M0107832-01 (en-us)
October 2019

Systems Operation Testing and Adjusting

C3.6 and C2.8 Industrial Engines

J37 1-UP (Engine)
J29 1-UP (Engine)

PUBLICATIONS.CAT.COM

i06558969

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, including human factors that can affect safety. 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 verify that you are authorized to perform this work, and have read and understood the operation, lubrication, maintenance and repair information.

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

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

WARNING

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

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

A non-exhaustive list of operations that may cause product damage are identified by “NOTICE” labels on the product and in this publication.

Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this publication and on the product are, therefore, not all inclusive. You must not use this product in any manner different from that considered by this manual without first satisfying yourself that you have considered all safety rules and precautions applicable to the operation of the product in the location of use, including site-specific rules and precautions applicable to the worksite. If a tool, procedure, work method or operating technique that is not specifically recommended by Caterpillar is used, you must satisfy yourself that it is safe for you and for others. You should also ensure that you are authorized to perform this work, and that the product will not be damaged or become unsafe by the operation, lubrication, maintenance or repair procedures that you intend to use.

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. Cat dealers have the most current information available.

WARNING

When replacement parts are required for this product Caterpillar recommends using Cat replacement parts.

Failure to follow this warning may lead to premature failures, product damage, personal injury or death.

In the United States, the maintenance, replacement, or repair of the emission control devices and systems may be performed by any repair establishment or individual of the owner's choosing.

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Systems Operation Section

General Information

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Introduction

SMCS Code: 1000

The C3.6 and C2.8 diesel engines are electronically controlled. The C3.6 and C2.8 engines have an Electronic Control Module (ECM) that receives signals from the fuel injection pump and other sensors to control the electronic unit injector. The fuel injection pump supplies fuel to the high-pressure manifold (rail). The high-pressure manifold (rail) distributes fuel to the electronic unit injectors.

The four 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 left side of the cylinder head. The ports for the inlet valves are on the right side of the cylinder head. Each cylinder valve has a single valve spring.

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

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

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

The front housing is made of aluminum. The engine oil pump is located in the front housing. The engine oil pump is driven from the front of the crankshaft. The water pump is on the front housing. The water pump pulley is driven by the front-end drive belt.

The timing gears are located in the flywheel housing. The timing gears are stamped with timing marks 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 camshaft gear will align with the marks that are on the fuel injection pump gear, and the gear on the crankshaft.

The crankshaft gear turns the camshaft gear and the idler gear. The camshaft gear turns the fuel injection pump gear. The idler gear turns the accessory drive gear (if equipped).

The camshaft runs at half the rpm of the crankshaft.

The fuel injection pump runs at the same rpm of the crankshaft.

The fuel injection pump that is installed on the right side of the engine is gear-driven from the rear gear train. The fuel is transferred from the fuel tank through the low-pressure fuel system to the fuel injection pump.

The fuel injection pump increases the fuel to a maximum pressure of 200 MPa (29000 psi). The fuel injection pump delivers the fuel to the high-pressure manifold (rail). The suction control valve and the fuel temperature sensor on the fuel injection pump are serviceable. The engine uses speed sensors and the ECM to control the engine speed.

Refer to Systems Operation Testing and Adjusting, Fuel Injection for more information.

For the specifications of the C3.6 and C2.8 engines, refer to the Specifications, “Engine Design”.

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

C3.6 Engine Views

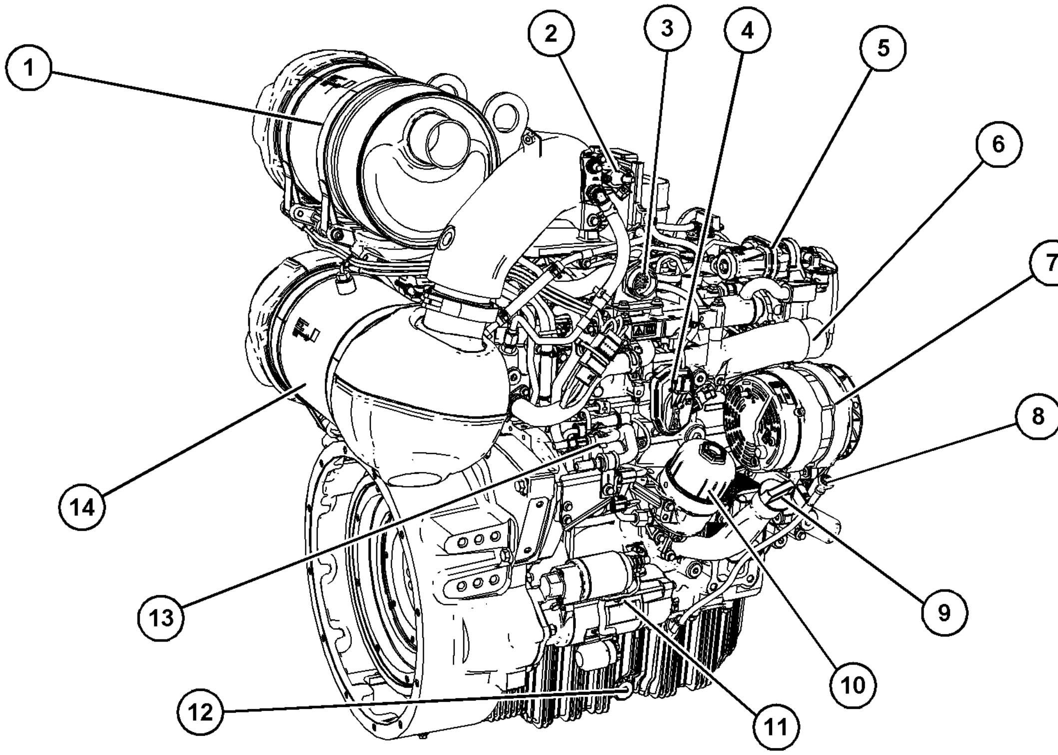

Illustration 1 g06297496

Typical example

(1) Selective Catalytic Reduction (SCR)
(2) Diesel Exhaust Fluid (DEF) injector
(3) Engine harness interface
(4) Intake throttle valve for the NOx Reduction System (NRS)
(5) Exhaust gas valve (NRS)
(6) Air intake from air charge cooler
(7) Alternator
(8) Oil gauge (Dipstick)
(9) Oil filler (lower)
(10) Oil filter assembly
(11) Electric starting motor
(12) Oil drain plug
(13) Fuel injection pump
(14) Diesel Particulate Filter (DPF)

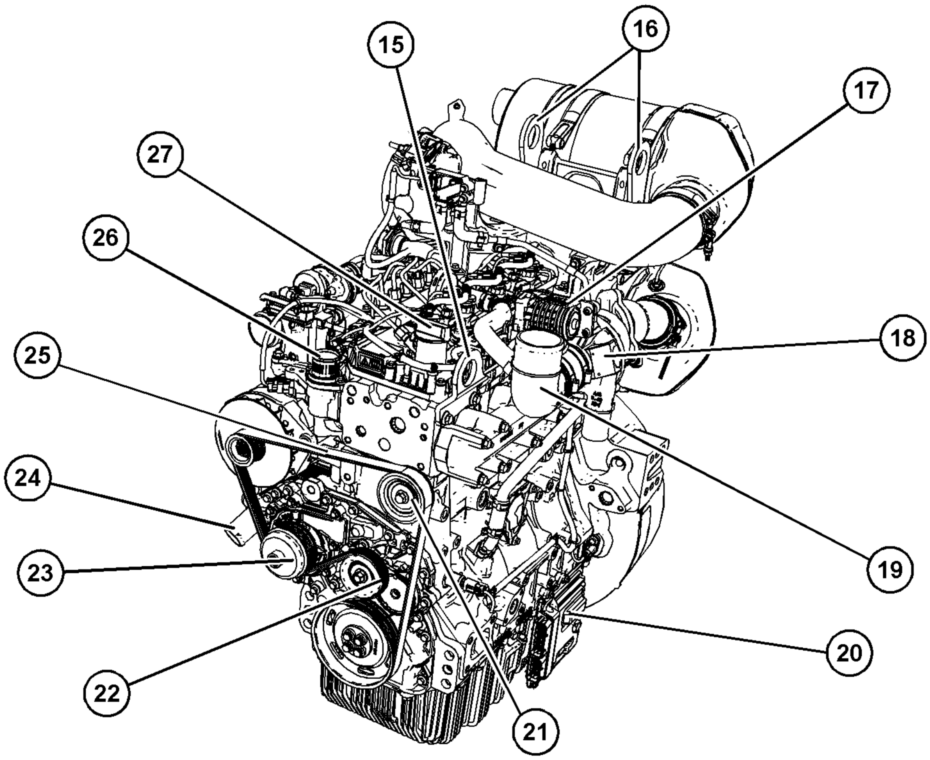

Illustration 2 g06297569

Typical example

(15) Front lifting eye
(16) Rear lifting eyes
(17) Actuator for turbocharger
(18) Turbocharger
(19) Air intake from air cleaner
(20) Electronic Control Module (ECM), location for transportation only
(21) Idler for drive belt
(22) Belt tensioner
(23) Water pump pulley
(24) Coolant intake
(25) Drive belt
(26) Coolant outlet
(27) Top oil filler

Loose or Off Engine Components

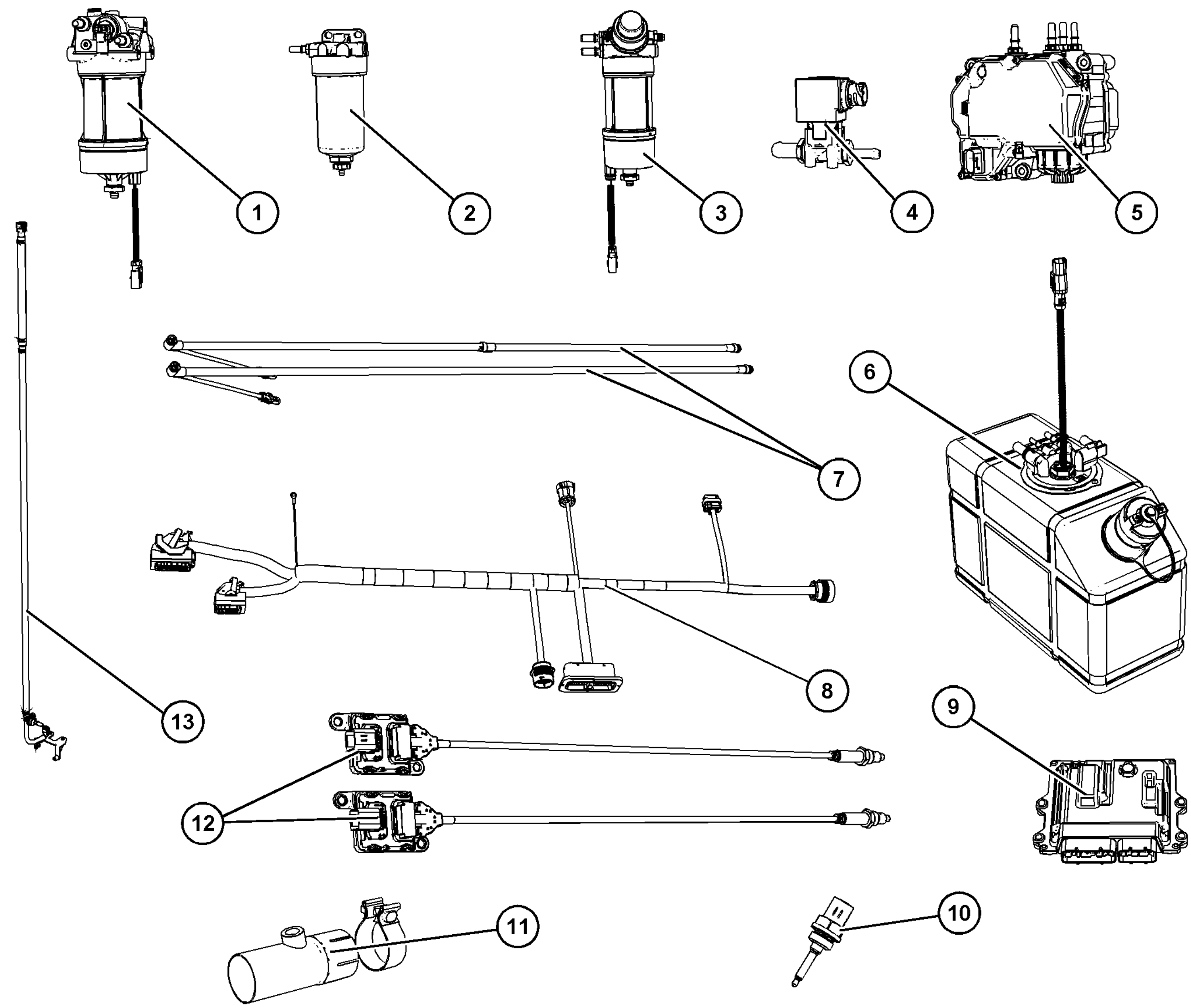

Illustration 3 g06297651

Typical example

(1) Primary fuel filter, combined with electric fuel priming pump and Water-In-Fuel (WIF) sensor
(2) If equipped, secondary fuel filter
(3) Primary fuel filter, combined with manual fuel priming pump and Water-In-Fuel (WIF) sensor
(4) Coolant diverter valve
(5) Diesel Exhaust Fluid (DEF) pump with DEF pump filter
(6) DEF tank with DEF header installed
(7) DEF heated lines
(8) Link harness
(9) Electric Control Module (ECM)
(10) Inlet air temperature sensor
(11) Exhaust assembly
(12) Nitrogen Oxide (NOx) sensors
(13) Low-pressure fuel line

C2.8 Engine Views

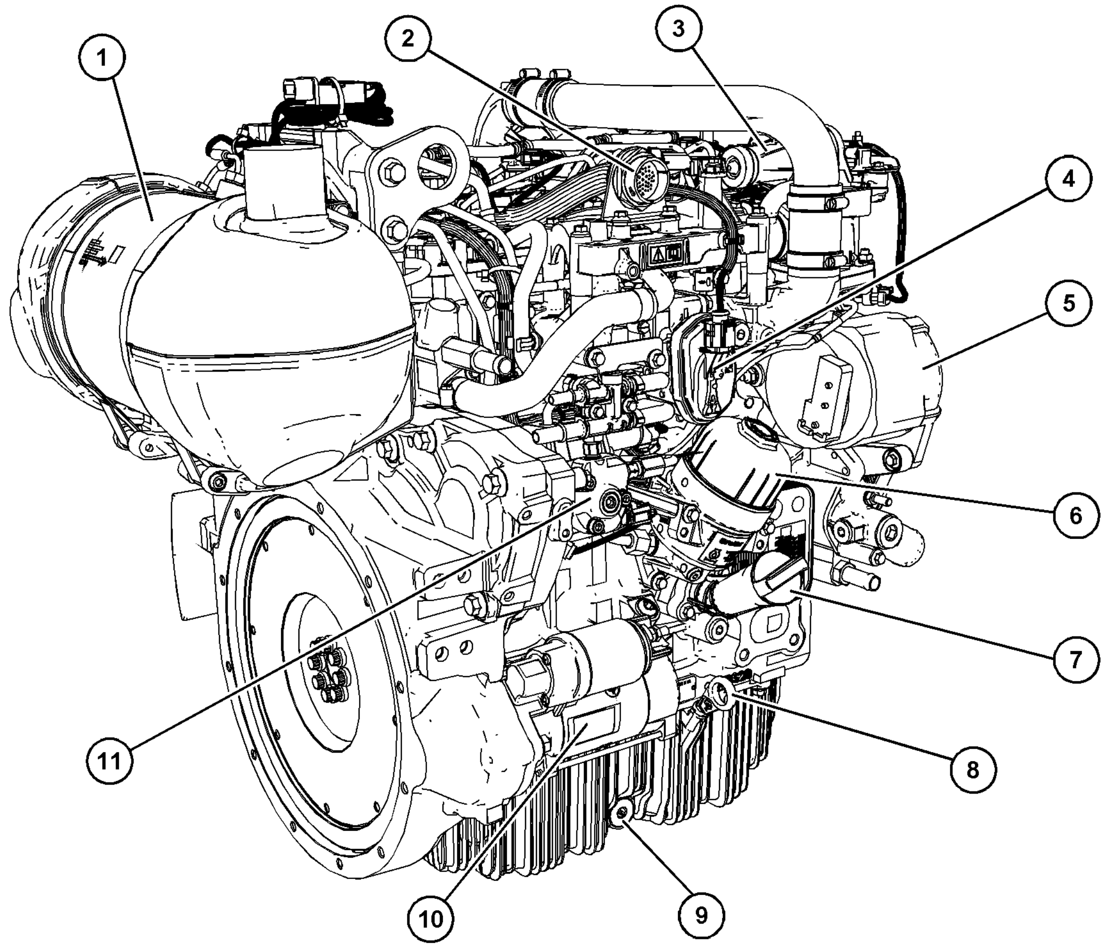

Illustration 4 g06481332

Typical example

(1) Diesel Particulate Filter (DPF) and Diesel Oxidation Catalyst (DOC)
(2) Engine harness interface
(3) Exhaust gas valve (NRS)
(4) Intake throttle valve for the NOx Reduction System (NRS)
(5) Alternator
(6) Oil filter assembly
(7) Oil filler (lower)
(8) Oil gauge (Dipstick)
(9) Oil drain plug
(10) Electric starting motor
(11) Fuel injection pump

