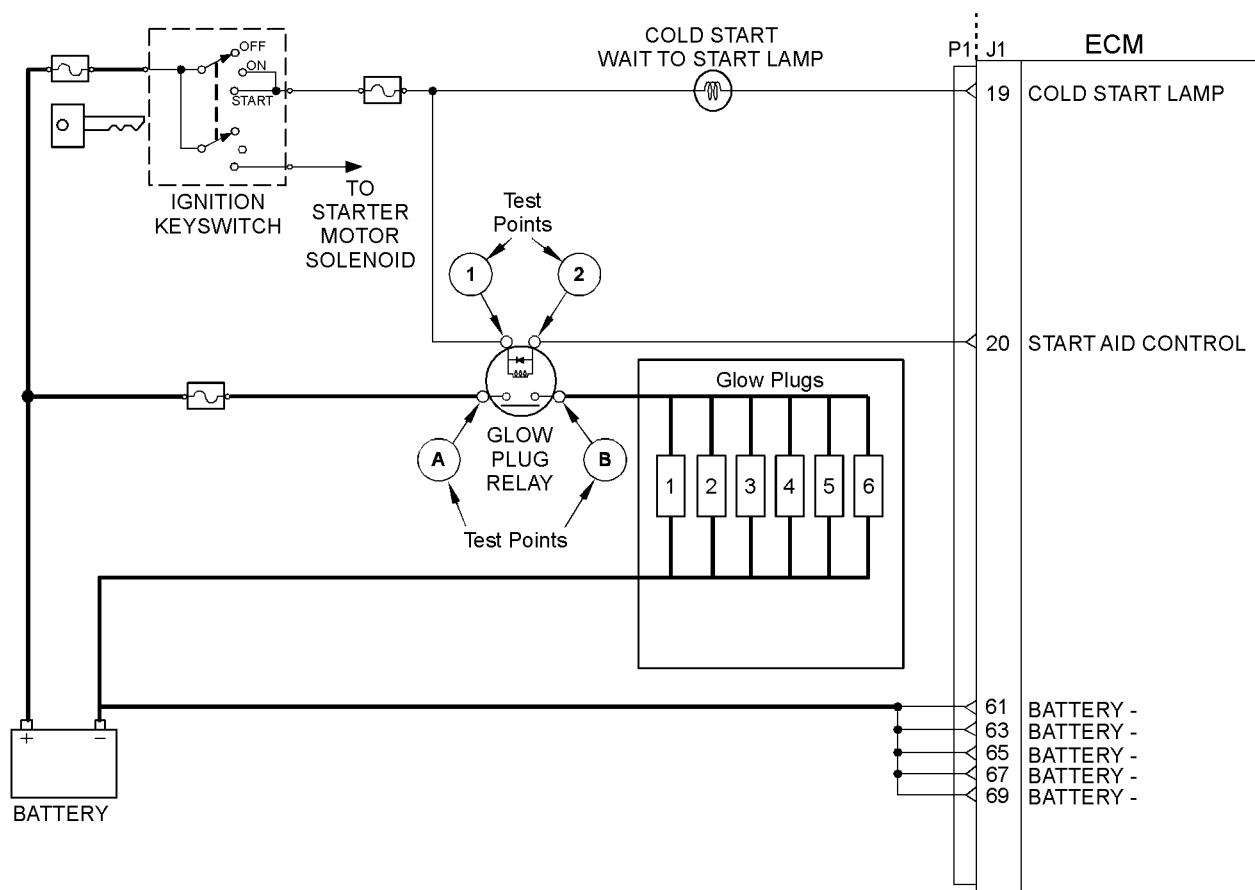


Illustration 54
Typical example

g01909413

Power Supply for the ARD Fuel Pump

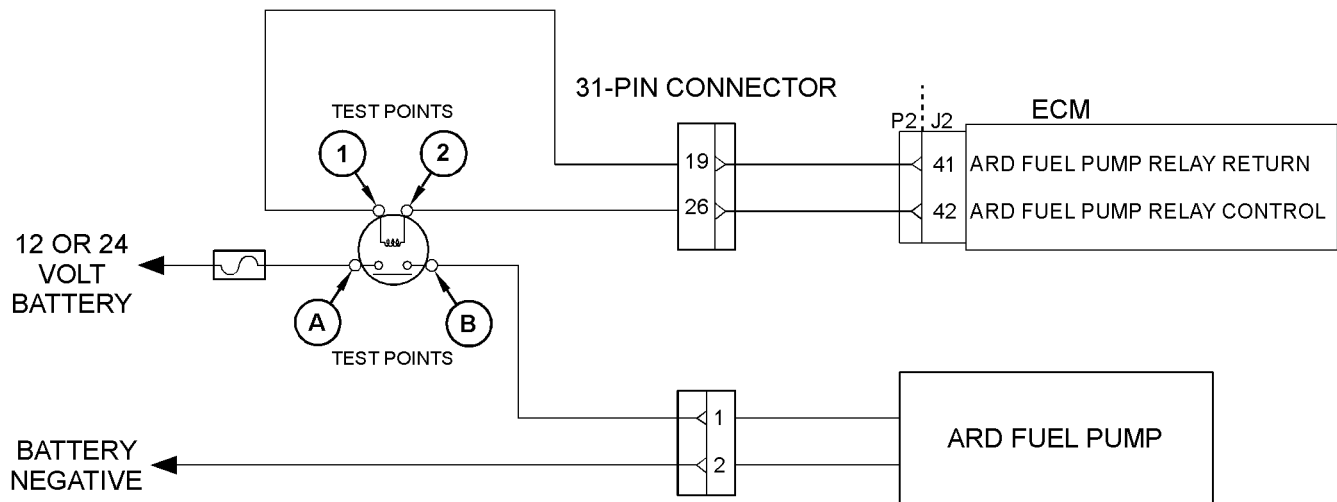


Illustration 55
Typical example

g02159018

Power Supply for the ARD Ignition Circuit

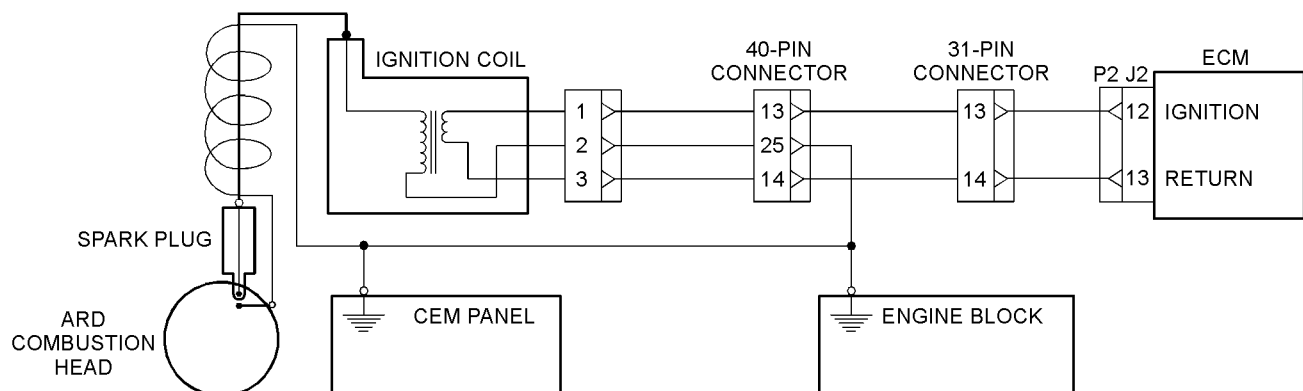


Illustration 56
Typical example

g02165596

Power Supply for the ARD Nozzle Heater Circuit

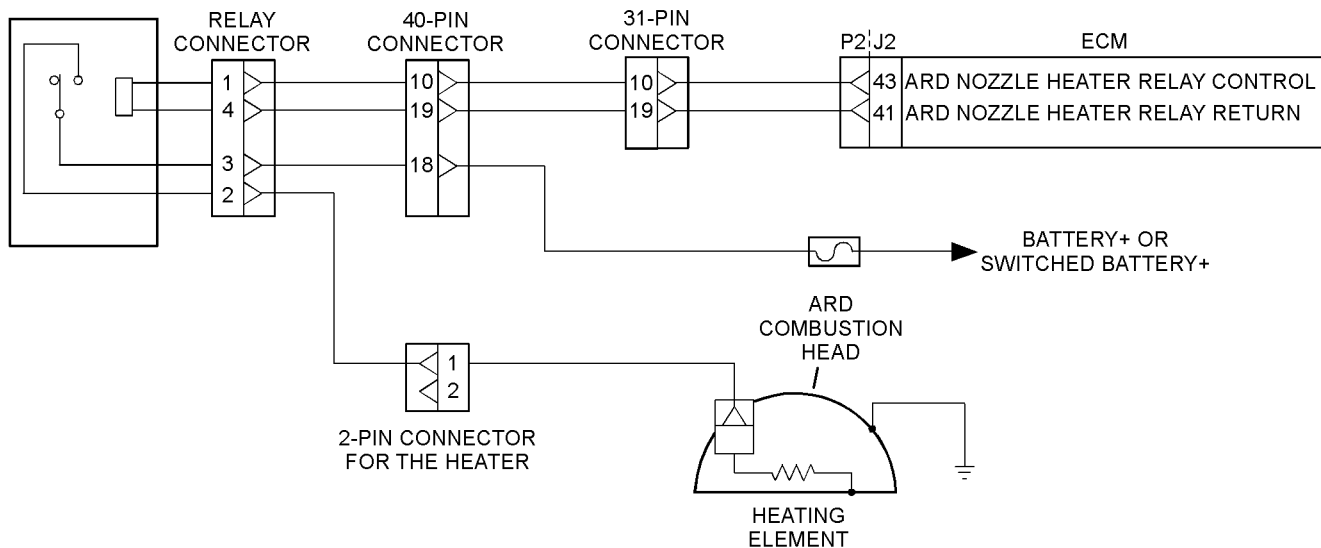


Illustration 57

g02168697

Typical example

Note: The relay is a solid state design with no moving contacts inside.

i04103752

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 the Aftertreatment Regeneration Device, a diesel oxidation catalyst and a diesel particulate filter.

Aftertreatment Regeneration Device (ARD) – The ARD is a device that intermittently raises the temperature of the exhaust gases in order to regenerate the diesel particulate filter.

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.

ARD Fuel Pump – The ARD fuel pump provides high-pressure fuel to the fuel system for the aftertreatment regeneration device.

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

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

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

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

CAN Data Link (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.

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.

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 the DPF, the temperature of the exhaust gas is raised by the Aftertreatment Regeneration Device (ARD) 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.

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

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

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

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

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

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

Engine Speed/Timing Sensor – An engine speed/timing sensor is a hall effect 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.

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.

Fuel Injection Pump – This item is sometimes referred to as the High Pressure Fuel Pump. This is a device that supplies fuel under pressure to the fuel manifold (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 an electronic signal to the ECM that is dependent on the pressure of the fuel in the fuel rail.

Fuel Pump – See “Fuel Injection Pump”.

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

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

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

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

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

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

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

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

High Pressure Fuel Rail Pump Solenoid Valve – See “The Solenoid Valve for the Fuel Injection Pump”.

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

Injector Trim Codes – Injector trim codes are codes that contain 30 characters. The 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 Sensor – The inlet manifold air temperature sensor detects the air temperature in the inlet manifold. The ECM monitors the air temperature and other data in the inlet manifold in order to adjust injection timing and other performance functions.

Inlet Manifold Pressure Sensor – The Inlet Manifold Pressure Sensor measures the pressure in the inlet manifold. 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 formation of oxides of nitrogen (NOx) in the combustion process. 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 application 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.

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. The electronic system requires correct passwords in order to change some parameters (Factory Passwords). Refer to Troubleshooting, “Factory Passwords” for more information.

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

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

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

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

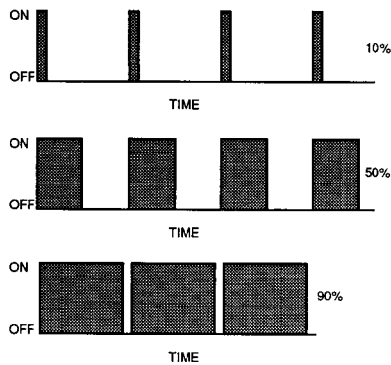


Illustration 58

g00284479

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

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

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

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.

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

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

Throttle Position – The throttle position is the interpretation by the ECM of the signal from the throttle position sensor or the throttle switch.

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

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

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

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

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

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

Wastegate Regulator – The wastegate regulator controls the pressure in the intake manifold to a value that is determined by the ECM. The wastegate regulator provides the interface between the ECM and the wastegate.

Testing and Adjusting Section

i04103212

Fuel System

i04081693

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.

Air in Fuel - Test

Table 1

Required Tools			
Tool	Part Number	Part Description	Qty
A	T400024	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. If the electric fuel transfer pump is not operating, refer to Troubleshooting, "Fuel Pump Relay Circuit - Test".
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.

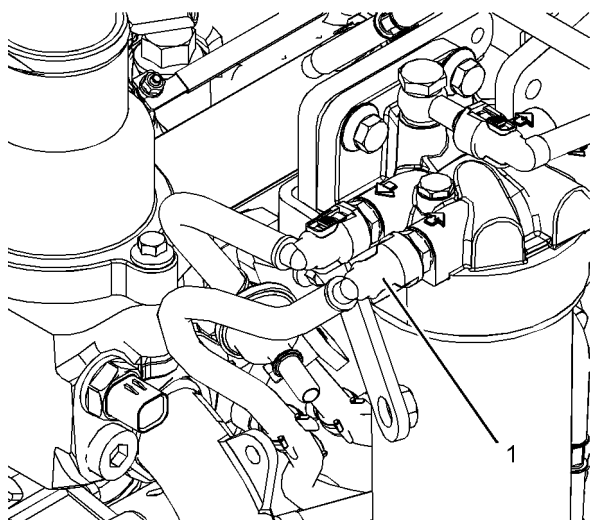


Illustration 59

g02305093

Typical example

7. If necessary, remove the low-pressure fuel line from the retaining clips. Remove the low-pressure fuel line from the inlet connection (1) of the secondary fuel filter base.

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

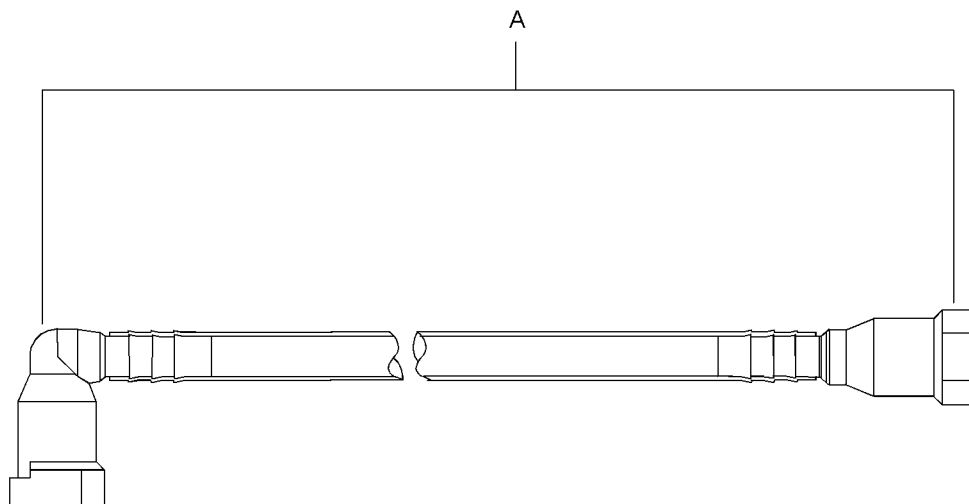


Illustration 60

g02352952

8. Connect Tooling (A) to the low-pressure fuel line and the secondary fuel filter base. Connect the open end of the tube to the inlet connection (1) of the secondary fuel filter base. 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 in the connections of the inline fuel strainer. Check for leaks between the fuel tank and the inlet at the fuel transfer pump. If necessary, replace the low-pressure fuel lines.

11. Remove Tooling (A). Reconnect the low-pressure lines.

12. Prime the fuel system. Refer to Operation and Maintenance Manual, "Fuel System - Prime" for the correct procedure.

i04102933

Finding Top Center Position for No. 1 Piston

Table 2

Required Tools			
Tool	Part Number	Part Name	Qty
A ⁽¹⁾	21825576	Crankshaft Turning Tool	1
A ⁽²⁾	27610291	Barring Device Housing	1
	27610289	Gear	1
B	27610212	Camshaft Timing Pin	1
C	T400014	Crankshaft Timing Pin	1
	27610287	Adapter	1

(1) The Crankshaft Turning Tool is used on the front pulley.

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

Note: Either Tooling (A) can be used. Use the Tooling that is most suitable.

1. Remove the front cover. Refer to Disassembly and Assembly, "Front Cover - Remove and Install".
2. Use Tooling (A) in order to rotate the crankshaft until the hole (X) in the camshaft gear (1) aligns with the hole in the front housing. Refer to illustration 61.

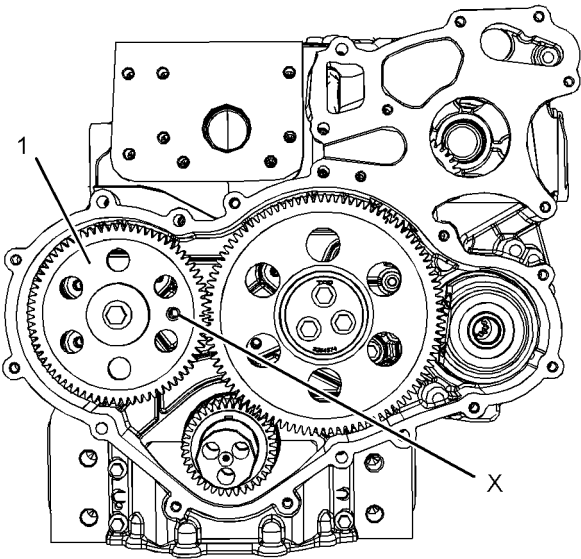


Illustration 61

g01907734

Typical example

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

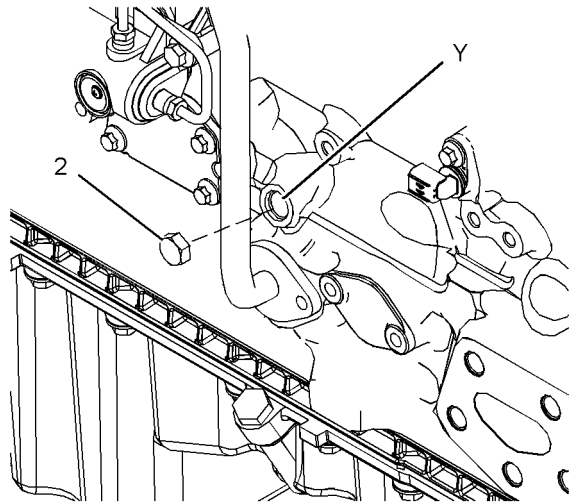


Illustration 62

g01907735

Typical example

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

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

i04102932

Fuel Injection Timing - Check

Table 3

Required Tools			
Tool	Part Number	Part Name	Qty
A ⁽¹⁾	21825576	Crankshaft Turning Tool	1
A ⁽²⁾	27610291	Barring Device Housing	1
	27610289	Gear	1
B	T400014	Crankshaft Timing Pin	1
	27610287	Adapter	1
C	T400015	Timing Pin (Fuel Injection Pump)	1

(1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

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.