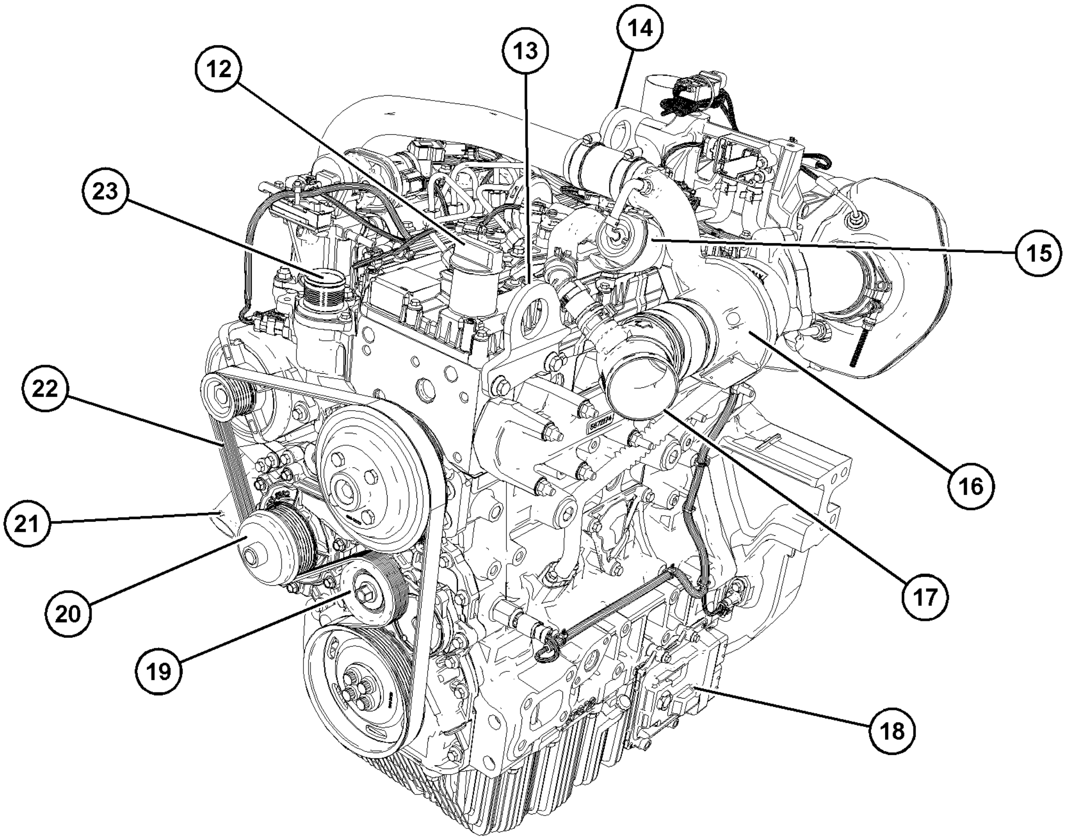

Illustration 5 g06481335

Typical example

(12) Oil filler (upper)
(13) Front lifting eye
(14) Rear lifting eyes
(15) Actuator for turbocharger
(16) Turbocharger
(17) Air intake from air cleaner
(18) Electronic Control Module (ECM), location for transportation only
(19) Belt tensioner
(20) Water pump pulley
(21) Coolant intake
(22) Drive belt
(23) Coolant outlet

Engine Operation

i06871191

Basic Engine

SMCS Code: 1200

Introduction

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

- Cylinder block
- Cylinder head
- Pistons
- Connecting rods
- Crankshaft
- Front housing
- Rear gear train
- Camshaft

Cylinder Block

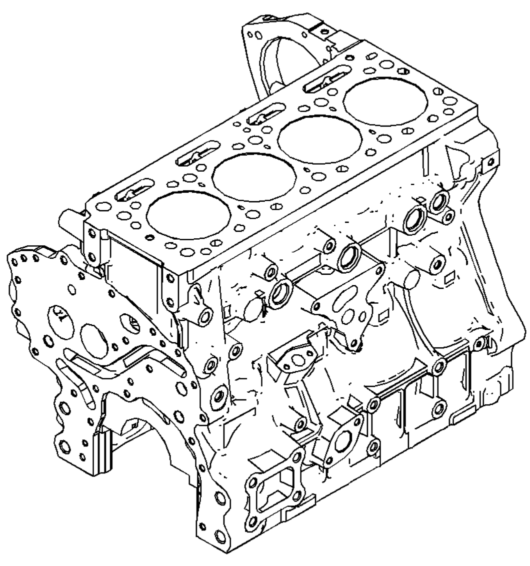

Illustration 6 g06148238

Typical example

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

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

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

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

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

The 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 to cool the piston.

A Multi-Layered Steel (MLS) cylinder head gasket is used between the engine block and the cylinder head to seal combustion gases, water, and oil.

Cylinder Head

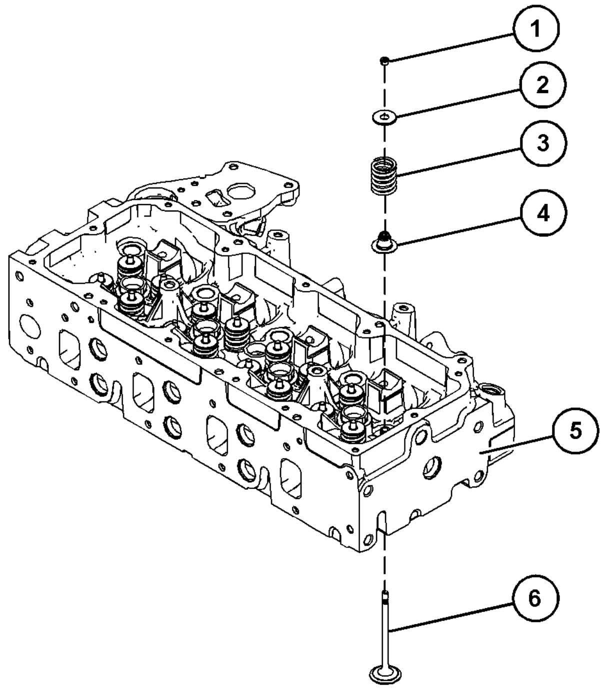

Illustration 7 g06162667

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 right side of the cylinder head. The ports for the exhaust valves are on the left side of the cylinder head. The valve stems move in valve guides that are pressed 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

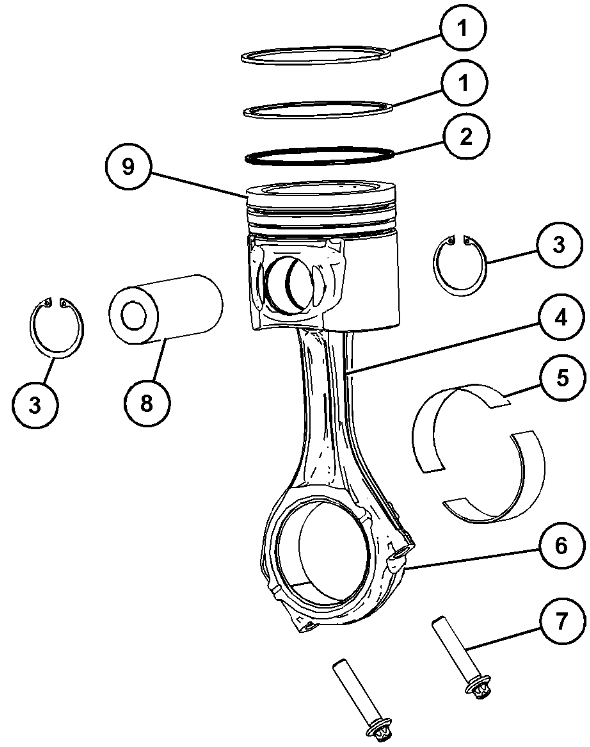

Illustration 8 g06162684

Typical example

The pistons (9) have a Quiescent combustion chamber in the top of the piston to provide an efficient mix of fuel and air. The piston pin (8) is off-center 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 to reduce wear of the groove. The piston skirt has a low friction coating to reduce the risk of seizure when the engine is new.

The correct piston height is important to ensure that the piston does not contact the cylinder head. The correct piston height also ensures the efficient combustion of fuel which is necessary to conform to requirements for emissions.

The 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 an unique serial number. When a connecting rod is assembled the serial numbers for the connecting rod and bearing cap must match.

Crankshaft

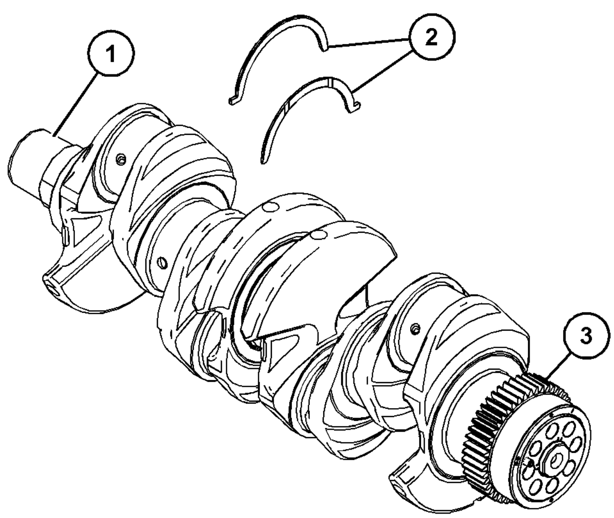

Illustration 9 g06148343

Typical example

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

The crankshaft is a spheroidal graphite iron casting.

The crankshaft has five main journals. Thrust washers are installed on both sides of number 3 main bearing to control the end play of the crankshaft.

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

A gear at the rear of the crankshaft drives the timing gears. The crankshaft gear turns the idler gear and the camshaft gear. The camshaft gear turns the fuel injection pump gear. The idler gear turns the accessory drive gear (if equipped).

A friction shim is installed onto the face of the crankshaft palm.

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

Gear Train

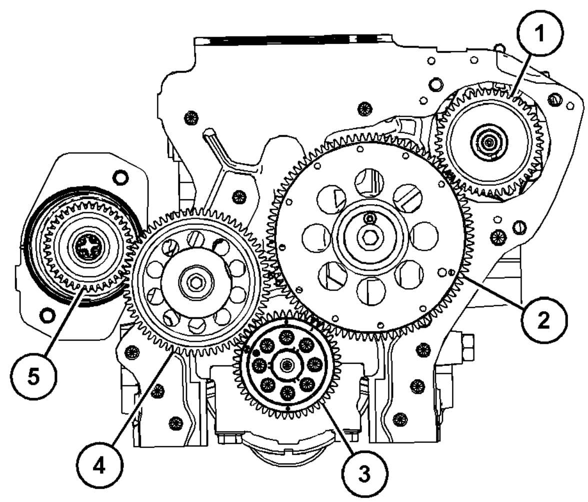

Illustration 10 g06148329

Typical example

The timing gears are made of steel.

The crankshaft gear (3) drives the camshaft gear (2) and the idler gear (4). The camshaft gear (2) drives the fuel injection pump gear (1). The idler gear (4) drives the accessory drive gear (5) (if equipped).

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 rear 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.

Front Housing

The crankshaft oil seal is mounted in the cover of the front housing. The front housing is made from aluminum.

The engine oil pump is located in the front housing. The engine oil pump is driven from the front of the crankshaft.

The water pump is on the front housing. The water pump pulley is driven by the front-end drive belt.

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Air Inlet and Exhaust System

SMCS Code: 1050

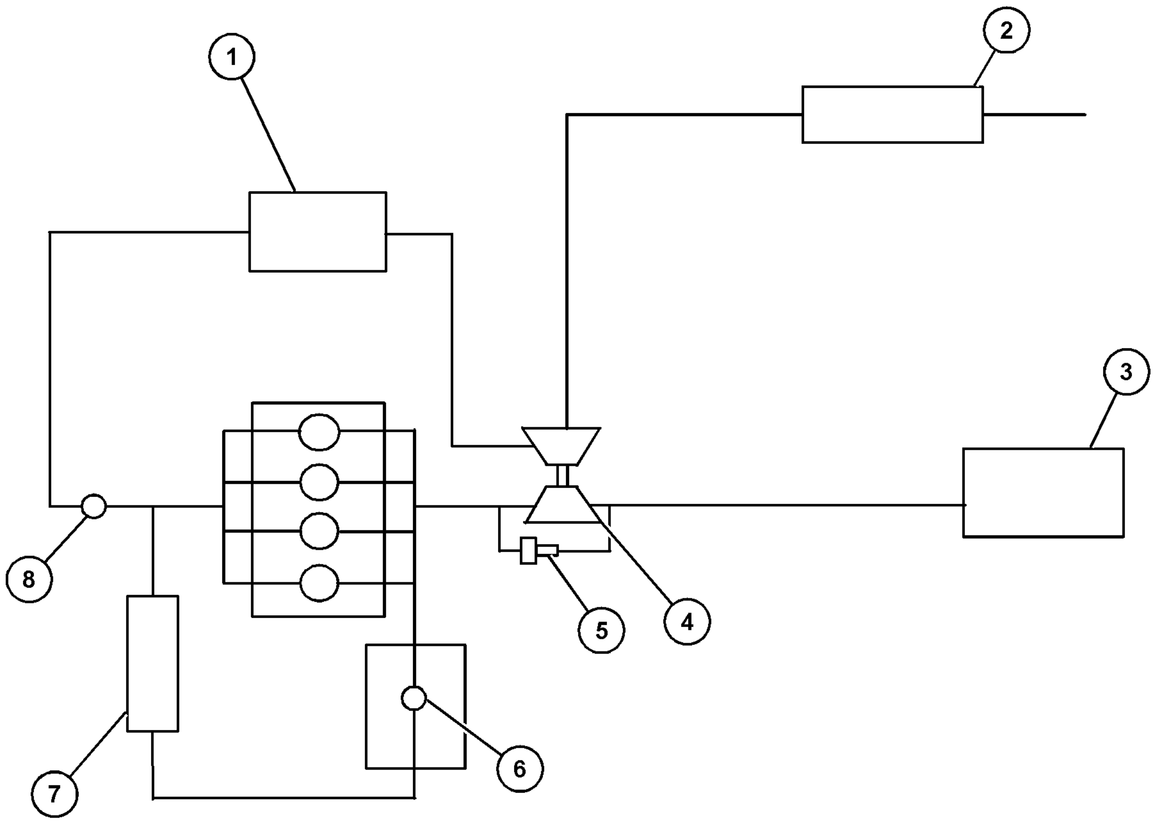

Illustration 11 g06163107

Typical example of the air inlet and exhaust system

(1) Aftercooler core
(2) Air filter
(3) Clean Emissions Module (CEM)
(4) Turbocharger
(5) Wastegate actuator
(6) Exhaust gas valve (NRS)
(7) Exhaust cooler (NRS)
(8) Inlet gas throttle valve

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

- Air cleaner
- Exhaust cooler (NRS)
- Exhaust gas valve (NRS)
- Inlet gas throttle valve
- Turbocharger
- Aftercooler
- Inlet manifold
- Cylinder head, injectors, and glow plugs
- Valves and valve system components
- Piston and cylinder
- Exhaust manifold
- Clean Emissions Module (CEM)

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

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

From the aftercooler, the air flows to the air inlet connection and then to the inlet gas throttle valve for the NOx Reduction System (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. This initiates the exhaust stroke. The exhaust valves open. The exhaust gases are forced through the open exhaust valves into the exhaust manifold.