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

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

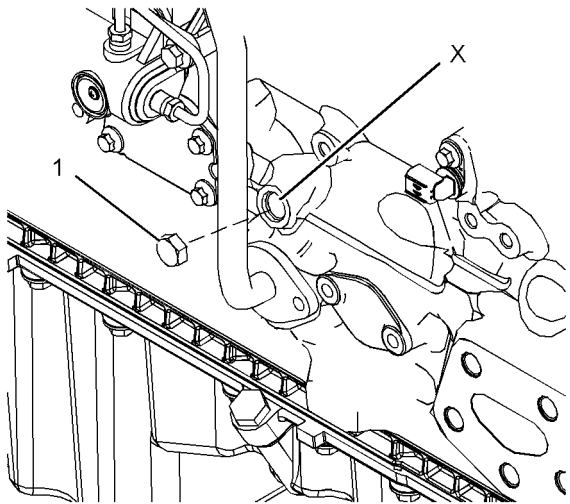


Illustration 63
Typical example

g01958182

1. Remove the plug (1) from the cylinder block. Use Tooling (A) to rotate the crankshaft until the number one piston is at the top center position.

Note: The number one piston may be on the compression stroke or the exhaust stroke.

2. Install Tooling (B) into the hole (X) in the cylinder block. Use Tooling (B) in order to locate the crankshaft in the correct position.

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

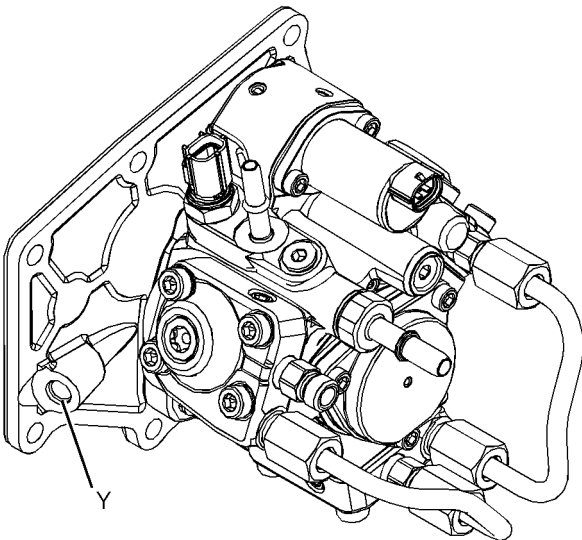


Illustration 64
Typical example

g02334279

3. Install Tooling (C) into hole in adapter plate at position (Y). Rotate the gear for the fuel injection pump until Tooling (C) snaps into the slot in the gear for the fuel injection pump.
4. Install the fuel injection pump. Refer to Disassembly and Assembly, "Fuel Injection Pump - Install" for the correct procedure.
5. Remove the Tooling (C) from the adapter plate.

i04026058

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.
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.

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

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.

i04081709

Fuel System - Prime

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.

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 procedure 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.
2. Turn the keyswitch to the "RUN" position.
3. The keyswitch will allow the electric priming pump to operate. Operate the electric priming pump for 2 minutes.

4. Turn the keyswitch to the “OFF” position. The fuel system should now be primed and the engine should be able to start.
5. Operate the engine starting motor 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”.

i04102991

ARD Fuel System - Flush (Clean Emissions Module)

NOTICE

Replace the in-line fuel filter connector assemblies on the Fuel Control Manifold is required when replacing the ARD Combustion Head or the Fuel Control Valves.

IMPORTANT: Do not use anti-seize or any other substance on the threads of the fittings.

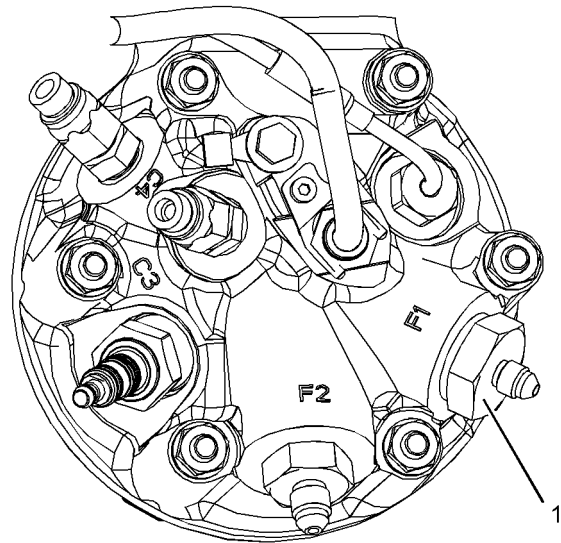


Illustration 65

g02304653

Typical example

(1) Pilot in-line filter fitting

1. Remove the pilot fuel line. Refer to Disassembly and Assembly, “Combustion Head Group (ARD) - Remove and Install” for the correct procedure.

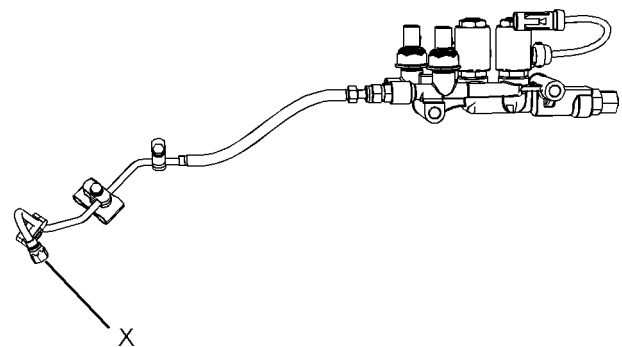


Illustration 66

g02304654

Typical example

2. Attach a 1.22 m (4 ft) length of hose and a suitable hose clamp to the fuel line at position (X).

Note: The internal diameter of the hose that is required should be 16 mm (0.63 inch).

3. Route the hose to a suitable container for fuel that can hold a minimum of 11.4 L (3 US gal) to catch the fuel being flushed.

Note: A quantity of 7.6 to 11.4 L (2 to 3 US gal) of fuel will be flushed in this procedure. Ensure that the container that is used to catch the fuel is adequately sized.

4. Select the "ARD Fuel Line Flush" service test. The "ARD Fuel Line Flush" is completed in 5 minutes.
5. Install the fuel line to the ARD combustion head. Refer to Disassembly and Assembly, "Combustion Head Group (ARD) - Remove and Install" for the correct procedure.
4. Install the fuel injection pump and gear assembly (3). Refer to Disassembly and Assembly, "Fuel Injection Pump - Install" for the correct procedure.
5. Make sure that the timing marks on the gears (1), (2) and (3) are in alignment. If the timing marks are not aligned, refer to Disassembly and Assembly, "Gear Group (Front) - Remove and Install".

i03578027

Gear Group (Front) - Time

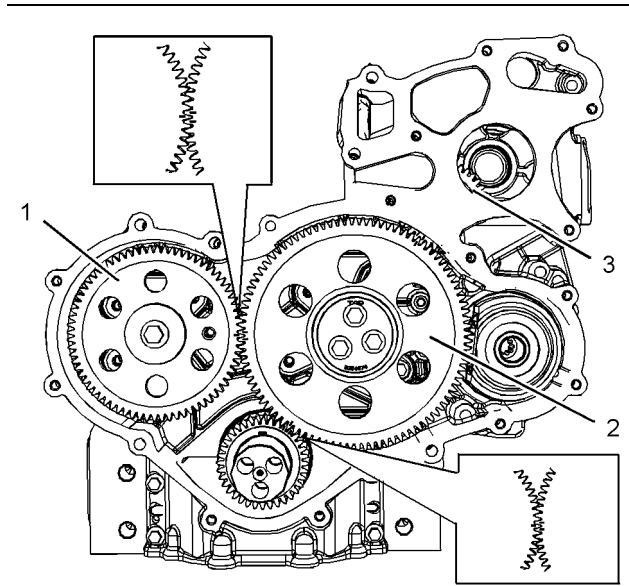


Illustration 67

g01907773

Typical example

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

1. Install the camshaft gear (1) onto the camshaft. Refer to Disassembly and Assembly, "Camshaft Gear - Remove and Install" for the correct procedure.
2. Ensure that the crankshaft and the camshaft are locked in the correct position. Refer to Systems Operation, Testing and Adjusting, "Finding Top Center Position for No. 1 Piston" for the correct procedure. Ensure that the fuel injection pump is locked in the correct position. Refer to Disassembly and Assembly, "Fuel Injection Pump - Remove" for the correct procedure.
3. Install the idler gear (2). Refer to Disassembly and Assembly, "Idler Gear - Remove and Install" for the correct procedure.

Air Inlet and Exhaust System

i04087489

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.

Inspection of the Crankcase Breather

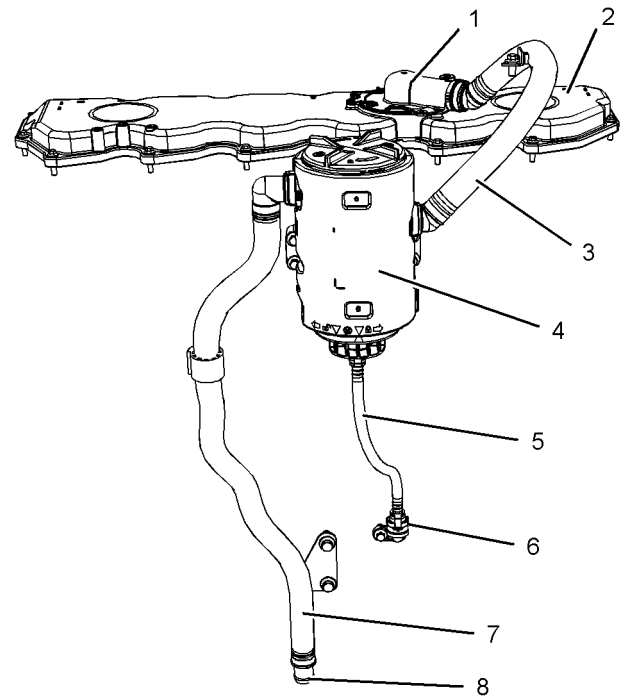


Illustration 68

g02295353

Typical example

- (1) Separator
- (2) Valve mechanism cover
- (3) Breather tube
- (4) Breather assembly
- (5) Drain tube
- (6) One-way valve
- (7) Breather tube
- (8) Outlet

If the filter for the crankcase breather becomes blocked, the pressure relief valve will operate. The pressure relief valve will also operate if there is a blockage in the system.

A general visual inspection should be made of the crankcase breather. To indicate that the pressure relief valve for the crankcase breather has been in operation, the following issues will be seen. These issues are found behind the breather canister.

- Smearing of the oil
- Droplets of oil
- Wet patches of oil

1. Check the element for the engine crankcase breather. If necessary, replace the element for the crankcase breather. Refer to Operation and Maintenance Manual, "Engine Crankcase Breather Element - Replace".

2. If there is sludge or debris in the canister, remove the canister. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install". Clean the inside of the canister. Check that the gas inlet, the outlet connections, and the connections for the oil drain are clear.
 - a. Remove the breather hoses and visually check the insides for signs of blockage and check with low-pressure air. If necessary, clean the hoses.
 - b. If necessary, replace the element for the crankcase breather. Refer to Operation and Maintenance Manual, "Engine Crankcase Breather Element - Replace".
 - c. Install the canister and hoses. Refer to Disassembly and Assembly, "Crankcase Breather - Remove and Install".
3. Check that the outlet for the crankcase breather is clean and free of obstructions. Ice can cause an obstruction in adverse weather conditions.

If excessive crankcase pressure is experienced and the pressure relief valve for the crankcase breather has not activated, there could be a blockage in the valve mechanism cover.

1. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install" for the correct procedure.
2. Inspect the inside of the valve cover for debris. The separator for the oil in the cover must be inspected. Ensure that all debris is removed from the cover.

Note: Do not attempt to remove the separator from the cover. The separator can be cleaned if the separator is still attached to the cover.

i04103753

Turbocharger - Inspect (Series Turbochargers)

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

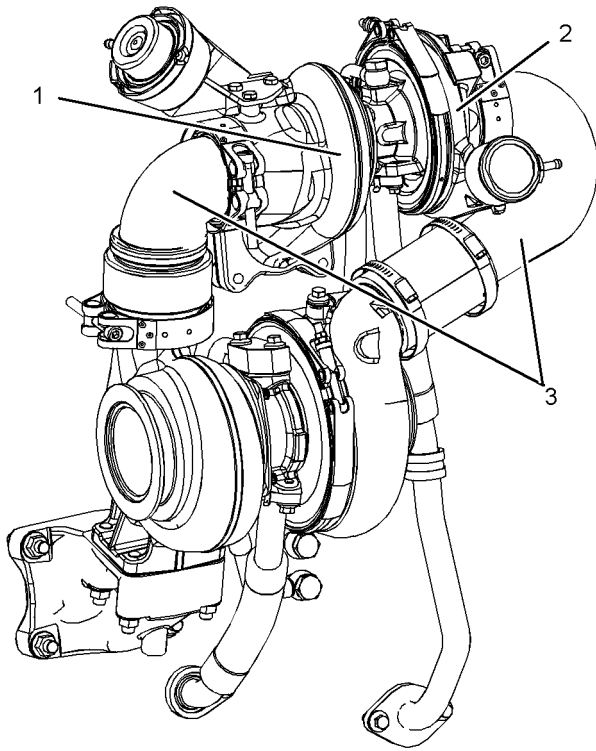


Illustration 69

g02299035

Typical example

- (1) Turbine housing
(2) Compressor housing
(3) Ducts

1. Inspect the compressor wheel and the ducts 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 oil sludge. Inspect the oil drain hole for oil sludge. Inspect the oil drain line for oil sludge in the drain line. If necessary, clean the oil drain line.
- 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.

1. Inspect the turbine for damage by a foreign object. If there is damage, determine the source of the foreign object. Replace turbocharger (2). If there is no damage, go to step 2.
2. Inspect the turbine wheel for the carbon and other foreign material. Inspect turbine housing (1) for carbon and foreign material. Replace the turbocharger, if necessary. If there is no buildup of carbon or foreign material, go to step 3.
3. Turn the rotating assembly by hand. While you turn the assembly, push the assembly sideways. The assembly should turn freely. The turbine wheel should not rub turbine wheel housing (1). Replace turbocharger (2) if turbine wheel rubs turbine housing (1). If there is no rubbing or scraping, go to step 4.
4. Inspect the turbine and turbine housing (1) for oil leakage. Inspect the turbine and turbine housing (1) for oil coking. Some oil coking may be cleaned. Heavy oil coking may require replacement of the turbocharger. If the oil is coming from the turbocharger center housing go to step 4.a. Otherwise go to "Inspection of the Wastegate".

- a. Remove the pipe for the oil drain. Inspect the drain opening. Inspect the area between the bearings of the rotating assembly shaft. Look for oil sludge. Inspect the oil drain hole for oil sludge. Inspect the oil drain line for oil sludge. If necessary, clean the drain line.
- b. If crankcase pressure is high, or if the oil drain is restricted, pressure in the center housing may be greater than the pressure of turbine housing (1). Oil flow may be forced in the wrong direction and the oil may not drain. Check the crankcase pressure and correct any problems.
- c. If the oil drain line is damaged, replace the oil drain line.
- d. Check the routing of the oil drain line. Eliminate any sharp restrictive bends.
- e. If steps 4.a through 4.d did not reveal the source of the oil leakage, turbocharger has internal damage. Replace 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 actuator, the pressure overcomes the spring and the wastegate will open. The rpm of the turbocharger becomes limited. The rpm limitation occurs because a portion of the exhaust gases bypass the turbine wheel of the turbocharger.

The following levels of boost pressure indicate a 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, which 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 4

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

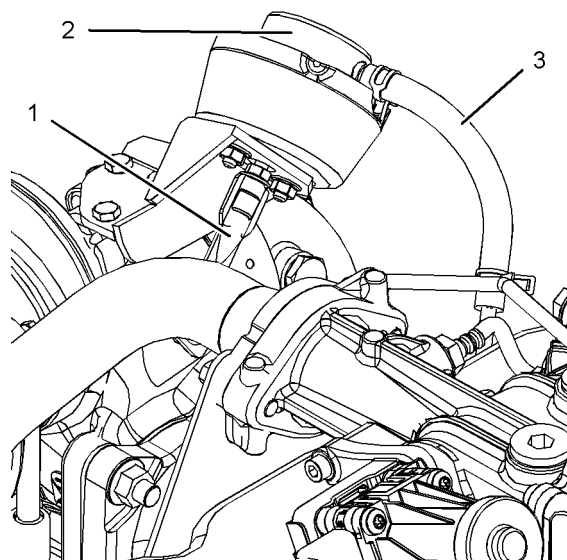


Illustration 70

g02299036

Typical example

Note: The wastegate actuator is installed to the high-pressure turbocharger.

1. Disconnect the pipe for the boost sensor (3) 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 (1) is in contact with Tooling (A). This will measure axial movement of the actuator rod (1).

3. Slowly apply air pressure to the wastegate so that the actuator rod (1) moves 1.0 mm (0.039 inch). Refer to Specifications, "Turbocharger" for the correct pressure for the wastegate. Ensure that the dial indicator returns to zero when the air pressure is released. Repeat the test several times. This will ensure that an accurate reading is obtained.
4. If the operation of the wastegate is not correct, the turbocharger will need to be replaced.
5. Repeat steps 2 to 4 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 (3).

i04102969

Exhaust Cooler (NRS) - Test

Air Under Water Leak Test Procedure.

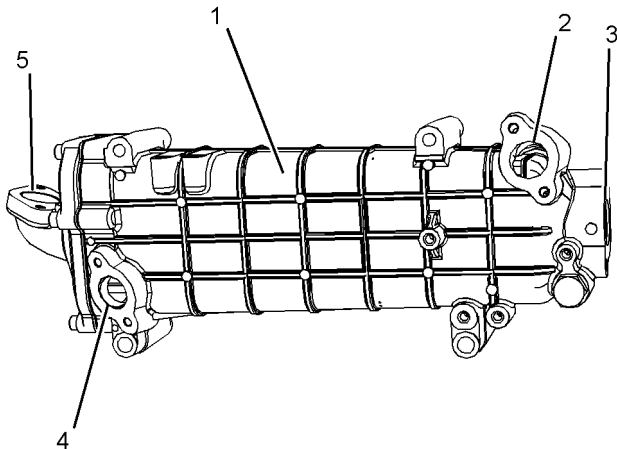


Illustration 71
Typical example

g02294237

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 (4) of the exhaust gas cooler (NRS) (1).
 - b. Plug the coolant outlet port (2) 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 pressure gauge 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.

- d. Use a suitable pressure gauge 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 (5) of the exhaust gas cooler (NRS) (1).
- b. Plug the gas outlet port (3) 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 pressure gauge 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.

i04102970

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.

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 a DPF. Refer to Operation and Maintenance Manual for the intervals of service hours for cleaning of the DPF.

1. Connect the engine to the electronic service tool before the 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 DPF to cool until the DPF can be safely removed.

2. Remove the 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 DPF. Refer to Troubleshooting for problem identification and the disposition of the DPF.

3. The DPF must be cleaned. Contact your nearest Perkins distributor for assistance.
4. Reinstall the 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 DPF volume back to the "Clean State". The resetting will allow the regeneration of the 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.

3. The electronic service tool will display "Ash Service Calibration Successful" when the calibration has been completed.

i04027325

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.

i04102949

Engine Valve Lash - Inspect

Table 5

Required Tools			
Tool	Part Number	Part Description	Qty
A ⁽¹⁾	21825576	Crankshaft Turning Tool	1
A ⁽²⁾	27610291	Barring Device Housing	1
	27610289	Gear	1
B	T400014	Timing Pin (Crankshaft)	1
	27610287	Adapter	1
C	21825617	Dial Indicator Group	1

- (1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

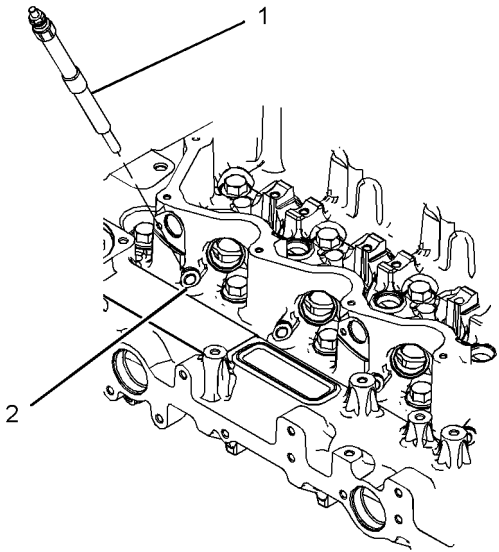


Illustration 72
Typical example

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.
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.