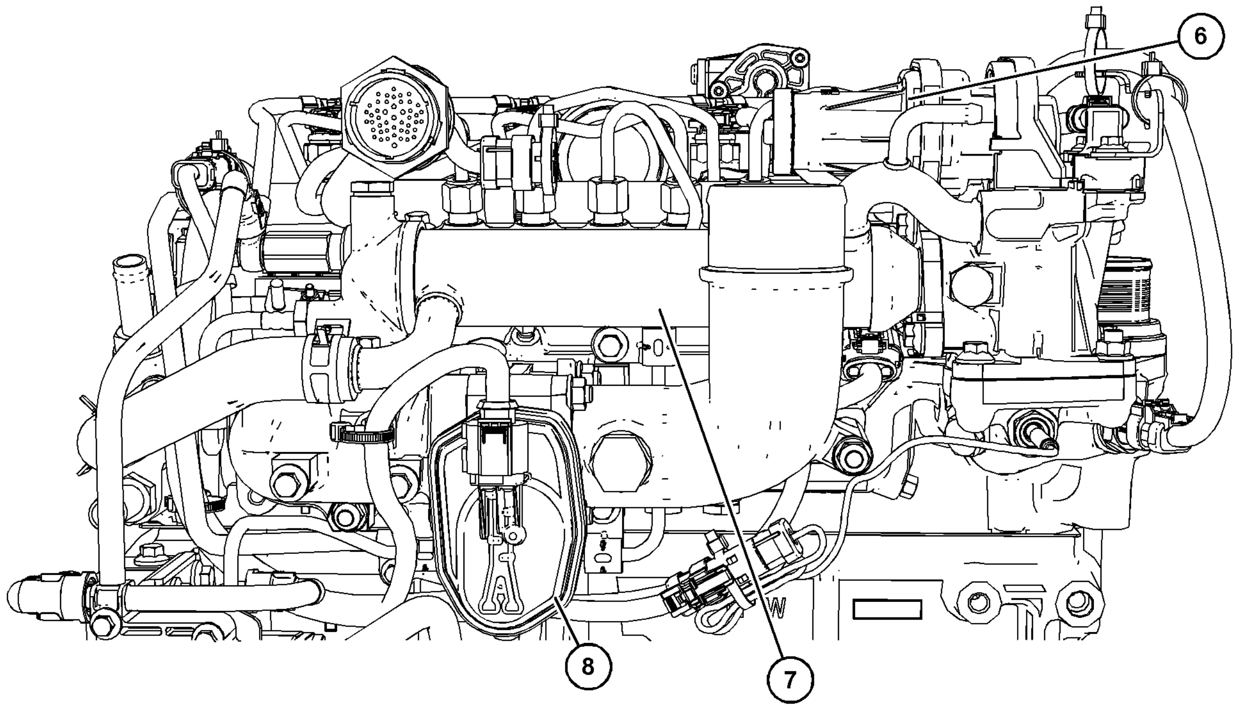

Illustration 12

g06163129

Typical example

The NOx Reduction System (NRS) operates with the transfer of the hot exhaust gas from the exhaust manifold to the exhaust gas valve (NRS) (6).

As the electronically controlled valve (6) starts to open the flow of cooled exhaust gas from the exhaust cooler (7) mixes with the air flow from the charge air aftercooler. 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 hot exhaust gas is cooled in the exhaust cooler (7). The cooled exhaust gas passes through the exhaust cooler (7) to the inlet manifold.

The electronically controlled exhaust gas valve (6) and the inlet gas throttle valve (8) 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 (6) and the inlet gas throttle valve (8) for the NOx Reduction System (NRS) to generate the required flow of exhaust gas.

The inlet gas throttle valve (8) for the NOx Reduction System (NRS) works by reducing the pressure in the inlet manifold to draw through extra exhaust gas.

Exhaust gases from the exhaust manifold enter the inlet of the turbocharger to turn the turbocharger turbine wheel. The turbine wheel is connected to a shaft that rotates. The exhaust gases pass from the turbocharger through the following components: exhaust outlet, Clean Emissions Module, and exhaust pipe.

Turbocharger

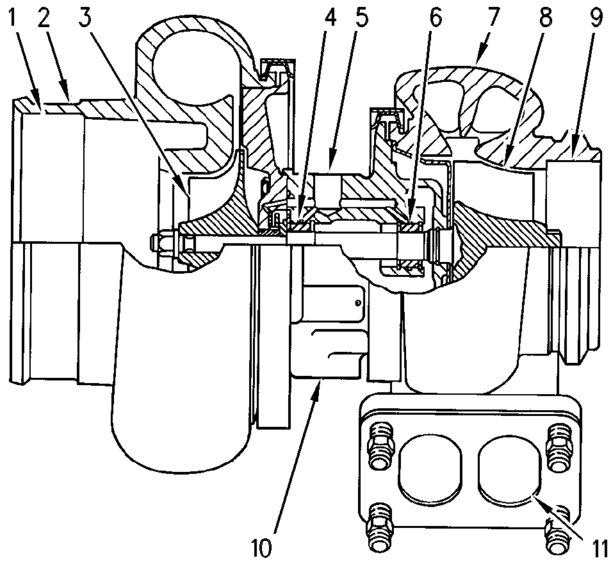

Illustration 13 g00302786

Typical example of a cross section of a turbocharger

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

The turbocharger is mounted on the outlet of the exhaust manifold. The exhaust gas from the exhaust manifold enters the exhaust inlet (11) and passes through the turbine housing (7) of the turbocharger. Energy from the exhaust gas causes the turbine wheel (8) to rotate. The turbine wheel is connected by a shaft to the compressor wheel (3).

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

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.

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.

Electronic Actuated Turbocharger Wastegate (EWG)

A wastegate is installed on the turbine housing of the turbocharger. The wastegate actuator is installed on the compressor housing of the turbocharger.

The wastegate is a valve that allows exhaust gas to bypass the turbine wheel of the turbocharger. The position of the valve varies the amount of exhaust gas that flows into the turbine.

The wastegate valve is connected to an actuating lever. The actuating lever is connected to an electronic actuated wastegate actuator.

Inside the wastegate actuator is an electric motor. The wastegate actuator is controlled by the engine Electronic Control Module (ECM). The ECM uses inputs from several engine sensors to determine the optimum boost pressure. This will achieve the best exhaust emissions and fuel consumption at any given engine operating condition.

When higher boost pressure is needed for the engine performance, a signal is sent from the ECM to the wastegate actuator. The actuating rod acts upon the actuating lever to close the valve in the wastegate. 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 actuator. The actuating rod 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.

Wastegate Actuator

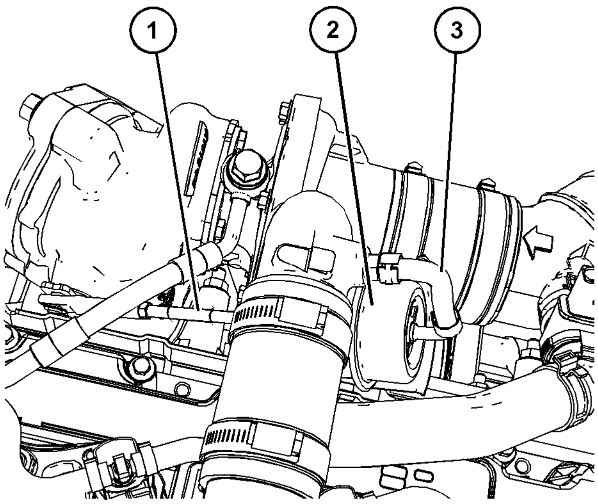

Illustration 14 g06457169

Typical example

(1) Actuating lever
(2) Wastegate actuator
(3) Line (boost pressure)

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 depends 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.

When higher boost pressure is needed for the engine performance, a reduction in pressure in the air inlet pipe acts on the diaphragm within the wastegate actuator. The spring within the wastegate actuator 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, high pressure in the air inlet pipe acts on the diaphragm within the wastegate actuator. The actuating rod 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.

Crankcase Breather

NOTICE

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

The engine crankcase breather is a closed circuit system.

A separator is built into the valve mechanism cover. The separator removes most of the liquid oil from the gas. The liquid oil is then returned to the engine.

The gas then passes back through the induction system via the breather outlet hose.

A valve is installed into a drilling in the cylinder block on the right-hand side of the engine. The liquid oil passes through the valve to the engine oil pan. The valve prevents gases from passing up the gallery.

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

Valve System Components

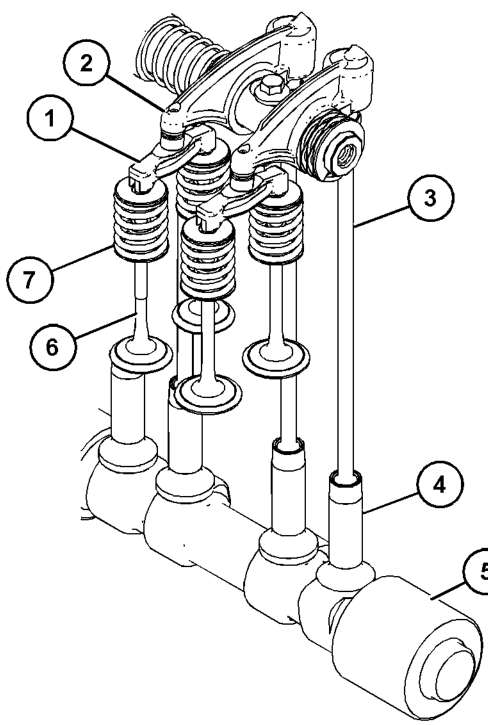

Illustration 15 g06162689

Valve system components

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

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 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.

Upward movement of the pushrod against rocker arm (2) results in a downward movement that acts on the valve bridge (1). This action opens a pair of valves (6) which compresses the valve springs (7). 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 (7) under compression start to expand. The valve stems are under tension of the springs. The stems are pushed upward 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.

The rocker arm (2) incorporates a hydraulic lash adjuster which removes valve lash from the valve mechanism. The hydraulic lash adjuster uses engine lubricating oil to compensate for wear of system components so that no service adjustment of valve lash is needed.

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

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

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

i06870359

Clean Emissions Module (Diesel Oxidation Catalyst (DOC), Diesel Particulate Filter (DPF) and Selective Catalytic Reduction (SCR) System)

SMCS Code: 1062; 108B; 108E; 108F; 108M

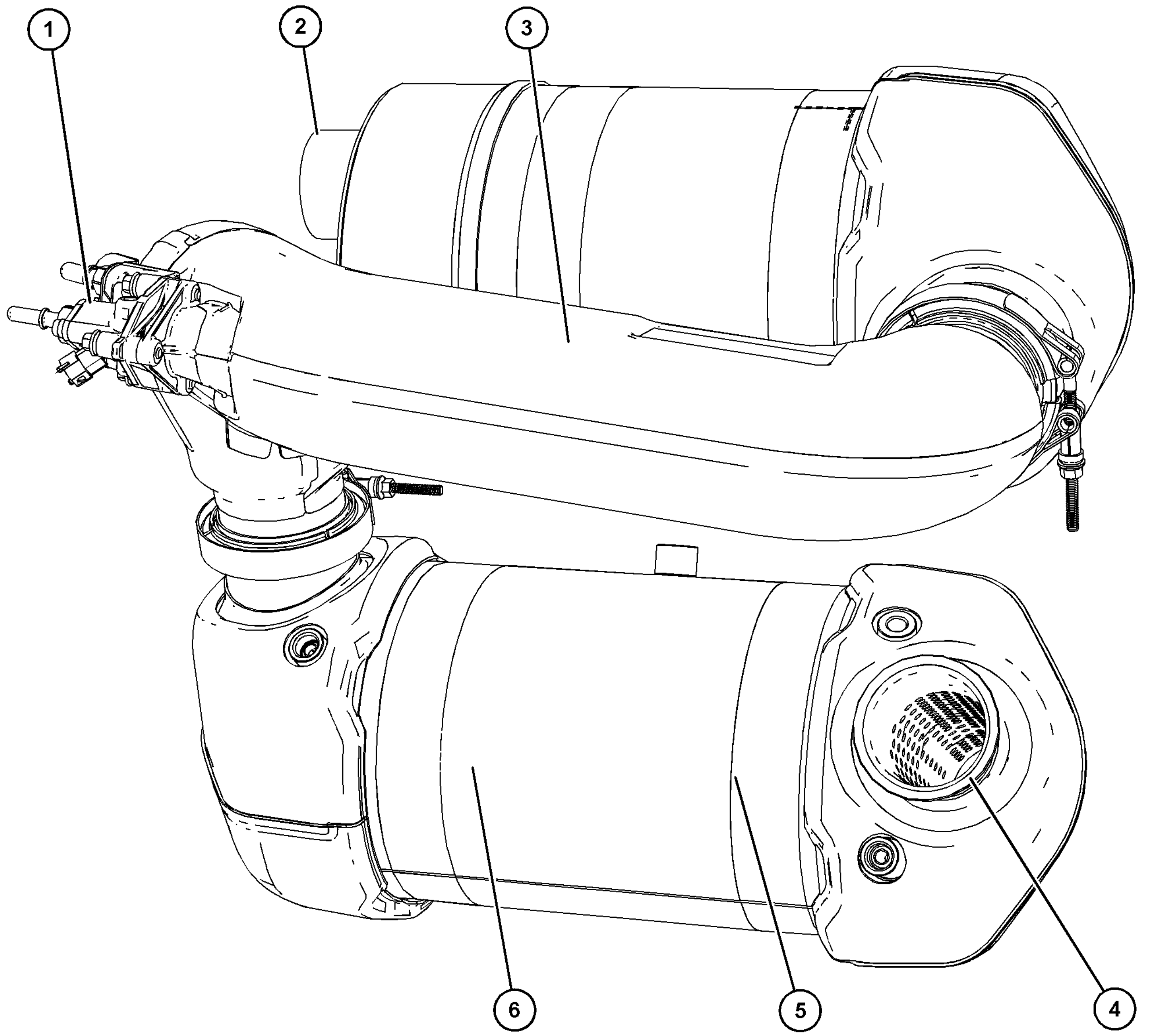

Illustration 16 g06367512

Typical example

(1) Diesel Exhaust Fluid (DEF) injector
(2) Exhaust outlet connection
(3) Selective Catalytic Reduction (SCR) system
(4) Exhaust intake connection
(5) Diesel Oxidation Catalyst (DOC)
(6) Diesel Particulate Filter (DPF)

To meet current emissions legislation requirements, some certain chemical compounds that are emitted by the engine must not be allowed to enter the atmosphere.

The Clean Emissions Module (CEM) for the engine consists of the following components.

- Diesel Oxidation Catalyst (DOC)
- Diesel Particulate Filter (DPF)
- Selective Catalytic Reduction (SCR) system

The DOC oxidizes the carbon monoxide and the hydrocarbons that are not burnt in the exhaust gas into carbon dioxide and water. The DOC also acts on the oxides of nitrogen to increase the nitrogen dioxide fraction for improved efficiency of the SCR system. The DOC is a through flow device that will continue to operate during all normal engine operating conditions.

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

An exhaust pipe connects the engine to the Clean Emissions Module (CEM). Refer to Disassembly and Assembly for the correct procedure to install the 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 under normal engine operating conditions. The filter is designed to contain all the ash that is produced for the useful emissions life of the engine.

The engine aftertreatment system is designed to oxidize the soot in the DPF at the same rate as the soot is produced by the engine. The oxidization of the soot will occur when the engine is operating under normal conditions. The soot in the DPF is constantly monitored. If the engine is operated in a way that produces more soot than the oxidized soot, the engine management system will automatically activate the inlet gas throttle valve to raise the exhaust temperature. The raising of the exhaust temperature will ensure that more soot is oxidized than the soot that is produced by the engine. The oxidization of more soot returns the DPF to a reduced level of soot. The inlet gas throttle valve is then deactivated when the soot level has been reduced.

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

- Delta pressure measurement across the DPF

The information gathered is then converted into a percentage of soot output that is viewed through the electronic service tool. The soot level may be displayed as a graphical bar, or as an actual percentage.

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

After the DPF, the exhaust gases are injected with a Diesel Exhaust Fluid (DEF) by a Diesel Exhaust Fluid (DEF) injector. The exhaust gases and the DEF are mixed in a mixing chamber. The mixture decomposes to form ammonia and carbon dioxide. The mixture passes to the main Selective Catalytic Reduction (SCR) reaction chamber.

Exhaust gases and an atomized mist of ammonia and carbon dioxide enter the SCR reaction chamber. Together with the SCR catalyst inside the chamber, the mixture undergoes a chemical reaction that produces nitrogen gas and water vapor.

There is an oxidation catalyst after the SCR catalyst. The oxidation catalyst reacts with the excess ammonia to produce oxides of nitrogen and water vapor.

Refer to Systems Operation, Testing and Adjusting, “DEF Dosing Control System” for more information on the DEF system.

i07577155

Clean Emissions Module (Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF))

SMCS Code: 1062; 108B; 108E; 108F; 108M

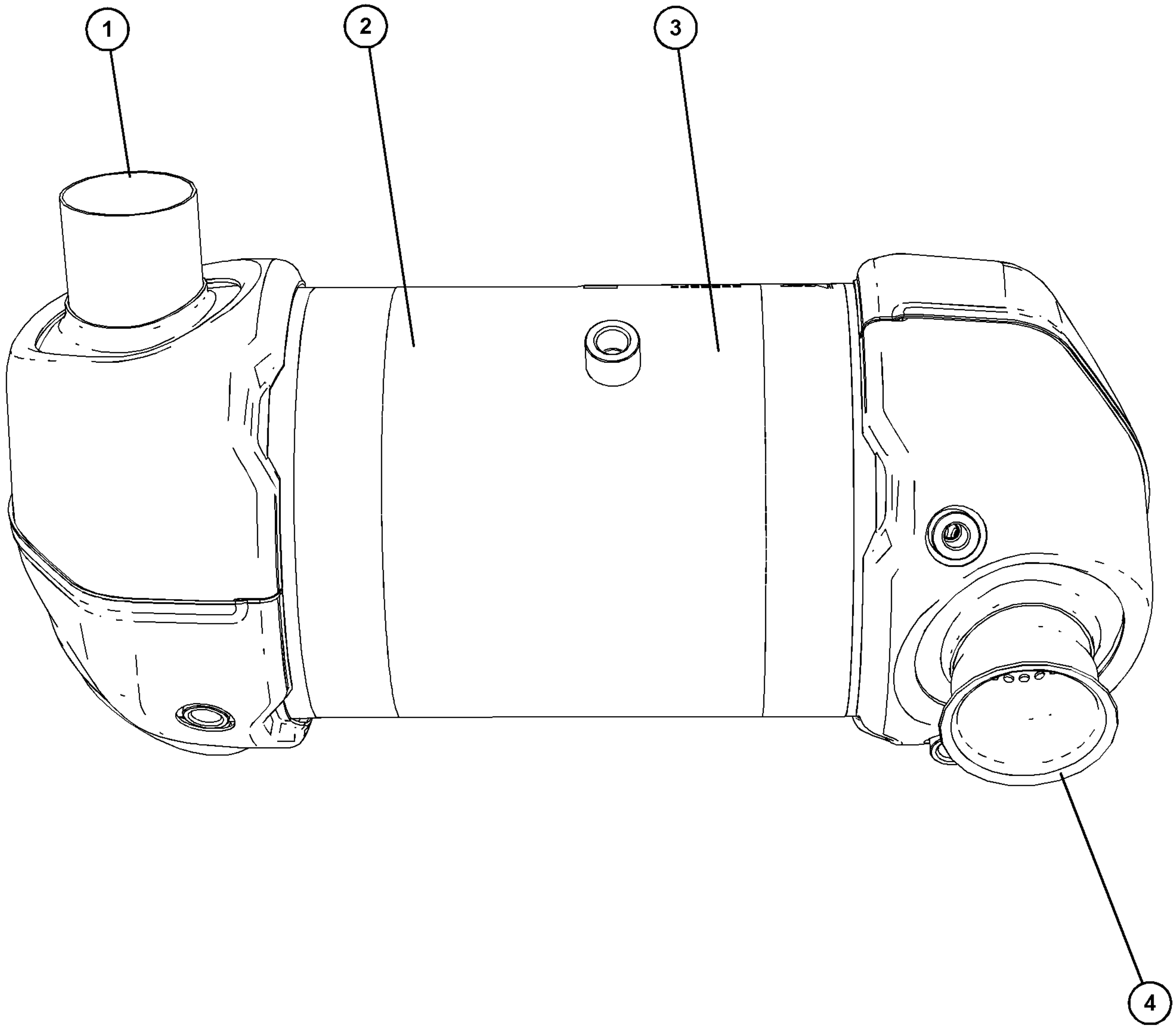

Illustration 17 g06367525

Typical example

(1) Exhaust outlet connection
(2) Diesel Particulate Filter (DPF)
(3) Diesel Oxidation Catalyst (DOC)
(4) Exhaust intake connection

To meet current emissions legislation requirements, some certain chemical compounds that are emitted by the engine must not be allowed to enter the atmosphere.

The Clean Emissions Module (CEM) for the engine consists of the following components.

- Diesel Oxidation Catalyst (DOC)

- Diesel Particulate Filter (DPF)

The DOC oxidizes the carbon monoxide and the hydrocarbons that are not burnt in the exhaust gas into carbon dioxide and water. The DOC also acts on the oxides of nitrogen to increase the nitrogen dioxide fraction. The DOC is a through flow device that will continue to operate during all normal engine operating conditions.

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

An exhaust pipe connects the engine to the Clean Emissions Module (CEM). Refer to Disassembly and Assembly for the correct procedure to install the 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 under normal engine operating conditions. The filter is designed to contain all the ash that is produced for the useful emissions life of the engine.

The engine aftertreatment system is designed to oxidize the soot in the DPF at the same rate as the soot is produced by the engine. The oxidization of the soot will occur when the engine is operating under normal conditions. The soot in the DPF is constantly monitored. If the engine is operated in a way that produces more soot than the oxidized soot, the engine management system will automatically activate the inlet gas throttle valve to raise the exhaust temperature. The raising of the exhaust temperature will ensure that more soot is oxidized than the soot that is produced by the engine. The oxidization of more soot returns the DPF to a reduced level of soot. The inlet gas throttle valve is then deactivated when the soot level has been reduced.

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

- Delta pressure measurement across the DPF

The information gathered is then converted into a percentage of soot output that is viewed through the electronic service tool. The soot level may be displayed as a graphical bar, or as an actual percentage.

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

i07925834

DEF Dosing Control System

SMCS Code: 108H; 108I; 108J; 108K; 108T

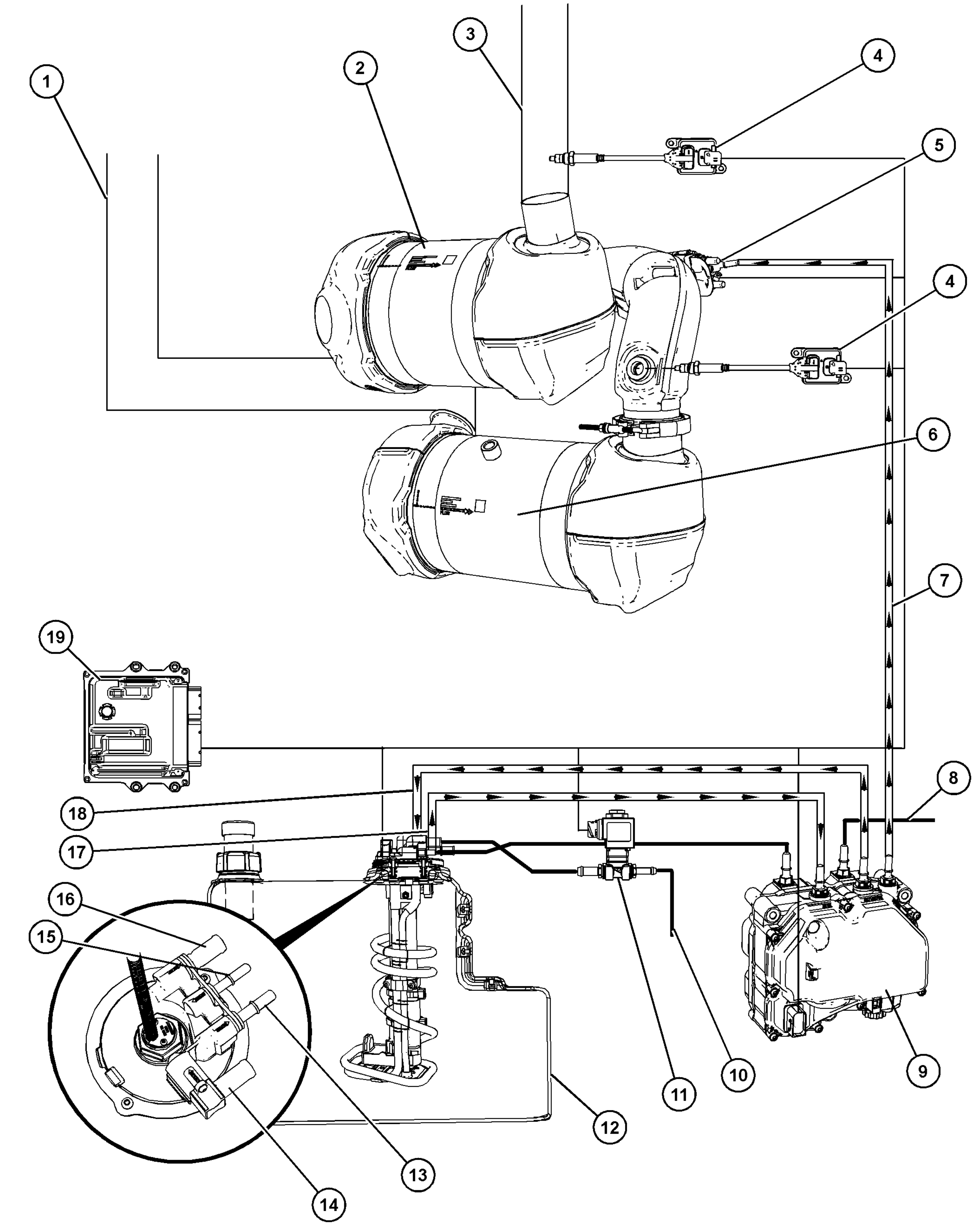

Illustration 18 g06360423

Typical example

(1) Exhaust inlet
(2) Selective Catalytic Reduction (SCR) system
(3) Exhaust out
(4) Nitrogen Oxide (NOx) sensor
(5) Diesel Exhaust Fluid (DEF) injector
(6) Diesel Particulate Filter (DPF)
(7) Diesel Exhaust Fluid (DEF) supply line
(8) Coolant return to engine line
(9) Diesel Exhaust Fluid (DEF) pump
(10) Coolant supply from engine line
(11) Coolant diverter valve
(12) Diesel Exhaust Fluid (DEF) tank
(13) Suction connector
(14) Coolant supply connector
(15) Backflow connector
(16) Coolant return connector
(17) DEF backflow line
(18) DEF suction line
(19) Electronic Control Module (ECM)

The Diesel Exhaust Fluid (DEF) Dosing Control System consists of the following components.

- DEF pump
- DEF injector
- DEF manifold
- Coolant diverter valve
- DEF System Heated Lines

Diesel Exhaust Fluid (DEF) Pump

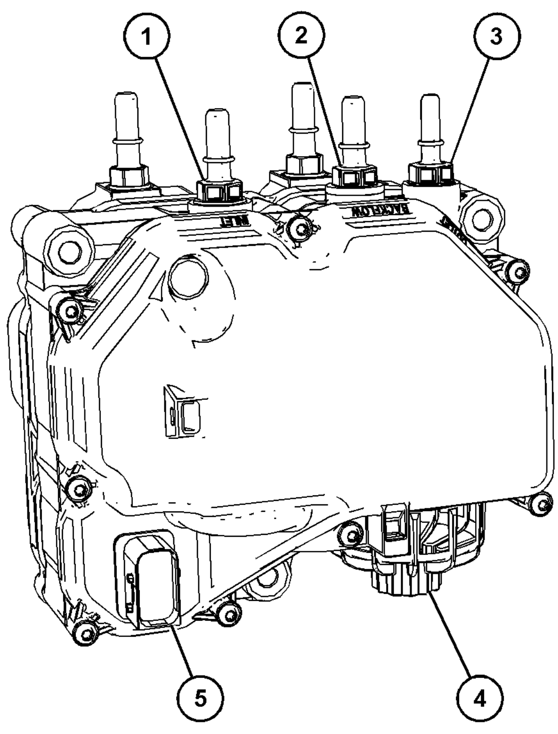

Illustration 19 g06147641

Typical example

(1) Inlet
(2) Backflow
(3) Outlet
(4) DEF filter
(5) Electrical connection

The pump supplies filtered DEF fluid to the DEF injector. The pump consists of inlet port (1) which is the suction side of the pump. The pump then pressurizes the fluid up to 900 kPa (131 psi) and supplies the fluid though outlet port (3). There is a fixed orifice within the pump that purges the pressure off the pressurized circuit. This pressure relief will stabilize the pressure in the line when the DEF injector is opening and closing.

Once the engine is shut down, the pump will start to go into a purge mode. The DEF Injector will open and the reverting valve within the pump will reverse the flow of the pump and purge the pump and pressure line. This reversed flow will route any remaining DEF fluid back to the tank.

Refer to Operation and Maintenance Manual for the correct procedure to replace the DEF filter.

Electric Components of the DEF System

The electric components of the DEF system consist of the following components:

Coolant Diverter Valve

Controls coolant flow to the DEF tank and pump.

Heated Lines

The heated lines are electrically heated lines that will turn on any time the ambient temperature is cold. These lines will thaw frozen DEF after starting in cold ambient temperatures. The heated lines will also stay heated during operation to prevent any freezing during operation.

DEF Level Sensor

The level sensor will measure the amount of DEF in the tank. The system uses an ultrasonic level sensor to determine the amount of DEF in the DEF tank. To measure the level of DEF, the sensor measures the distance to the surface of the fluid. The sensor provides a signal to the ECM that will be converted into a “DEF Level Percentage” .

DEF Tank Temperature Sensor

This sensor is at the bottom of the tank and is integrated within the DEF Level Sensor.

DEF Quality Sensor

At the bottom of the tank header next to the DEF tank header filter is the DEF quality sensor. The ultrasonic DEF quality sensor uses the speed of sound within a fluid to identify the concentration of the fluid. This is achieved by measuring the time taken for the emitted ultrasonic signal to be reflected off a known fixed reference point. Based on these chemical properties and fluid temperature, the sensor is able to detect urea concentration with an accuracy of up to 2 percent. If the sensor detects the quality of DEF is not within specifications, a fault code will trip indicating the DEF concentration is not correct. The engine may derate.

DEF Tank

The DEF tank stores the DEF. The size of the DEF tank will depend on the application.

The DEF solution is made of 32.5 percent urea solution and 67.5 percent deionized water. Urea is a compound of nitrogen that turns to ammonia when heated.

Ensure that the correct specification of DEF is used. Refer to Operation and Maintenance Manual for more information.

DEF does degrade over time at elevated temperatures. Due to freezing risk, the tank, pump, and lines must be heated and designed to contain frozen DEF.

DEF Tank Header

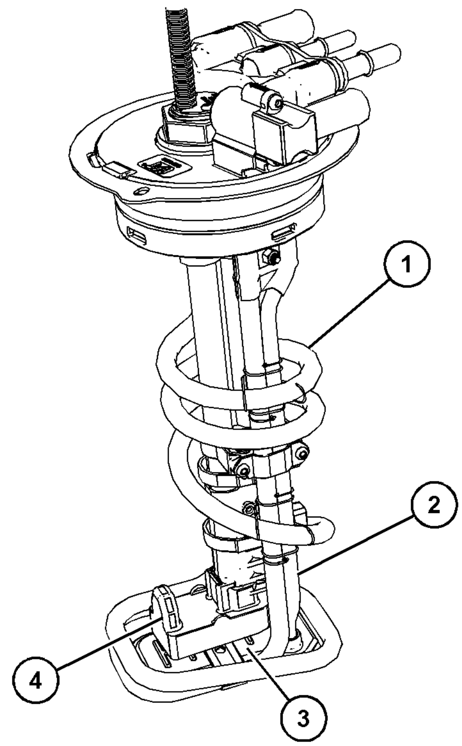

Illustration 20 g06357840

Typical example

(1) Coolant tubes
(2) DEF pickup tube
(3) DEF tank header filter
(4) DEF tank temperature sensor, level sensor, and quality sensor

The DEF tank header is located in the DEF tank. The tank header consists of several parts and performs the following functions:

Coolant Tubes

The coolant supplied by the engine will flow through the tubes when the coolant diverter valve opens. Coolant runs along the pickup tube to the bottom of the tank and then spirals around the level sensor. The heat from the coolant will thaw any frozen DEF in the tank or header. The heat will also prevent the DEF from freezing around the pickup tube.

DEF Pickup Tube

The DEF is pulled from the bottom of the tank through a screen.

DEF Tank Header Filter

At the end of the DEF Pickup tube is a 40 micron filter to filter debris from entering the system.

DEF Return

The DEF is returned back to the tank from the DEF injector.

DEF Tank Temperature Sensor

At the bottom of the tank header near the DEF tank header filter is a tank temperature sensor. The temperature sensor is a passive thermistor. The resistance of the thermistor varies with temperature. This sensor monitors the temperature of the DEF in the tank. This temperature is used to determine when to turn on the coolant diverter valve.