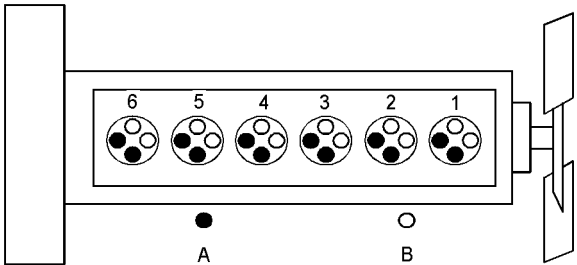


Illustration 73
Cylinder and valve location
(A) Exhaust valve
(B) Inlet valve

Too much valve lash can cause broken valve stems, springs, and spring retainers. This 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 lifters

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

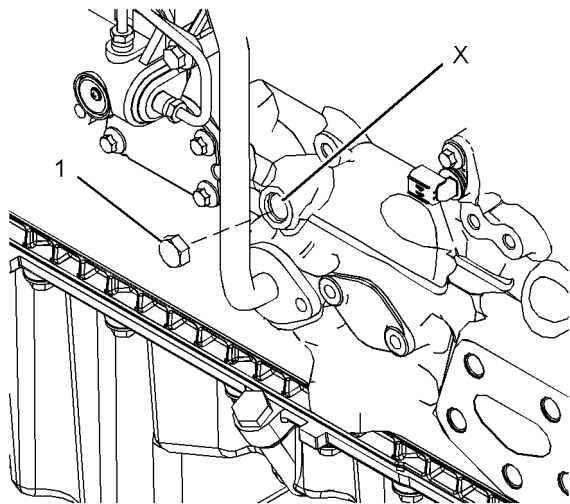


Illustration 74

g01958182

Typical example

2. Remove the plug (1) from the cylinder block. Use Tooling (A) to rotate the crankshaft until the number one piston is at the top center position.

Note: The number one piston may be on the compression stroke or the exhaust stroke.

3. Install Tooling (B) into the hole (X) in the cylinder block. Use Tooling (B) in order to locate the crankshaft in the correct position.

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

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

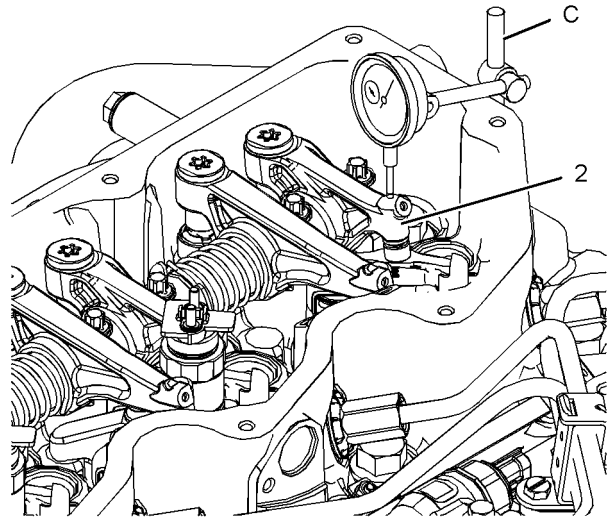


Illustration 75

g02313353

Typical example

One electronic unit injector is not shown for clarity.

5. If there is engine valve lash at any position the engine valve lash may be caused by a normal leakdown of the hydraulic lifter. Push the affected rocker arm (2) against the pushrod. Mount Tooling (C) with the pointer that is touching the top face of the rocker arm (2). Monitor the rocker arm for movement. The rocker arm (2) should rotate as the pushrod is pushed up by the recovery of the hydraulic lifter. Once all motion has ceased test again for engine valve lash. There should be no engine valve lash.
6. Remove Tooling (B) from the crankshaft. Use Tooling (A) to rotate the crankshaft in a clockwise direction. The crankshaft should be rotated 360 degrees. Install Tooling (B) to the crankshaft.
7. Check the rocker arms for engine valve lash. There should be no engine valve lash.
8. If there is engine valve lash at any position the engine valve lash may be caused by a normal leakdown of the hydraulic lifter. Push the affected rocker arm (2) against the pushrod. Mount Tooling (C) with the pointer that is touching the top face of the rocker arm (2). Monitor the rocker arm for movement. The rocker arm (2) should rotate as the pushrod is pushed up by the recovery of the hydraulic lifter. Once all motion has ceased test again for engine valve lash. There should be no engine valve lash.
9. If engine valve lash is found in any position, examine the valve mechanism components for excessive wear or damage. This includes the hydraulic lifters.

i04103769

Valve Depth - Inspect

Table 6

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

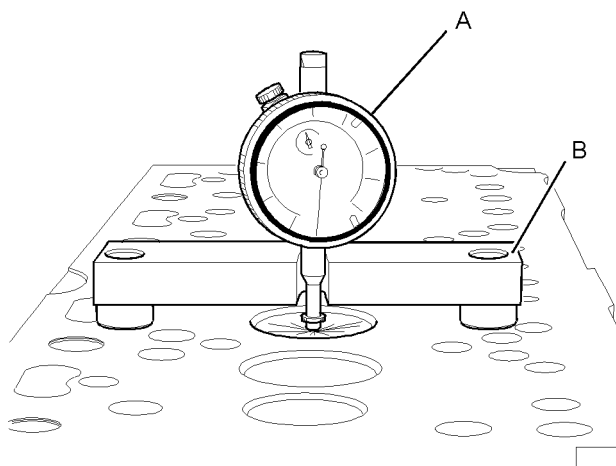


Illustration 76

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.

i03577785

Valve Guide - Inspect

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

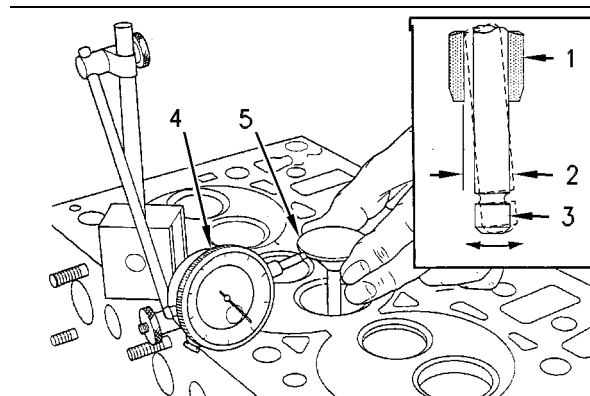


Illustration 77

g00314806

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

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

1. Place a new valve in the valve guide.
2. Place a dial indicator with a magnetic base on the face of the cylinder head.
3. Lift the edge of the valve head to a distance of 15.0 mm (0.60 inch).
4. Move the valve in a radial direction away from the dial indicator. Make sure that the valve moves away from the dial indicator as far as possible. Position the contact point of the dial indicator on the edge of the valve head. Set the position of the needle of the dial indicator to zero.

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

The maximum clearance for the inlet valve stem in the valve guide with a valve lift of 15.0 mm (0.60 inch) is the following value. 0.26 mm
(0.01024 inch)

The maximum clearance for the exhaust valve stem in the valve guide with a valve lift of 15.0 mm (0.60 inch) is the following value. 0.33 mm
(0.01299 inch)

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

Lubrication System

i03577861

Engine Oil Pressure - Test

Low Oil Pressure

The following conditions will cause low oil pressure.

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

A worn oil pressure relief valve can allow oil to leak through the valve which lowers the oil pressure.

The minimum oil pressure at the maximum engine speed and at normal operating temperature is 315 kPa (45 psi). A lower pressure is normal at low idle.

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

High Oil Pressure

High oil pressure can be caused by the following conditions.

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

i03578023

Engine Oil Pump - Inspect

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

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

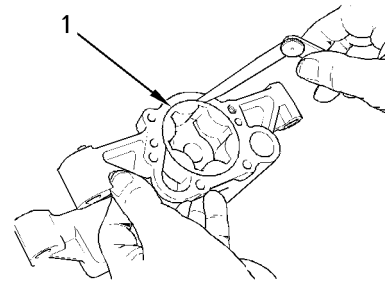


Illustration 78

g00938064

Typical example

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

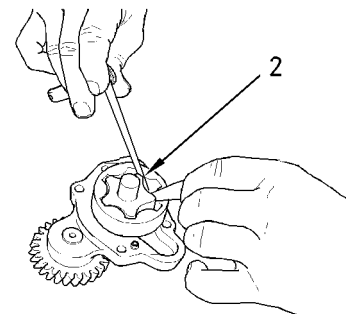


Illustration 79

g00938061

Typical example

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

i02414692

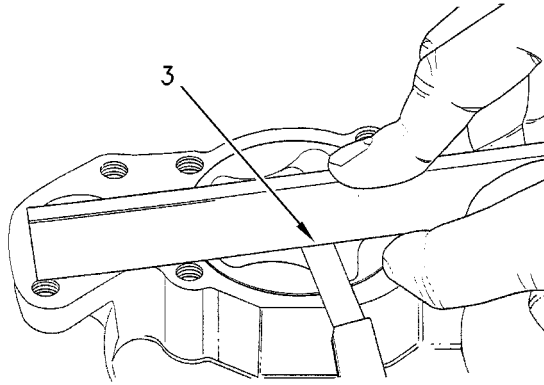


Illustration 80

g00938799

End play measurement of the rotor

5. Measure the end play of the rotor with a straight edge and a feeler gauge (3).
6. Clean the top face of the oil pump and the bottom face of the cover. Install the cover on the oil pump. Install the oil pump on the engine.

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.