Coolant Diverter Valve

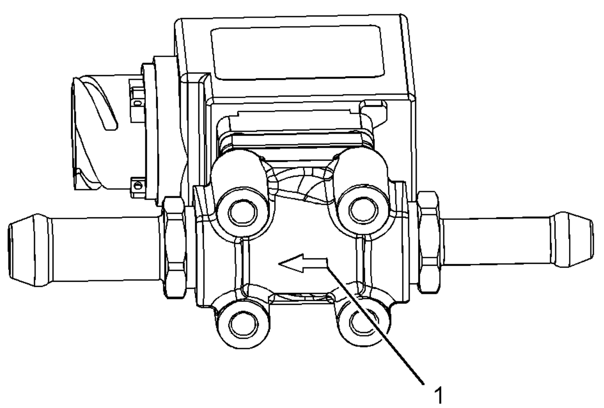

Illustration 21 g03403819

Typical example

(1) Flow direction indicator

The coolant diverter valve is mounted to the application. The coolant diverter valve is a normally closed valve. The valve is a unidirectional flow valve. The system is used to thaw the frozen DEF fluid in the DEF tank and pump before dosing occurs. Warming the system is achieved by taking warm coolant from the engine and routing the coolant through the DEF tank and pump. The coolant diverter valve will open when the tank temperature needs to be increased. With the coolant diverter valve fully opened, engine coolant will flow to the DEF tank header and pump and then back to the engine. Once the DEF tank temp is warm enough, the system will start dosing. The coolant diverter valve will close to prevent any further heat transfer to the DEF tank. This avoids DEF in the DEF tank overheating. The usable temperature of the DEF is between −10° to 55°C (14° to 99°F).

After the keyswitch is moved to the OFF position, the ECM will cycle the coolant diverter valve open and then closed. The coolant diverter valve is cycled open and then closed to exercise the coolant diverter valve so that the coolant diverter valve does not seize up over time.

DEF Injector

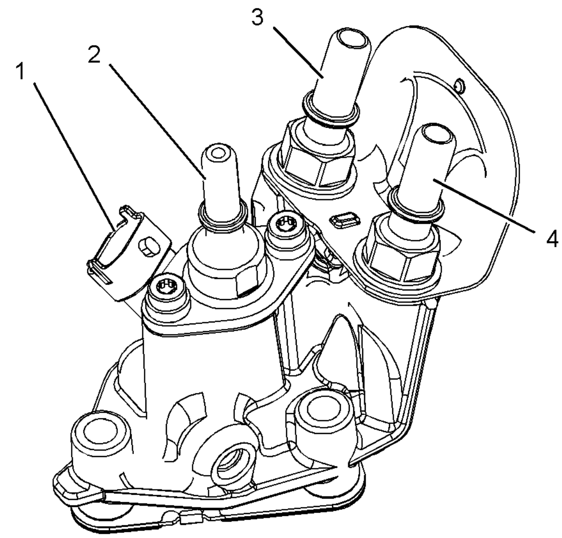

Illustration 22 g03403923

Typical example

(1) Electrical Connector
(2) DEF Supply line
(3) Coolant return port
(4) Coolant supply port

The DEF injector is mounted to the Clean Emissions Module (CEM). The DEF injector is a valve that injects DEF as a fine spray into the exhaust gases as an atomized mist. The spray pattern being conical for good mixing with the exhaust is critical.

The tip of the injector, that is located in the exhaust flow, is cooled by coolant that flows through an internal coolant passage from the engine coolant supply.

Nitrogen Oxide (NOx) Sensors

There are two NOx sensors supplied with the engine. One NOx sensor is installed before the Selective Catalytic Reduction (SCR) system. The other NOx sensor is installed in the tube assembly after the SCR canister.

The engine produces NOx as the engine operates. The engine out NOx sensor measures the amount and communicates that value to the Electronic Control Module (ECM). The tailpipe out NOx sensor monitors the NOx level out of the catalyst and communicates that value to the ECM. Based on the engine out and the tail pipe out NOx sensor values, the flow rate of the Diesel Exhaust Fluid (DEF) will adjust to meet the desired tail pipe out target.

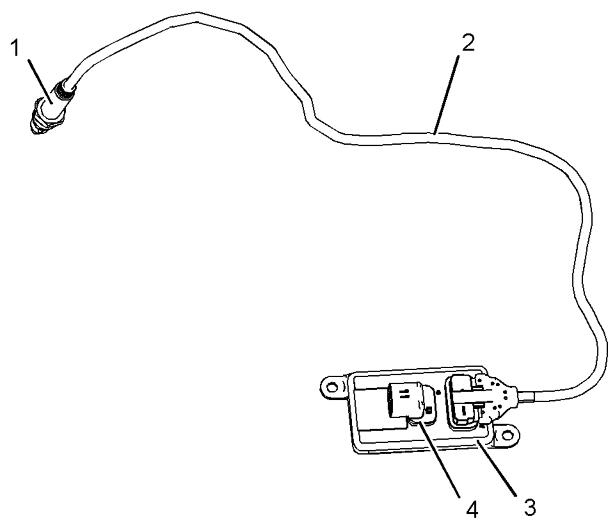

Illustration 23 g03403971

Typical example

(1) Sensing unit
(2) Cable (black for engine out, gray for CEM out)
(3) Sensor electronic control unit
(4) Electrical connector

The NOx sensor contains a sensing element, a harness, and an electronic control unit. The sensing element is composed of two chambers and a heater. The first chamber measures the amount of oxygen and the second chamber measure the amount of NOx and NH_3. Using electrochemistry, a ceramic material attracts ions at approximately 800° C (1472° F) and an electrode on the chamber wall measures the electrical charge in voltage or current. The voltage or current signal is then received by the NOx sensors electronic control unit and interpreted into a NOx concentration. The heater is used to maintain the sensing element temperature, as sensing element is sensitive to moisture. If the sensor sees any moisture while at 800° C (1472° F), then the moisture could quickly cool the element which would cause the element to crack. At engine start-up there is always some moisture within the exhaust pipes. So the sensors will not start working until the exhaust temperature around the sensors is greater than 125° C (257° F) for approximately two and a half minutes.

DEF System Heated Lines

The DEF flows in the heated lines from the DEF tank to the DEF pump. The DEF then travels through another heated line from the DEF pump to the DEF injector. The heated lines are heated by an electrical resistance.

Even though the system has been purged of DEF there are small quantities of DEF that can be left behind. The DEF supply line, suction, and the back flow line are heated to thaw any remaining DEF in the lines. The heated lines will prevent restrictions in the pump and injector once the system begins to dose.

The heated lines have the following characteristics.

- Thermoplastic core tube with fabric reinforcement
- Stainless steel heating wire
- Extruded thermoplastic jacket
- Heat/abrasion shield
- Quick disconnect connector

Cold-Weather Operation

Since DEF freezes at −11.5° C (11.3° F), the system can thaw the DEF before dosing.

Engine coolant is supplied to the DEF tank. The coolant diverter valve will turn on anytime the DEF Tank temperature is less than 15° C (59° F) at start-up. During operation, if the DEF tank temperature drops below 20° C (68° F) or ambient temperature falls below 0° C (32° F) then the coolant diverter valve will activate to keep the DEF from freezing. The tubes running through the tank will thaw the DEF to a useable temperature. Then DEF dosing will occur once the DEF has been thawed and the DEF tank temperature is greater than −8° C (18° F). The DEF dosing will not wait for the entire tank to thawed. The DEF pump is heated by engine coolant. The coolant will then return to the engine water pump inlet. The DEF supply lines, suction lines, and backflow lines are heated electrically.

The DEF dosing system must be fully functional within 70 minutes following initial start-up.

Note: If the DEF has not been removed from the lines and pump during cold-weather operation, the DEF will expand as the fluid freezes and damage the pump. For this reason the purge process must be followed in cold weather. The purge process will take 2 minutes of run time. Do NOT turn off battery power until this pump has completed the purge cycle.

Operator Level Inducement

Inducement is defined as something that helps bring about an action or a desired result. The purpose of inducements is to prompt the operator to repair or perform maintenance on the emissions control system.

Inducement strategies are control actions required by Environmental Protection Agency (EPA) and California Air Resource Board (ARB) Tier 4 Final and European Union (EU) Stage V regulations. Inducement strategies ensure prompt correction of various issues in the engine NOx emissions control system. They require actions to limit engine performance and define required indications such as visual alarms including lamps and messages, as well as audible alarms, while the control actions are imposed. The times for lights, derates, and alarms will vary between EPA and EU.

The Inducements are separated into categories. DEF Level has unique inducement fault codes and is separate from the other inducement categories. While DEF level inducements are simply based on the DEF level, the other inducement categories are based on escalating time. The escalating time inducements will always have an associated fault code along with the inducement fault code. The associated fault is the root cause. The escalating time inducement fault code is just an indicator of what level of inducement the engine is in and how much time remains until the next level of inducement.

The times for each level of inducement also vary depending on if the inducement is in first occurrence or repeat occurrence. Occurrences are defined as:

First occurrence

When an escalating time inducement fault becomes active for the first time.

Repeat occurrence

When any escalating time inducement fault becomes active again within 40 hours of the first occurrence. Engine must run for 40 hours without tripping any escalating time inducement fault before it can get back on first occurrence times.

Note: Refer to Troubleshooting, “SCR Warning System Problem” for the associated codes for each of the escalating time categories.

The inducements are initiated by the engine ECM. The “Emissions Malfunction Indicator Lamp” will illuminate if any inducement fault code, including DEF level, becomes active. The system reaction is varied based on the category of the fault code and what inducement parameters are selected.

Inducements include derates and forced idle down or shutdown. When the engine derates, the rpm and torque are reduced. Using the electronic service tool, the customer can choose either idle or shutdown for a Level 3 inducement. The engine default is shutdown.

Note: Visual and audible warnings on industrial applications may vary from what is shown under the Lamp Strategy table. Industrial applications will not have audible alarms.

Programmable parameters to select different Inducements options

- Engine Emissions Operator Inducement Regulation Configuration
- Engine Emissions Operator Inducement Progress Configuration
- Engine Emissions Operator Final Inducement Action

Engine Emissions Operator Inducement Progress Configuration

“**Reduced Performance**” configuration allows operation of the engine for a longer time period, but the engine will progressively derate the longer the engine is operated.

“**Reduced Time**” configuration allows operation of the engine with full power, but for a reduced amount of time.

Engine Emissions Operator Inducement Regulation Configuration

This programmable parameter will define the emissions regulation that the engine will follow in the event an inducement becomes active. The location of the engine must be considered before selecting this parameter. The “Worldwide” configuration may be used in any region of the world and will be emissions-compliant. The “European Union” may only be selected if the engine will operate in Europe. Once the “European Union” configuration is selected, the unit cannot go back to “Worldwide” . If used outside of this region the engine will not be emissions-compliant. Only a select number of industrial engines will be allowed to select “European Union” configuration. Changing configuration can only be done by an authorized distributor with factory passwords.

Engine Emissions Operator Third Level Inducement Action

This configuration determines what will happen when the third level of inducement occurs. In “Idle Down” configuration, once the engine enters the third level of inducement, the engine will experience a 100 percent derate, and the engine speed will be limited to 1000 rpm.

In “Shutdown” configuration, once the engine enters the third level of inducement, the engine will shut down. The operator may restart the engine. The engine will run for 5 minutes at 100 percent derate and then shut down. This event will occur until the issue is resolved.

Note: If low idle is set higher than 1000 rpm, then only "Shutdown" configuration can be selected.

Safe Harbor Mode (Worldwide)

Safe Harbor Mode (Worldwide) is a 20 minute engine run time period that the engine can be operated with full power after reaching a level 3 inducement. Once in level 3 inducement, the operator can perform a key cycle and the engine will enter **Safe Harbor Mode**. The safe harbor mode can be used to move the machine to a location where the machine can be serviced. If 20 minutes of engine running time has passed and the fault has not been corrected, the engine will reach final inducement with derates until the fault has been fixed. **Safe Harbor Mode** can only be implemented once. **Safe Harbor Mode** is not allowed for DEF level inducements with Worldwide configuration.

Safe Harbor Mode (European Union)

Safe Harbor Mode (European Union) is a 30 minute engine run time period that the engine can be operated with full power after reaching a level 3 inducement. Once in level 3 inducement, the operator can perform a key cycle and the engine will enter **Safe Harbor Mode**. The safe harbor mode can be used to move the machine to a location where the machine can be serviced. If 30 minutes of engine running time has passed and the fault has not been corrected, the engine will reach final inducement with derates until the fault has been fixed. **Safe Harbor Mode** can only be implemented up to three times.

Engine Emissions Operator Inducement Service Mode Override

Engine Emissions Operator Inducement Service Mode Override allows a technician to service inducement-related faults on a machine while having full engine operation and no derate effects. This mode is initiated through a connection with the electronic service tool. This mode requires a factory password to activate. Engine Emissions Operator Inducement Service Mode Override can be entered as many times as necessary and does not have a time limit. However, if electronic service tool loses connection, the Override will automatically turn off. The electronic service tool "Engine Emissions Operator Inducement Service Mode" is located in the "Diagnostic Tests" , "System Troubleshooting Section" of the engine ECM.

Service Tests Which Override Inducements

There are several service tests which will be allowed to run while inducements are active. Service tests provide the ability to diagnose and fix the issue that led to inducement without the use of factory passwords. While these tests can always be run on machines, not all industrial applications will be able to run service tests while inducements are active. In those cases, the Engine Emissions Operator Inducement Service Mode Override with factory passwords will need to be used.

Service Test that Override Inducements:

- Aftertreatment System Functional Test
- Aftertreatment NOx Sensor Functional Test
- EGR System Test
- DEF Coolant Diverter Valve Test

Inducement Strategy for DEF Level (Worldwide)

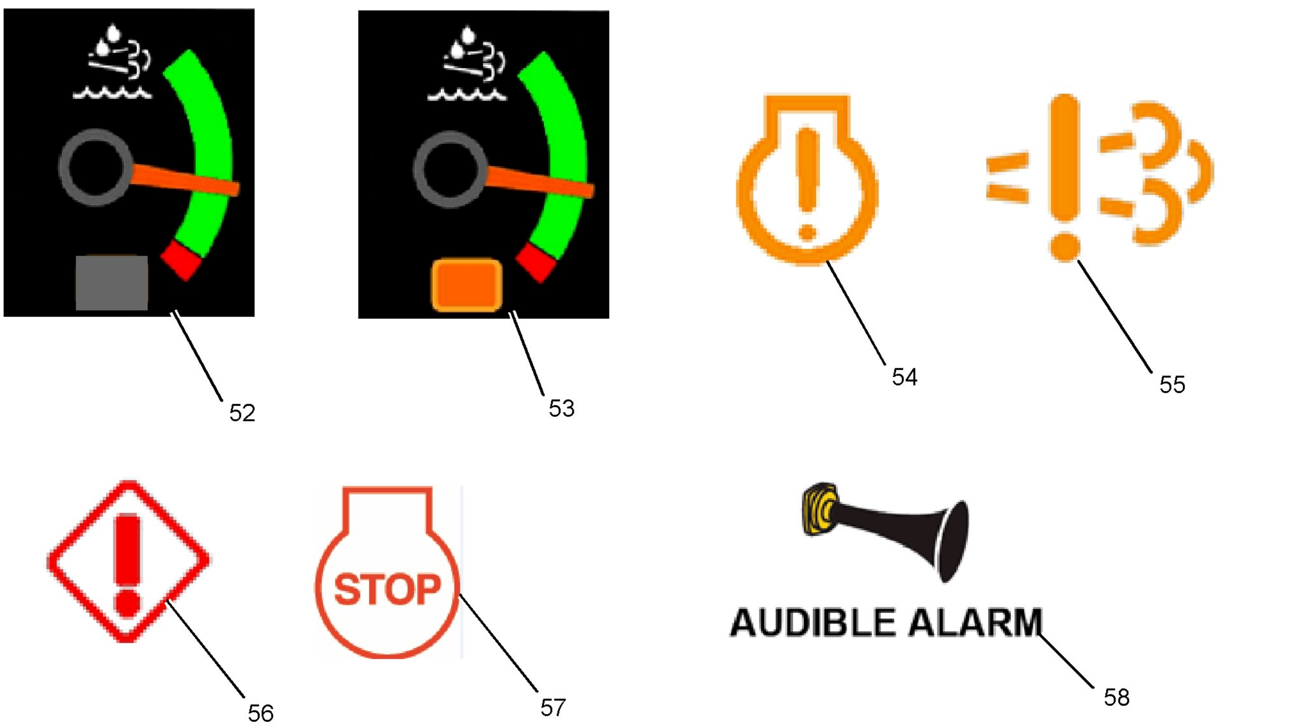

Illustration 24 g06152707

Typical example

(52) DEF Level Gauge: This gauge shows the amount of DEF in the DEF tank.

(53) DEF Level Gauge Amber lamp: This amber lamp indicates that the DEF level is low.

(54) Check Engine Lamp (CEL): This lamp activates for all engine and aftertreatment faults that affect the engine.

(55) Emissions Malfunction Indicator Lamp (EMIL): This lamp activates for all emissions faults that trigger inducement strategy.

(56) Action Lamp: For machine engines, this lamp indicates that a Level 2 or Level 3 fault is active.

(57) Red Stop Lamp: For industrial engines, this lamp indicates that a Level 3 fault is active. Symbols may vary.

(58) Audible Alarm: For machines, the alarm sounds when a Level 3 fault is active.

Low DEF Level Warning

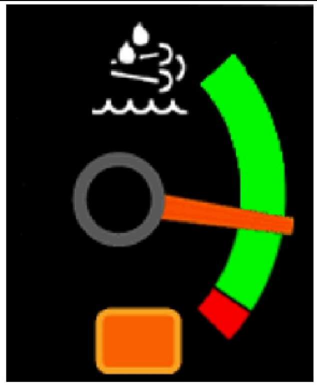

Illustration 25 g03523436

Typical example

If the DEF level falls below 20 percent, the DEF level gauge amber lamp will illuminate. To avoid inducements, turn the key to the OFF position and add DEF to the DEF tank.

Level 1 Inducement

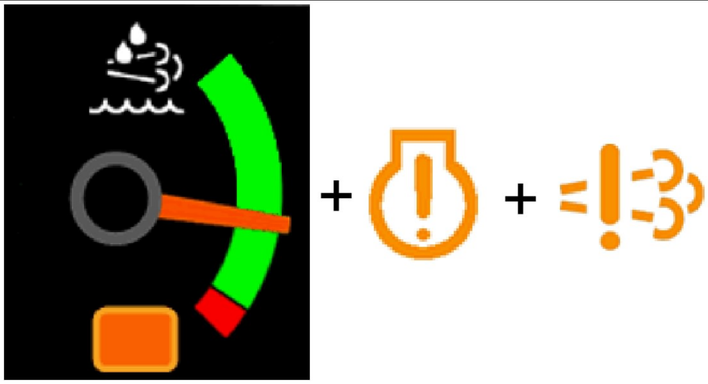

Illustration 26 g03523619

Typical example

If the DEF level falls below 13.5 percent, the engine will be in level 1 inducement. A 1761-17 or E954 (1) Aftertreatment #1 Diesel Exhaust Fluid Tank Level : Low - least severe (1) diagnostic code will become active. The Check Engine Lamp (CEL) and Emissions Malfunction Indicator Lamp (EMIL) will illuminate solid. The DEF level gauge amber lamp will continue to illuminate.

Level 2 Inducement

Illustration 27 g03523621

Typical example

If the DEF level is below 7.5 percent, the engine will be in level 2 inducement. A 1761-18 or E954 (2) Aftertreatment #1 Diesel Exhaust Fluid Tank Level : Low - moderate severity (2) diagnostic code will become active. The DEF level gauge amber lamp, CEL, and EMIL will remain lit. The CEL and EMIL will begin to flash slowly. If the ECM is configured to “Reduced Performance” and the DEF level has reached 1 percent, the machine will have a 50 percent derate.

Level 3 Inducement

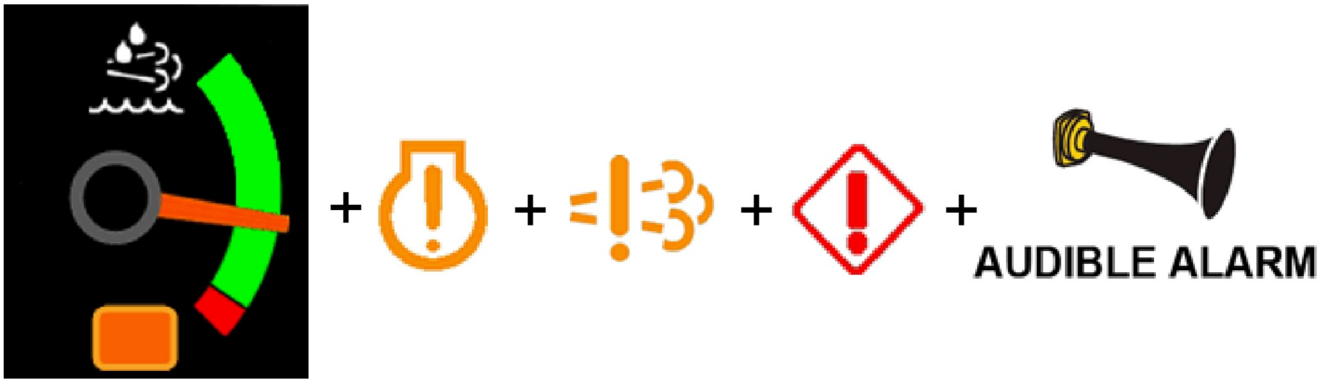

Illustration 28 g03523622

Typical example

Note: Industrial applications will use the stop lamp and not an action lamp. There is no audible alarm for industrial application.

If the ECM is configured to “Reduced Performance” and the DEF tank has been emptied of all DEF, the engine will be in a level 3 final inducement. If the ECM is configured to “Reduced Time” and the DEF level is 3 percent, the engine will be in a level 3 final inducement. When in level 3 inducement, a 1761 -1 or E954 (3) Aftertreatment #1 Diesel Exhaust Fluid Tank Level : Low - most severe (3) diagnostic code will become active. The DEF level gauge amber lamp, CEL, and EMIL will remain lit. The CEL and EMIL will flash at a faster rate and a red stop lamp will illuminate solid. The engine will have a 100 percent derate and be limited to 1000 rpm or low idle, whichever is greater. If the final inducement action in the electronic service tool is set to “Idle Down” , then engine will continue to idle at derated condition. If set to “Shutdown” , engine will shutdown after 5 minutes. The engine may be restarted, but will only run for 5 minutes at derated condition before shutting down again. This action will continue until the issue is resolved.

Note: Turn the key to the OFF position and add DEF to the DEF tank to reset the DEF level inducement.

Inducement Strategy for Escalating Time Inducement Categories (Worldwide)

Level 1 Inducement

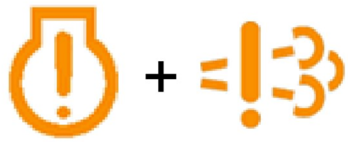

Illustration 29 g03523624

Typical example

Reduced Performance

The CEL and EMIL will illuminate solid for a level 1 inducement-related fault. When in level 1 inducement, a 5246 -15 or E1389 (1) Aftertreatment SCR Operator Inducement Severity (1) diagnostic code will become active. There are three inducement categories.

If the inducement is a result of a category 1 fault, then a level 1 inducement will occur for a duration of 2.5 hours for first occurrence. For repeat occurrence, a category 1 level 1 inducement fault will occur for a duration of 5 minutes.

If the inducement is a result of a category 2 fault, then a level 1 inducement will occur for a duration of 10 hours. There is no repeat occurrence for category 2, level 1 inducement faults.

If the inducement is a result of a category 3 fault, then a level 1 inducement will occur for a duration of 36 hours. There is no repeat occurrence for category 3, level 1 inducement faults.

Reduced Time

The CEL and EMIL will illuminate solid for a level 1 inducement-related fault. When in level 1 inducement, a 5246 -15 or E1389 (1) Aftertreatment SCR Operator Inducement Severity (1) diagnostic code will become active. There are three inducement categories.

If the inducement is a result of a category 1 fault, then a level 1 inducement will occur for a duration of 2.5 hours for first occurrence. For repeat occurrence, a category 1 level 1 inducement fault will occur for a duration of 5 minutes.

If the inducement is a result of a category 2 fault, then a level 1 inducement will occur for a duration of 5 hours. There is no repeat occurrence for category 2, level 1 inducement faults.

If the inducement is a result of a category 3 fault, then a level 1 inducement will occur for a duration of 18 hours. There is no repeat occurrence for category 3, level 1 inducement faults.

Level 2 Inducement

Illustration 30 g03523637

Typical example

Note: The action lamp will not illuminate for industrial applications.

Reduced Performance

If a fault condition exists for the entire duration of inducement level 1, the strategy advances to inducement level 2. When in level 2 inducement a 5246 -16 or E1389 (2) Aftertreatment SCR Operator Inducement Severity (2) diagnostic code will become active. The CEL and EMIL will remain lit. The CEL and EMIL will begin to flash slowly. The engine will have a 50% derate.

If the inducement is a result of a category 1 fault, then a level 2 inducement will occur for a duration of 70 minutes for first occurrence. For repeat occurrence, a category 1 level 2 inducement fault will occur for a duration of 5 minutes.

If the inducement is a result of a category 2 fault, then a level 2 inducement will occur for a duration of 10 hours. For repeat occurrence, a category 2 level 2 inducement fault will occur for a duration of 2 hours.

If the inducement is a result of a category 3 fault, then a level 2 inducement will occur for a duration of 64 hours. For repeat occurrence, a category 3 level 2 inducement fault will occur for a duration of 5 hours.

Reduced Time

If a fault condition exists for the entire duration of inducement level 1, the strategy advances to inducement level 2. When in level 2 inducement a 5246 -16 or E1389 (2) Aftertreatment SCR Operator Inducement Severity (2) diagnostic code will become active. The CEL and EMIL will remain lit. The CEL and EMIL will begin to flash slowly.

If the inducement is a result of a category 1 fault, then a level 2 inducement will occur for a duration of 70 minutes for first occurrence. For repeat occurrence, a category 1 level 2 inducement fault will occur for a duration of 5 minutes.

If the inducement is a result of a category 2 fault, then a level 2 inducement will occur for a duration of 5 hours. For repeat occurrence, a category 2 level 2 inducement fault will occur for a duration of 1 hour.

If the inducement is a result of a category 3 fault, then a level 2 inducement will occur for a duration of 18 hours. For repeat occurrence, a category 3 level 2 inducement fault will occur for a duration of 108 minutes.

Level 3 Inducement

Illustration 31 g03523639

Typical example

Note: Industrial applications will use the stop lamp and not an action lamp. There is no audible alarm for industrial application.

If a fault condition exists for the entire duration of inducement level 2, the strategy advances to inducement level 3. When in level 3 inducement a 5246 -0 or E1389 (3) Aftertreatment SCR Operator Inducement Severity (3) diagnostic code will become active. For machines only, an audible alarm will begin to sound 20 seconds prior to the level 3 inducement. The CEL and EMIL will flash at a faster rate and a red stop lamp will illuminate solid.

The engine will have a 100 percent derate and be limited to 1000 rpm or low idle, whichever is greater. If the final inducement action in the electronic service tool is set to “Idle Down” , then engine will continue to idle at derated condition. If set to “Shutdown” , engine will shutdown after 5 minutes. A key cycle will allow safe harbor mode to kick in. Safe harbor is only allowed once. After safe harbor, the engine will be in level 3 final inducement. If set to “Shutdown” , the engine may be restarted, but will only run for 5 minutes at derated condition before shutting down again. This action will continue until the issue is resolved.

Inducement Strategy for DEF Level (European Union)

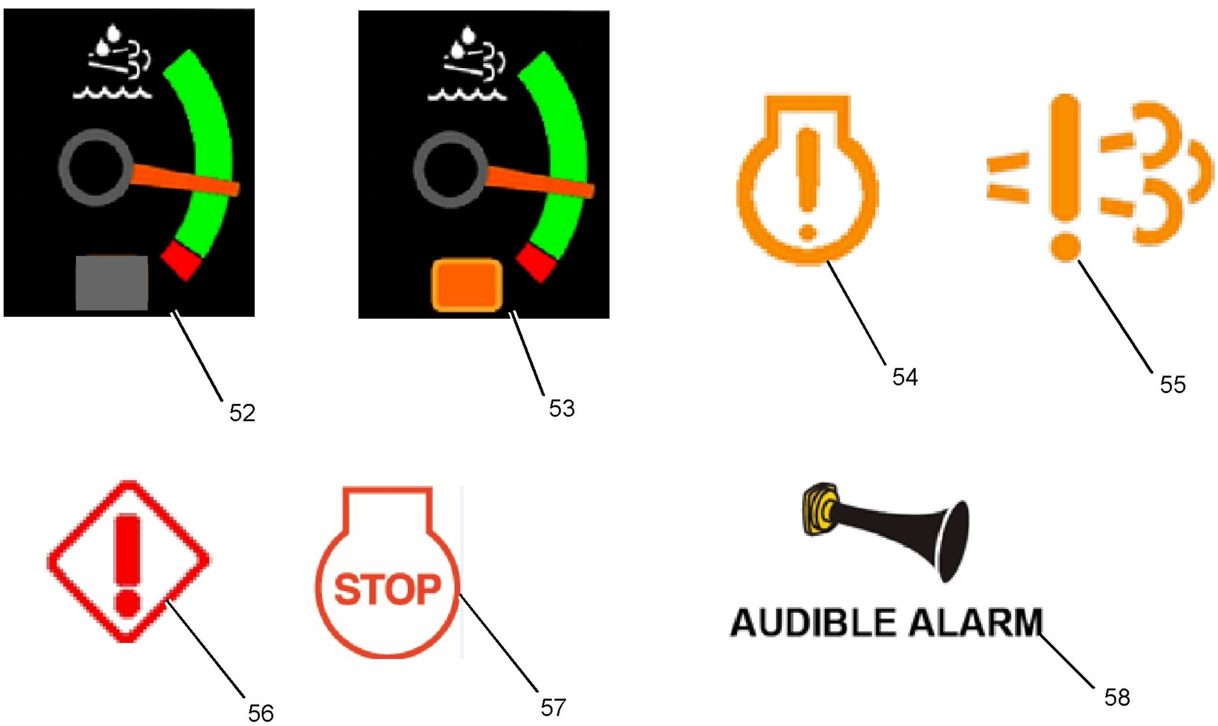

Illustration 32 g06152707

Typical example

(52) DEF Level Gauge: This gauge shows the amount of DEF in the DEF tank.

(53) DEF Level Gauge Amber lamp: This amber lamp indicates that the DEF level is low.

(54) Check Engine Lamp (CEL): This lamp activates for all engine and aftertreatment faults that affect the engine.

(55) Emissions Malfunction Indicator Lamp (EMIL): This lamp activates for all emissions faults that trigger inducement strategy.

(56) Action Lamp: For machine engines, this lamp indicates that a Level 2 or Level 3 fault is active.

(57) Red Stop Lamp: For industrial engines, this lamp indicates that a Level 3 fault is active. Symbols may vary.

(58) Audible Alarm: For machines, the alarm sounds when a Level 3 fault is active.

Low DEF Level Warning

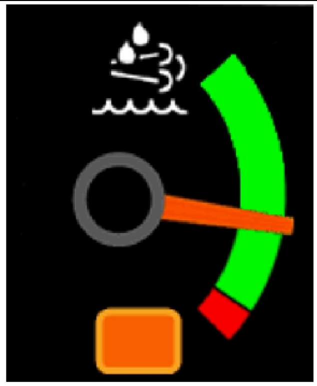

Illustration 33 g03523436

Typical example

If the DEF level falls below 20 percent, the DEF level gauge amber lamp will illuminate. To avoid inducements, turn the key to the OFF position and add DEF to the DEF tank.

Level 1 Inducement

Illustration 34 g03523619

Typical example

If the DEF level falls below 13.5 percent, the engine will be in level 1 inducement. A 1761-17 or E954 (1) Aftertreatment #1 Diesel Exhaust Fluid Tank Level : Low - least severe (1) diagnostic code will become active. The CEL and EMIL will illuminate solid. The DEF level gauge amber lamp will continue to remain lit.

Level 2 Inducement

Illustration 35 g03534876

Typical example

Reduced Performance

When the ECM is configured to “Reduced Performance” and the DEF level is below 1 percent, the engine will be in level 2 inducement. A 1761-18 or E954 (2) Aftertreatment #1 Diesel Exhaust Fluid Tank Level : Low - moderate severity (2) diagnostic code will become active. The CEL and EMIL will illuminate and flash slowly. The DEF level gauge amber lamp will remain lit. The engine will have a 50 percent derate. When the DEF tank has been emptied of all DEF, the engine will have a 100 percent derate and be limited to 1000 rpm or low idle, whichever is greater. No further inducement action will occur for “Reduced Performance” configuration. Safe Harbor Mode is allowed for 3 key cycles.

Reduced Time

When ECM is configured to “Reduced Time” and the DEF level is below 7.5 percent, a 1761-18 or E954 (2) Aftertreatment #1 Diesel Exhaust Fluid Tank Level: Low - moderate severity (2) diagnostic code will become active. The CEL and EMIL will illuminate and flash slowly. The DEF level gauge amber lamp will remain lit.