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

i03578002

Cooling System - Check

Engine And Cooling System Heat Problems

1. The following conditions indicate that a heat problem exists.
 - a. Hot coolant is released through the pressure cap during the normal operation of the engine. Hot coolant can also be released when the engine is stopped.
 - b. Hot coolant is released from the coolant system but not through the pressure cap during normal operation of the engine. Hot coolant can also be released when the engine is stopped.
 - c. Coolant must be added frequently to the cooling system. The coolant is not released through the pressure cap or through an outside leak.
2. If any of the conditions in Step 1 exist, perform the following procedures:
 - a. Run the engine at medium idle, which is approximately 1200 rpm, for three minutes after the high idle shuts off. Running the engine at medium idle will allow the engine to cool before the engine is stopped.
 - b. Inspect the poly v-belt for wear or for damage. If necessary, replace the poly v-belt. Refer to Disassembly and Assembly Manual, "Alternator Belt - Remove and Install" for the correct procedure.
3. Refer to "Visual Inspection Of The Cooling System" in order to determine if a leak exists in the cooling system.
 - a. Refer to "Testing The Radiator And Cooling System For Leaks" procedures.
4. If the coolant does not flow through the radiator and through other components of the cooling system, perform the following procedures.
 - a. Perform the "Testing The Water Temperature Regulator " procedures.

- b. Clean the radiator and other components with hot water or steam at low pressure. Detergent in the water may also be used. Compressed air may be used to remove materials from the cooling system. Identify the cause of the restriction before you choose the method for cleaning.
 - c. Straighten any fins of the radiator if the fins are bent.
5. Check the high idle of the engine. The engine may overheat if the high idle rpm is set too high.

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.

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.

i03577960

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 81. 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.

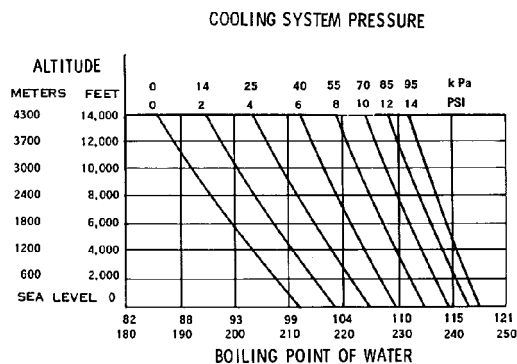


Illustration 81

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 five minutes.
- The dial indicator remains constant beyond five minutes.

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

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

Make any repairs, as required.

i03577886

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.

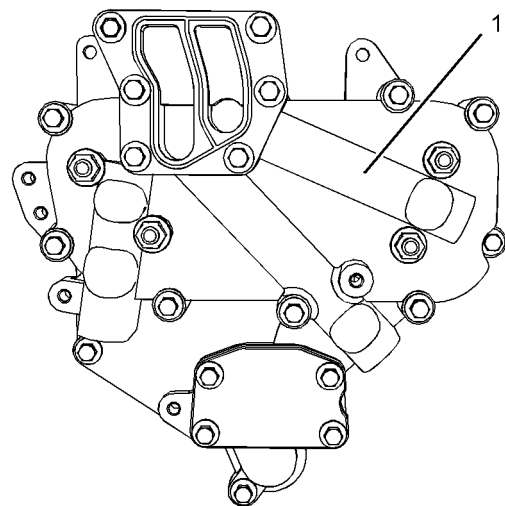


Illustration 82

g01907716

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.

i04175229

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

i04129072

Position the Valve Mechanism Before Maintenance Procedures

NOTICE

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

Table 7

Required Tools			
Tool	Part Number	Part Description	Qty
A ⁽¹⁾	21825576	Crankshaft Turning Tool	1
A ⁽²⁾	27610291	Barring Device Housing	1
	27610289	Gear	1
B	21825617	Dial Indicator Group	1

- (1) The Crankshaft Turning Tool is used on the front pulley.
(2) This Tool is used in the aperture for the electric starting motor.

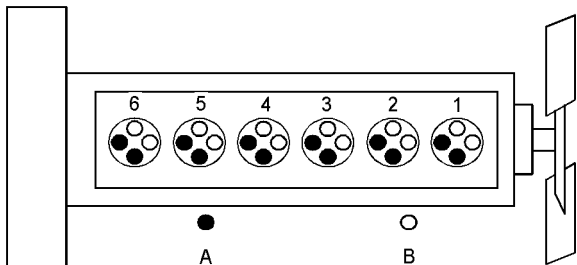


Illustration 83
Cylinder and valve location
(A) Exhaust valve
(B) Inlet valve

1. Remove the valve mechanism cover. Refer to Disassembly and Assembly, "Valve Mechanism Cover - Remove and Install" for the correct procedure.
2. Remove the glow plugs. Refer to Disassembly and Assembly, "Glow Plugs - Remove and Install" for the correct procedure.
3. Select an accessible exhaust rocker arm. The exhaust rocker arm can be on any cylinder.

4. Use Tooling (A) to rotate the crankshaft until the push rod end of the selected exhaust valve reaches the maximum height. This indicates that the hydraulic lifter is sitting on the base circle of the camshaft lobe.

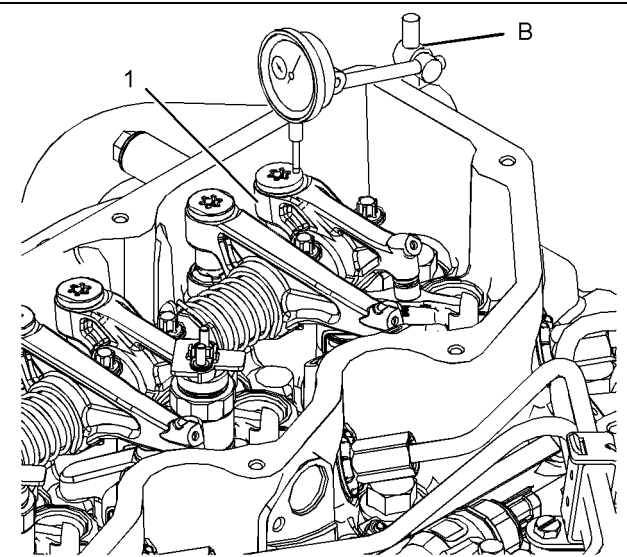


Illustration 84
Typical example
One electronic unit injector is not shown for clarity.

5. Mount Tooling (B) with the pointer that is touching the top face of the exhaust rocker arm (1) above the push rod.
6. Use Tooling (A) to rotate the crankshaft until the hydraulic lifter starts to open the exhaust valve. Continue to rotate the crankshaft until the finger of the indicator moves by 2.8 mm (0.11 inch).

Note: This is the safe position of 60 degrees. The precise position will vary depending whether the hydraulic lifter is leaked down or not. The reading on the dial indicator may reduce as the hydraulic lifter continues to leak down. As soon as a value of 2.8 mm (0.11 inch) is reached the crankshaft is in a safe position.

Note: Make temporary marks on the vibration damper 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.

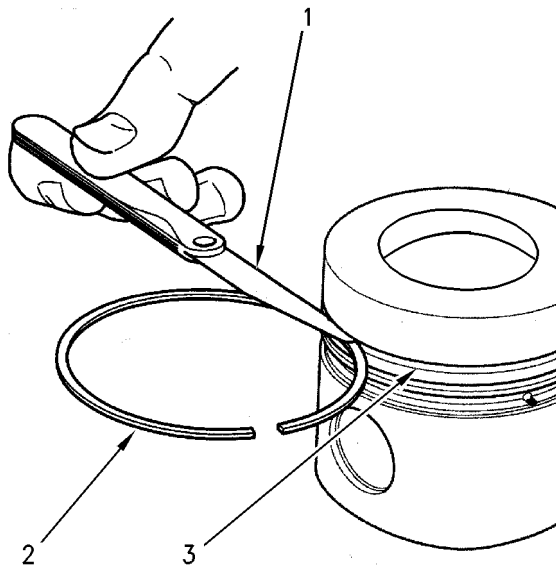


Illustration 85

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

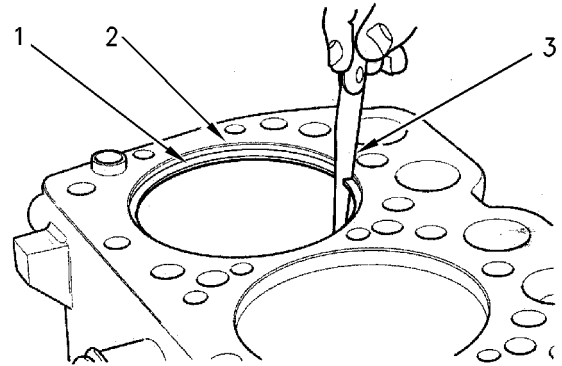


Illustration 86

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.

i04026502

Connecting Rod - Inspect

Note: If the crankshaft or the cylinder block are replaced, the piston height for all cylinders must be measured.

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

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

A single grade of connecting rod is used to control piston height. Refer to table 8 for more information.

i03929909

Piston Pin Bearings

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

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

1. Remove the piston pin bearing from the connecting rod. Install a new bearing in the connecting rod. The new bearing is partially finished. The new bearing must be bored off-center to the correct diameter. This off-center position is determined by the length of the connecting rod. Refer to table 8. The correct diameter of the bore in the piston pin bearing is given in Specifications, "Connecting Rod".

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

2. Machine the ends of the piston pin bearing to the correct length. Remove any sharp edges. Refer to Specifications, "Connecting Rod".

Table 8 references the following information: Grade of letter of the connecting rod, the color code of the connecting rod, and the length of the connecting rod.

Table 8

Specifications for the Connecting Rod		
Grade Letter	Color Code	Length Of The Connecting Rod (CRL)
B	Blue	161.107 to 161.140 mm (6.3428 to 6.3441 inch)

i03191701

Cylinder Block - Inspect

1. Clean all of the coolant passages and the oil passages.
2. Check the cylinder block for cracks and damage.
3. The top deck of the cylinder block must not be machined.
4. Check the front camshaft bearing for wear. Refer to Specifications, "Camshaft Bearings" for the correct specification of the camshaft bearing. If a new bearing is needed, use a suitable adapter to press the bearing out of the bore. Ensure that the oil hole in the new bearing faces the front of the block. The oil hole in the bearing must be aligned with the oil hole in the cylinder block. The bearing must be aligned with the face of the recess.