Level 3 Inducement

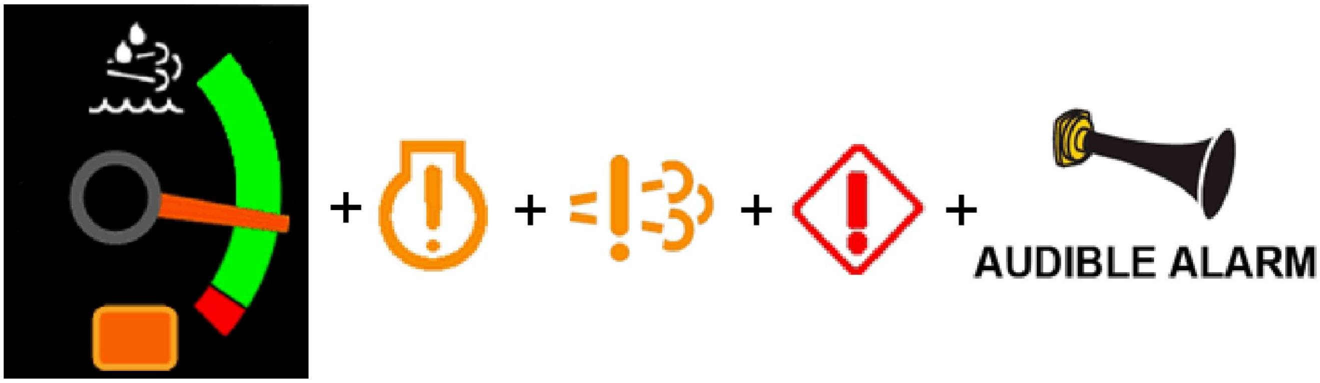

Illustration 36 g03523622

Typical example

Note: Industrial applications will use the stop lamp and not an action lamp. There is no audible alarm for the industrial application.

Note: The stop symbol may vary.

Reduced Time

If the ECM is configured to “Reduced Time” and the DEF level is 0 percent, a 1761 -1 or E954 (3) Aftertreatment #1 Diesel Exhaust Fluid Tank Level : Low - most severe (3) diagnostic code will become active. The CEL and EMIL will illuminate and flash at a fast rate. An action lamp or red stop lamp will illuminate solid. The DEF level gauge amber lamp will remain lit. The engine will have a 100% derate and be limited to 1000 rpm or low idle, whichever is greater. If the final inducement action in the electronic service tool is set to “Idle Down” , then engine will just continue to idle at derated condition. If set to “Shutdown” , engine will shut down after 5 minutes. Safe Harbor Mode is allowed for 3 key cycles. After Safe Harbor Mode is completed, the engine will return to idle or shut down. If in shutdown configuration, the engine may be restarted, but will only run for 5 minutes at derated condition before shutting down again. This action will continue until the issue is resolved.

Note: Turn the key to the OFF position and add DEF to the DEF tank to reset the DEF level inducement.

Inducement Strategy for Escalating Time Inducement Faults (European Union)

Level 1 Inducement

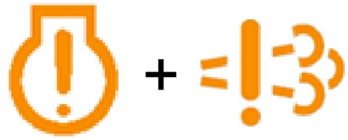

Illustration 37 g03523624

Typical example

Reduced Performance

The CEL and EMIL will illuminate solid for a fault a level 1 inducement-related fault. When in level 1 inducement, a 5246 - 15 or E1389 (1) Aftertreatment SCR Operator Inducement Severity (1) diagnostic code will become active. There are two inducement categories.

If the inducement is a result of a category 1 fault, then a level 1 inducement will occur for a duration of 36 hours.

If the inducement is a result of a category 2 fault, then a level 1 inducement will occur for a duration of 10 hours.

Reduced Time

The CEL and EMIL will illuminate solid for a fault a level 1 inducement-related fault. When in level 1 inducement, a 5246 - 15 or E1389 (1) Aftertreatment SCR Operator Inducement Severity (1) diagnostic code will become active. There are two inducement categories.

If the inducement is a result of a category 1 fault, then a level 1 inducement will occur for a duration of 18 hours.

If the inducement is a result of a category 2 fault, then a level 1 inducement will occur for a duration of 5 hours.

Level 2 Inducement

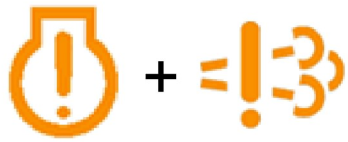

Illustration 38 g03523624

Typical example

Reduced Performance

If a fault condition exists for the entire duration of inducement level 1, the strategy advances to inducement level 2. When in level 2 inducement a 5246 -16 or E1389 (2) Aftertreatment SCR Operator Inducement Severity (2) diagnostic code will become active. The CEL and EMIL will flash slowly.

If the inducement is a result of a category 1 fault, then a level 2 inducement will occur for a duration of 64 hours for first occurrence. For repeat occurrence, a category 1 level 2 inducement fault will occur for a duration of 5 hours.

If the inducement is a result of a category 2 fault, then a level 2 inducement will occur for a duration of 10 hours. For repeat occurrence, a category 2 level 2 inducement fault will occur for a duration of 2 hours.

The engine will have a 50 percent derate. If the fault is not corrected before the inducement duration ends, the engine will become 100 percent derated and be limited to 1000 rpm or low idle, whichever is greater. No further inducements will occur for “Reduced Performance” configuration. Safe Harbor Mode is allowed for 3 key cycles.

Reduced Time

If a fault condition exists for the entire duration of inducement level 1, the strategy advances to inducement level 2. When in level 2 inducement a 5246 -16 or E1389 (2) Aftertreatment SCR Operator Inducement Severity (2) diagnostic code will become active. The CEL and EMIL will flash slowly.

If the inducement is a result of a category 1 fault, then a level 2 inducement will occur for a duration of 18 hours for first occurrence. For repeat occurrence, a category 1 level 2 inducement fault will occur for a duration of 108 minutes.

If the inducement is a result of a category 2 fault, then a level 2 inducement will occur for a duration of 5 hours. For repeat occurrence, a category 2 level 2 inducement fault will occur for a duration of 1 hours.

Level 3 Inducement

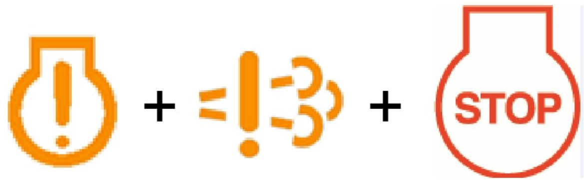

Illustration 39 g03535019

Typical example

Note: Industrial applications will use the stop lamp and not an action lamp. There is no audible alarm for the industrial application.

Note: The stop symbol may vary.

Reduced Time

If configured to "Reduced Time" and a fault condition exists for the entire duration of inducement level 2, the strategy advances to inducement level 3. When in level 3 inducement a 5246 -0 or E1389 (3) Aftertreatment SCR Operator Inducement Severity (3) diagnostic code will become active. The CEL and EMIL will flash at a fast rate. An action lamp or red stop lamp will also illuminate solid.

The engine will have a 100 percent derate and be limited to 1000 rpm or low idle, whichever is greater. If the final inducement action in the electronic service tool is set to "Idle Down" then engine will continue to idle at derated condition. If set to "Shutdown" , engine will shut down after 5 minutes. A key cycle will allow safe harbor mode to kick in. Safe harbor is allowed up to three times. After safe harbor, the engine will be in level 3 final inducement. If set to "Shutdown" , the engine may be restarted, but will only run for 5 minutes at derated condition before shutting down again. This action will continue until the issue is resolved.

i06870470

Cooling System

SMCS Code: 1350

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

The coolant flows from the bottom of the radiator to the centrifugal water pump. The water pump is installed on the front of the front housing. The water pump is driven by the front-end drive belt.

The water pump 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 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 coolant is then pumped by the water pump. Some coolant flows from the outlet of the water pump and passes over the element of the oil cooler. The oil cooler is on the left-hand side of the cylinder block.

Most of the coolant flows from the outlet of the water pump and enters the cylinder block. The coolant then enters the cylinder block. Coolant flows around the outside of the cylinders then flows from the cylinder block into the cylinder head.

Some coolant is diverted into the exhaust gas cooler by a coolant pipe in the rear of the cylinder head. The coolant then flows out of the exhaust gas cooler through the exhaust gas valve (NRS) to the cavity in the front of the cylinder head. The coolant then flows out of the cylinder head to the water temperature regulator. A small amount of coolant passes through the degassing connection on the exhaust gas valve (NRS).

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

i06870519

Lubrication System

SMCS Code: 1300

Lubricating oil from the oil pan flows through a strainer and a pipe to the suction side of the engine oil pump. Engine oil pressure for the lubrication system is supplied by the oil pump. The engine oil pump is located in the front housing. The crankshaft drives the inner rotor of the engine oil pump.

The pump has an inner rotor and an outer rotor. The axis of the inner rotor is off-center to the outer rotor. The inner rotor is driven by the crankshaft.

The inner rotor has eight lobes which mesh with the nine lobes of the outer rotor. When the pump rotates, the distance increases between the lobes of the outer rotor and the lobes of the inner rotor to create suction. When the distance decreases between the lobes, pressure is created, forcing oil into the lubricating system.

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

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

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

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

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

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 rear journal of the camshaft at a reduced pressure to the cylinder head. The oil then flows through the center of the rocker shaft to the rocker arm levers. The valve stems, the valve springs and the valve lifters are lubricated by the splash and the oil mist.

The hub of the idler gear is lubricated by oil from the oil gallery. The oil gallery is drilled through the cylinder head and the cylinder block to the rear gear train. The timing gears are lubricated by the splash from the oil.

Lubricating oil from the oil filter flows through a passage in the cylinder block to an external feed connection for the turbocharger. The feed connection supplies lubricating oil to the center housing of the turbocharger. Lubricating oil then flows from the drain for the turbocharger to the engine crankcase.

i06906339

Electrical System

SMCS Code: 1400; 1550; 1900

The electrical system is a negative ground system.

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

Starting Motor

The starting motor turns the engine via a gear on the engine flywheel. The starting motor speed must be high enough 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 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 on the shafts and the solenoid will disengage the pinion from flywheel ring gear back to the rest position.

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

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 inside the three-phase stator. The electromagnetic field is generated by electrical current flowing through a rotor. The stator generates alternating current and voltage.

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

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

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

i05354531

Cleanliness of Fuel System Components

SMCS Code: 1250

Cleanliness of the Engine

NOTICE

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

The entire engine should be washed with a high-pressure water system. Washing the engine will remove dirt and loose debris before a repair on the fuel system is started. Ensure that no high-pressure water is directed at the seals for the injectors or any electrical connector.

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 Caterpillar dealer 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”.

i06871110

Fuel Injection
(Engines with a Single Fuel Filter and Electric Fuel Priming Pump)

SMCS Code: 1251; 1252; 1253; 1254; 1281

Introduction

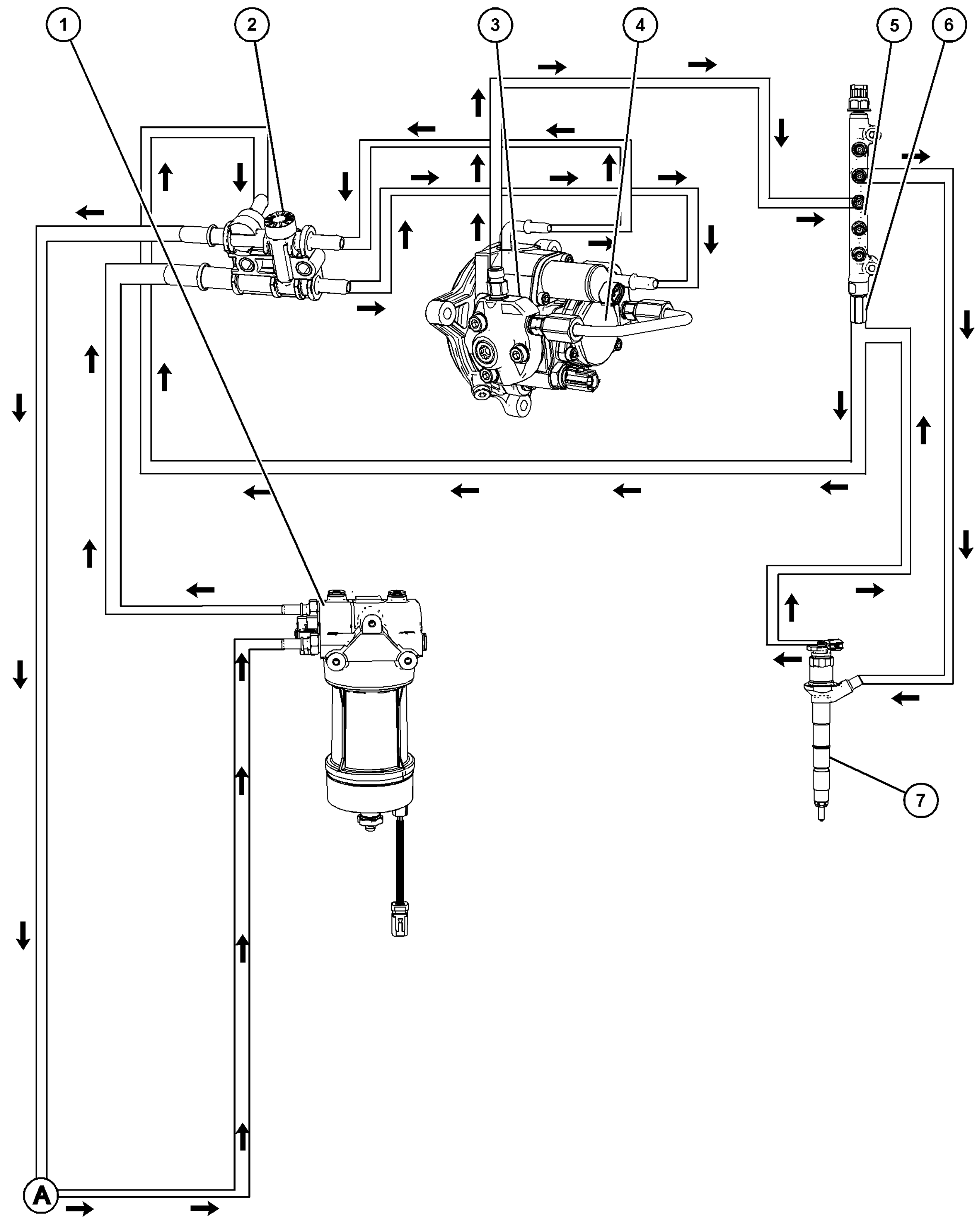

Illustration 40

g06359883

Typical example

(1) Fuel filter/water separator
(2) Pressure regulator
(3) Fuel injection pump
(4) Fuel transfer pump
(5) Fuel manifold (rail)
(6) Pressure relief valve
(7) Electronic unit injector

Fuel is drawn from the fuel tank through a 4 micron fuel filter and a water separator with an integrated electric fuel priming pump.

The fuel flows from the 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 a pressure of between 20 to 50 kPa (3 to 7 psi) when the engine is cranking until the engine speed is above 600 rpm.

The fuel then flows to the fuel transfer pump. The fuel transfer pump is part of the fuel injection pump.

At the fuel injection pump, the fuel is pumped at an increased pressure of up to 200 MPa (29000 psi) to the fuel manifold (rail). Fuel that is leak off from the electronic unit injectors flows to the return line.

Fuel that has too high a pressure from the fuel manifold (rail) returns through the pressure relief valve to the return line.