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).

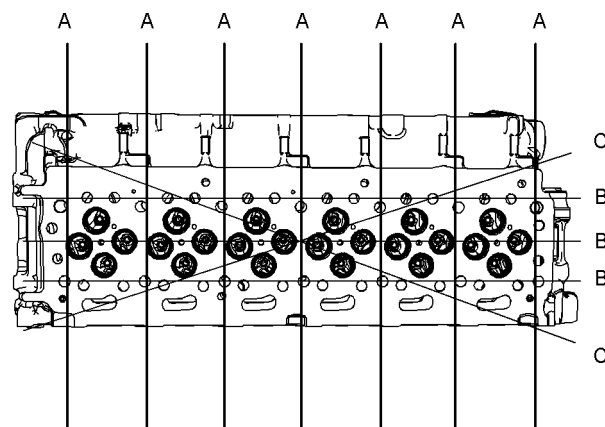


Illustration 87

g01907754

Flatness of the cylinder head (typical example)

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

8. Measure the cylinder head for flatness. Use a straight edge and a feeler gauge to check the cylinder head for flatness.
 - Measure the cylinder head from one side to the opposite side (A).

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

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

Resurfacing the Cylinder Head

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

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

Note: The thickness of the cylinder head must not be less than 150.8 mm (5.93700 inch) after the cylinder head has been machined.

Note: The dimension of the valve seats to the flame face must be corrected after resurfacing the cylinder head. Refer to Specifications, "Cylinder Head" for the correct dimensions for the valve seats.

i04156372

Piston Height - Inspect

Table 9

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

If the height of the piston above the cylinder block is not within the tolerance that is given in 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.

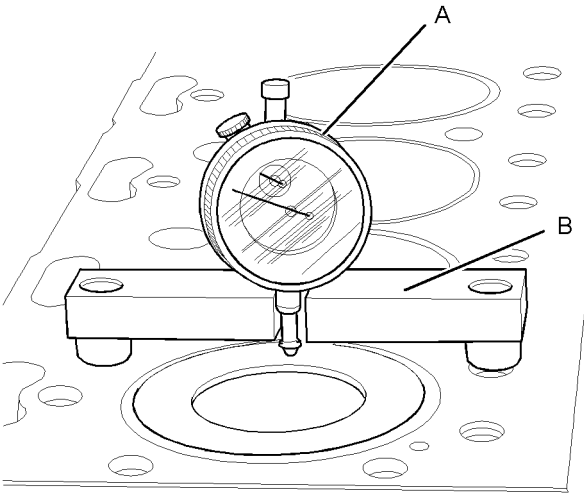


Illustration 88
Typical example

g01201898

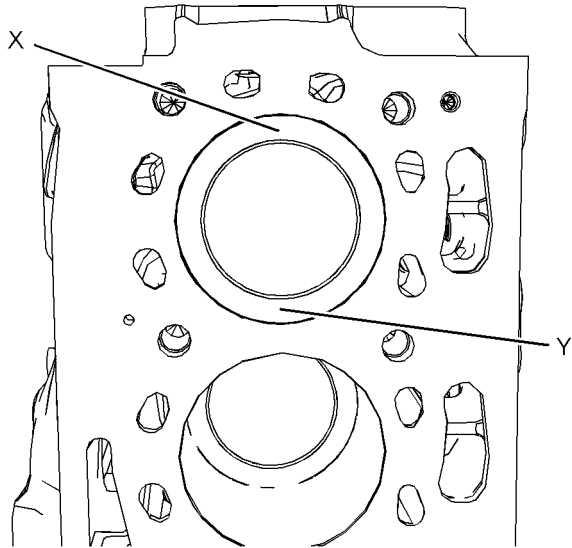


Illustration 89
Typical example

g02351060

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 10

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

Alignment of the Flywheel Face

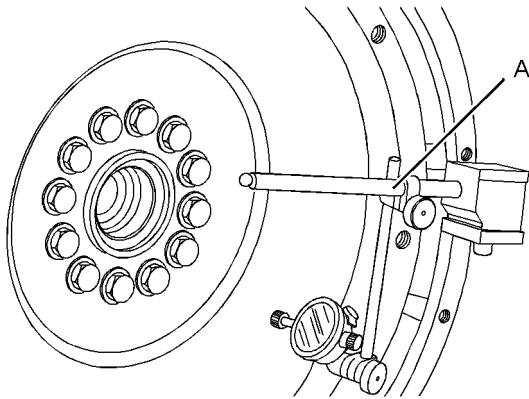


Illustration 90

g01332565

Typical example

1. Install Tooling (A) in illustration 90, 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

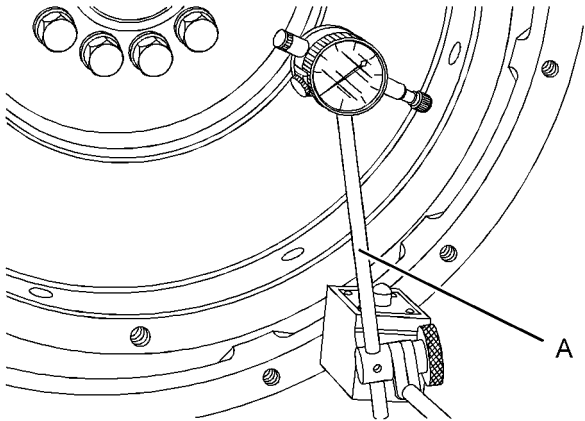


Illustration 91

g01321858

Typical example

1. Install Tooling (A) in illustration 91, 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 11

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.

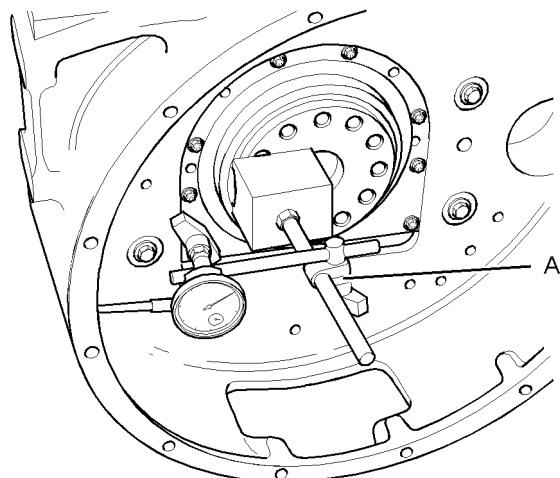


Illustration 92

g01199468

Typical example

1. Install Tooling (A). See illustration 92.
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 12.

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.

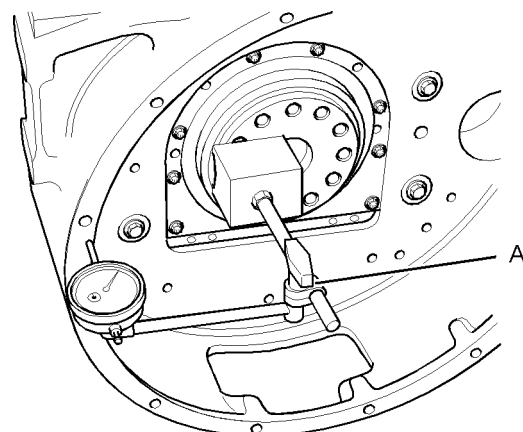


Illustration 93

g01199467

Typical example

1. Install Tooling (A). See illustration 93.
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 12.

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

Table 12

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)

i03578981

i04091609

Gear Group - Inspect

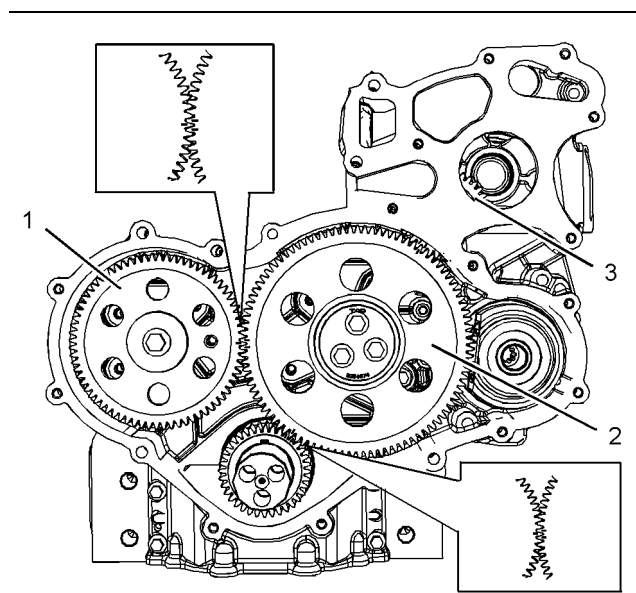


Illustration 94

g01907773

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

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

1. Inspect the gears for wear or for damage. If the gears are worn or damaged, use new parts for replacement.
2. Measure the backlash between the camshaft gear (1) and the idler gear (2). Refer to Specifications, "Gear Group (Front)" for the backlash measurement.
3. Measure the backlash between the idler gear (2) and the crankshaft gear (4). Refer to Specifications, "Gear Group (Front)" for the backlash measurement.
4. Measure the backlash between the fuel injection pump gear (3) and the idler gear (2). Refer to Specifications, "Gear Group (Front)" for the backlash measurement.
5. Measure the end play on idler gear (2). Refer to Disassembly and Assembly, "Idler Gear - Install" for the correct procedure. Refer to Specifications, "Gear Group (Front)" for the end play measurement.

Vibration Damper - Check

The vibration damper is installed on the front of the crankshaft. The vibration damper is installed in order to help control torsional vibration in the engine.

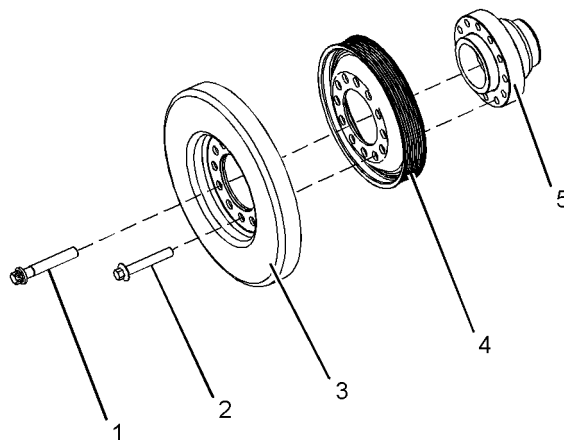


Illustration 95

g02153930

Typical example

- (1) Setscrews
(2) Setscrews
(3) Vibration damper
(4) Crankshaft pulley
(5) Crankshaft adapter

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

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

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

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

1. Remove any debris from the front face of the vibration damper. Remove any debris from the circumference of the vibration damper.
2. Mount the dial indicator on the front cover. Use the dial indicator to measure the outer face of the vibration damper. Set the dial indicator to read 0.00 mm (0.00 inch).
3. Rotate the crankshaft at intervals of 45 degrees and read the dial indicator.
4. The difference between the lower measurements and the higher measurements that are read on the dial indicator at all four points must not be more than 0.18 mm (0.007 inch).

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

5. Move the dial indicator so that the dial indicator will measure the circumference of the vibration damper. Set the dial indicator to read 0.00 mm (0.00 inch).
6. Slowly rotate the crankshaft in order to measure the runout of the circumference of the vibration damper. Use the highest reading and the lowest reading on the dial indicator. The maximum and the minimum readings on the dial indicator should not vary more than 0.12 mm (0.005 inch).

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

Electrical System

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.

- 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 fuse 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.

i03631789

Charging System - Test

The condition of charge in the battery at each regular inspection will show if the charging system is operating correctly. An adjustment is necessary when the battery is constantly in a low condition of charge or a large amount of water is needed. A large amount of water would be more than one ounce of water 28 ml per cell per week or per every 100 service hours. There are no adjustments on maintenance free batteries.

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

Alternator

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

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

1. Check that the nut on the "B+" terminal is secure and that the wire has a good connection to the "B+" terminal.
2. Start the engine. Set the throttle to at least 75% of full throttle. Turn on all accessories. Allow the engine to operate for at least three minutes.
3. Measure the voltage between the "B+" terminal and the ground for the alternator.
4. Measure the voltage across the battery. Put the red lead on the positive battery terminal, and the black lead on the negative battery terminal. Step 4 should be completed as quickly as possible after step 3.

Result

The voltage in step 3 is not more than 1 V for a 12 V system or 2 V for a 24 V system and higher than the voltage in step 4. The test is complete and the related wiring is correct at this time. Replace the alternator.

The voltage in step 3 is more than 1 V for a 12 volt system or 2 V for a 24 volt system and higher than the voltage in step 4. There is a high circuit resistance such as corrosion, loose connections or damaged wiring. Continue to step 5.

5. Check the voltage between the machine frame and the "B+" terminal of the alternator. Record the voltage.
6. Check the voltage between the machine frame and the positive battery post. Step 6 should be completed as quickly as possible after step 5.

Result

The voltage difference between step 5 and step 6 does not exceed 0.5 V on 12 V systems and 1 V for 24 V systems. The charging circuit is good. Go to step 7.

The voltage difference between step 5 and step 6 exceeds 0.5 V on 12 V systems and 1 V for 24 V systems. There is a high resistance in the circuit. The following items may cause the high resistance.

- Loose cables
- Corroded cables

- A fault with the circuit breaker

Correct the fault and retest the system.

7. Check the voltage between the negative battery post and the alternator case ground.

Result

The voltage does not exceed 0.5 V on 12 V systems and 1 V on 24 V systems. There is an internal problem with the alternator.

The voltage exceeds 0.5 V on 12 V systems and 1 V on 24 V systems. There is a high resistance in the circuit. The following items may cause the high resistance.

- Loose cables
- Corroded cables
- A fault with the circuit breaker

Correct the fault and retest the system.

i03577880

V-Belt - Test

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

Poly V-Belt

NOTICE

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

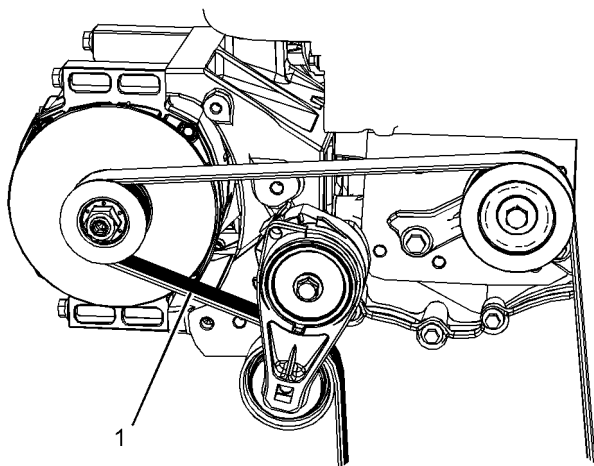


Illustration 96

g01906354

Typical example

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

- Check the poly v-belt (1) for cracks, splits, glazing, grease, 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 (1) 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 Disassembly and Assembly, "Alternator Belt - Remove and Install". If necessary, replace the belt tensioner. Refer to Disassembly and Assembly, "Alternator Belt - Remove and Install" for the correct procedure.

i04153911

Electric Starting System - Test

General Information

Power which is available during cranking varies according to the temperature and condition of the batteries. Table 13 shows the voltages which are expected from a battery at the various temperature ranges.

Table 13

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 14 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 14.

Table 14

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 14 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.

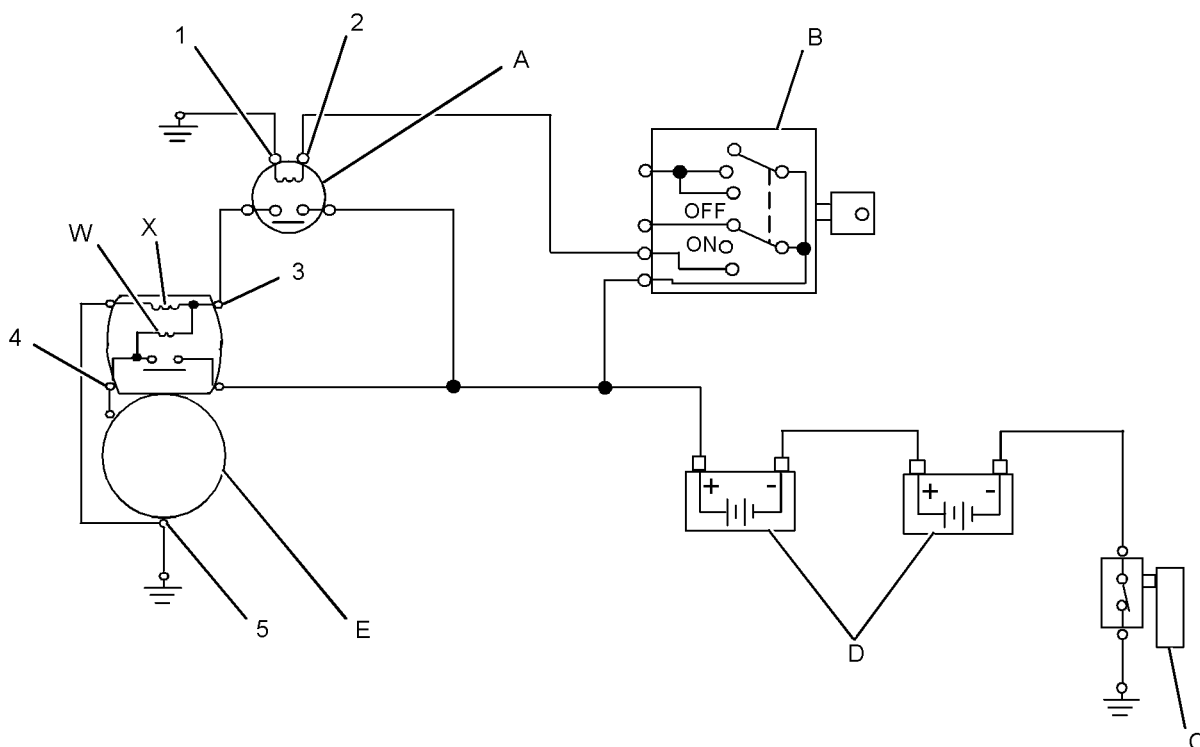


Illustration 97

g02349396

Typical 24 V starting circuit

- | | | |
|----------------|-----------------------|--------------------|
| (1) Test point | (5) Test point | (D) Batteries |
| (2) Test point | (A) Start relay | (E) Starting motor |
| (3) Test point | (B) Start switch | (X) Hold-in coil |
| (4) Test point | (C) Disconnect switch | (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 13, then go to step 3.

- b. The battery voltage is less than the voltage in table 13. 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 V of the lowest value in the applicable temperature range of table 13.
- 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 13, 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 13. 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 14.
- b. Voltage drops are equal to the voltage drops that are given in table 14 or the voltage drops are less than the voltage drops that are given in table 14. 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 14. 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 13, then go to step 3.

- b. The battery voltage is less than the voltage in table 13. 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 V of the lowest value in the applicable temperature range of table 13.
 - 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 13, 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 13. 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 14.
 - b. Voltage drops are equal to the voltage drops that are given in table 14 or the voltage drops are less than the voltage drops that are given in table 14. 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 14. 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 8 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 13, then go to step 3.
 - b. The battery voltage is less than the voltage in table 13. 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 700 amp or the maximum current that flows to the solenoid should be less than 700 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 V of the lowest value in the applicable temperature range of table 13.
- 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 13, 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 13. 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 14.
- b.** Voltage drops are equal to the voltage drops that are given in table 14 or the voltage drops are less than the voltage drops that are given in table 14. 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 14. 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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