High-Pressure Fuel System

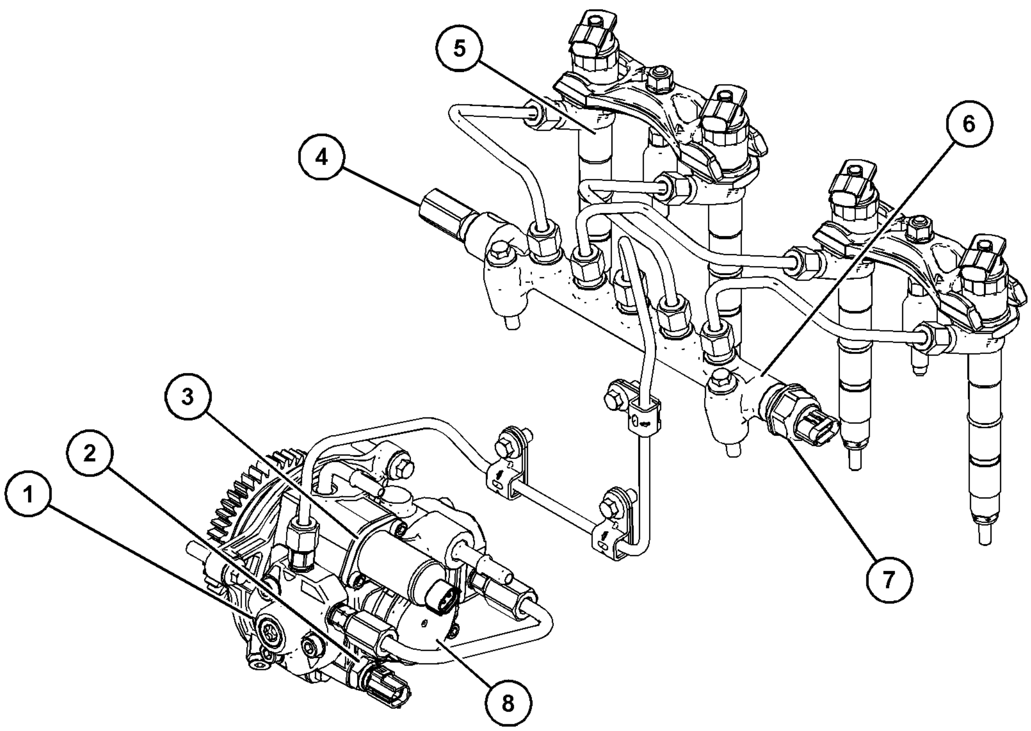

Illustration 41 g06148124

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 up to 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) 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 through fuel lines that are connected to the top of the electronic unit injectors. From the top of the electronic unit injectors, the fuel line is connected to the pressure relief valve. A fuel line is connected to the pressure relief valve to return the leakoff fuel to the fuel tank.

Components of the Fuel Injection System

The fuel injection system has the following mechanical components:

- Fuel filter/water separator
- 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.

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

Fuel Filter/Water Separator

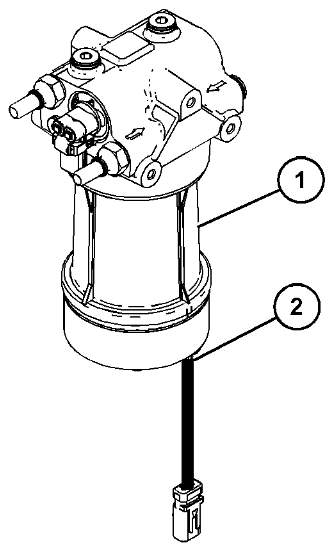

Illustration 42 g06148166

Typical example

The fuel filter/water separator (1) provides a 4 micron filtration level. The fuel filter/water separator is supplied with water in fuel sensor (2).

Fuel Pump Assembly

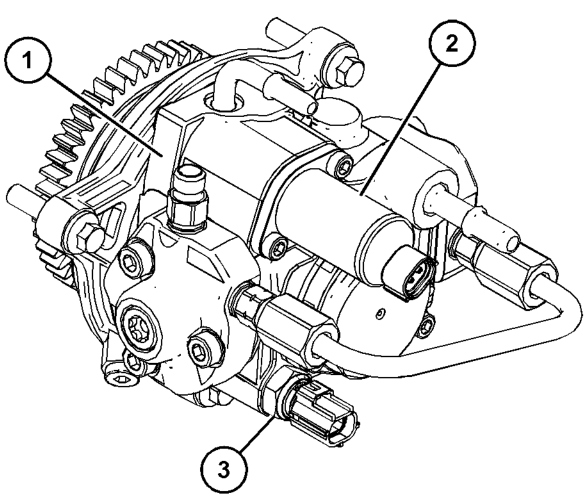

Illustration 43 g06148132

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 rear gear train at engine speed. The fuel injection pump (1) has two plungers that are driven by a camshaft. The fuel injection pump (1) delivers a volume of fuel two 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 (2) 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 (3) measures the temperature of the fuel. The ECM receives the signal from the fuel temperature sensor (3). 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

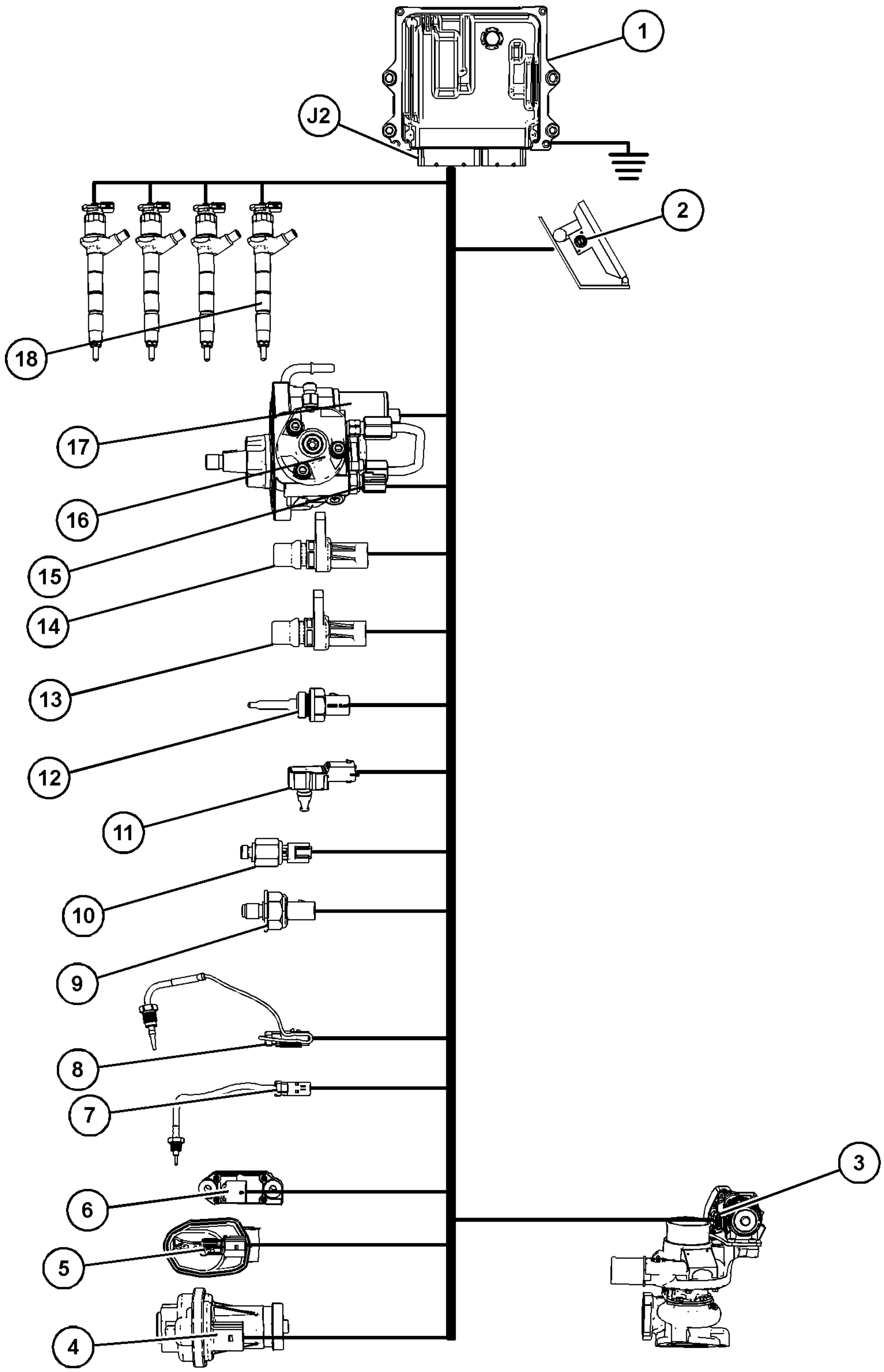

Illustration 44

g06359271

Typical example of the electrical control system for the fuel system

(1) Electronic Control Module (ECM)
(2) Throttle position sensor
(3) Turbocharger electronic wastegate
(4) Exhaust gas valve (NRS)
(5) Inlet throttle valve (NRS)
(6) Differential pressure sensor (NRS)

(7) Outlet temperature sensor (NRS)
(8) Inlet temperature sensor (NRS)
(9) Fuel pressure sensor
(10) Engine oil pressure switch
(11) Inlet manifold air pressure and temperature sensor
(12) Coolant temperature sensor
(13) Secondary speed/timing sensor
(14) Primary speed/timing sensor
(15) Fuel temperature sensor
(16) Fuel injection pump
(17) Suction control valve for the fuel injection pump
(18) Electronic unit injectors

The ECM determines the quantity, timing, and pressure of the fuel 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.

Electronic Unit Injectors

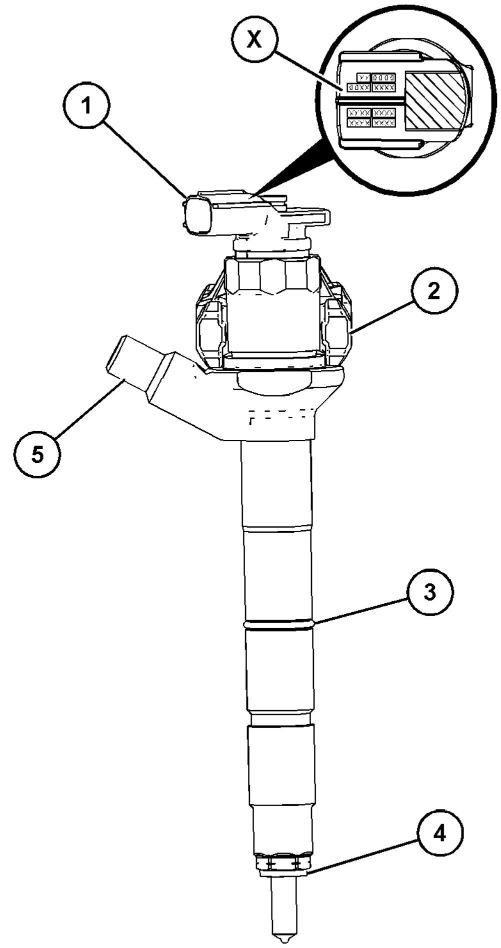

Illustration 45 g06148160

Typical example

(1) Electrical connections
(2) Clamp
(3) O-ring
(4) Combustion washer
(5) 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 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.

The pressurized fuel from the fuel manifold is injected into the combustion chamber by the electronic unit injector. The desired injection timing, injection quantity, and injection pattern are controlled by the ECM depending on engine operating conditions.

The injection process is controlled using a two-way valve. The supply of electrical current to the solenoid controls the two-way valve. When the two-way valve is not energized the out orifice is closed and there is no fuel leak. In this condition the pressure in the control chamber and the pressure at the nozzle needle are the same. In this condition the spring pressure on the command piston keeps the needle closed.

When an injection of fuel is required, the electrical current from the ECM charges the solenoid, which in turn energizes the two-way valve and lifts the valve. When the valve lifts the valve uncovers the out orifice. The fuel starts to flow and reduces the pressure in the control chamber. When the pressure difference at the nozzle needle exceeds the combined pressure of the control chamber pressure and the spring pressure, the nozzle lifts to start the injection process. The fuel coming out of the nozzle is atomized and injected as a very fine spray.

When the injection needs to be stopped, the electrical current to the solenoid is cut off and the pressure difference in the control chamber starts increasing. The increased pressure difference stops the injection process when the combined pressure exceeds the nozzle pressure.

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 (Rail)

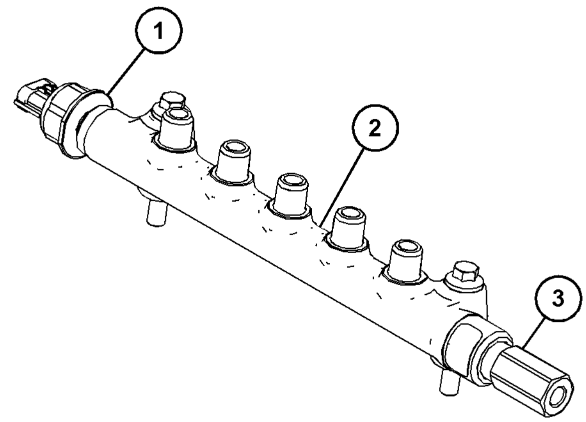

Illustration 46 g06148128

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 (1) measures the fuel pressure in the fuel manifold (3).

The pressure relief valve (3) 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.

i07561828

Fuel Injection
(Engines with a Single Fuel Filter and Manual Fuel Priming Pump)

SMCS Code: 1251; 1252; 1253; 1254; 1281

Introduction

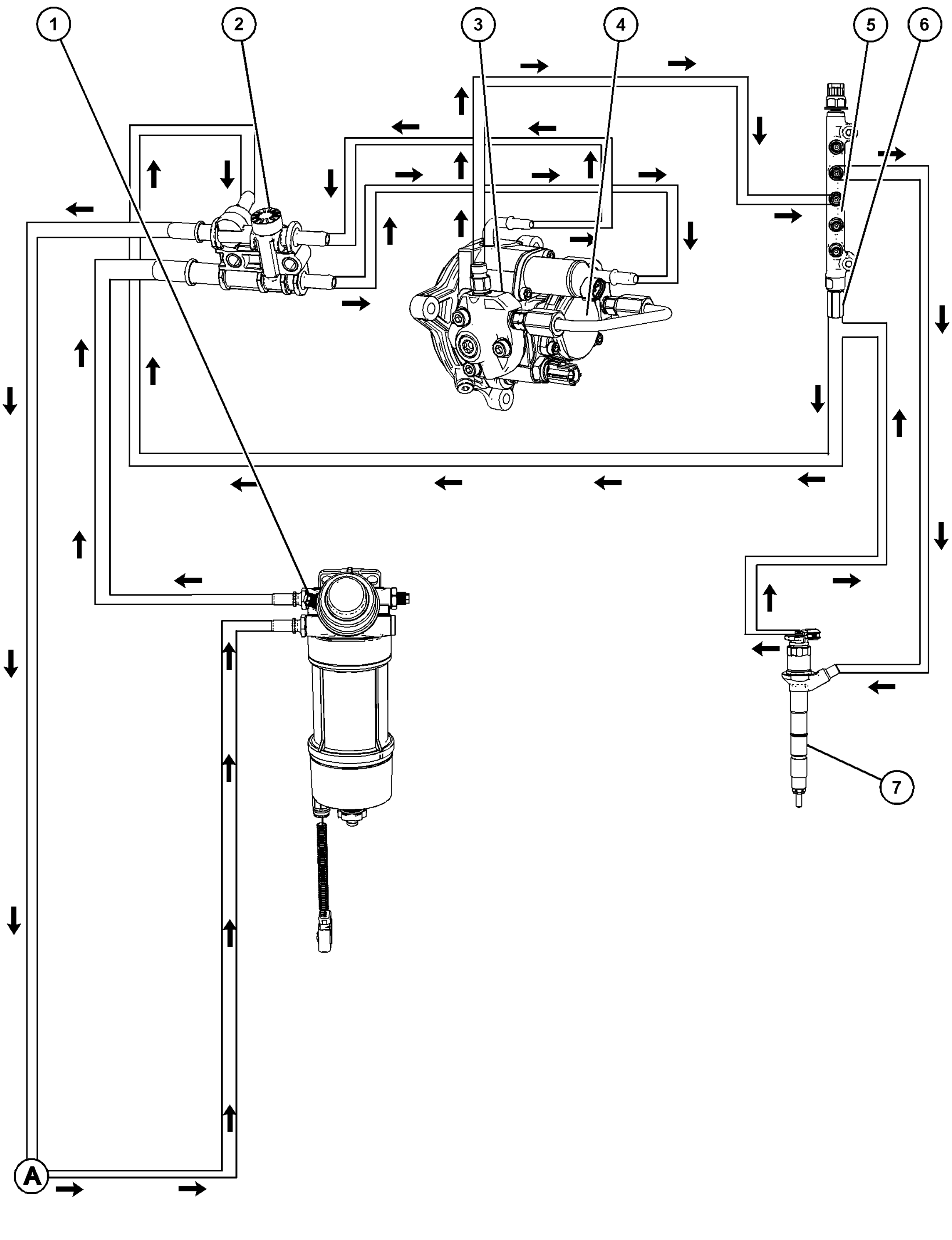

Illustration 47

g06359946

Typical example

(1) Fuel filter/water separator
(2) Pressure regulator
(3) Fuel injection pump
(4) Fuel transfer pump
(5) Fuel manifold (rail)
(6) Pressure relief valve
(7) Electronic unit injector

Fuel is drawn from the fuel tank through a 4 micron fuel filter and a water separator with an integrated manual fuel priming pump.

The fuel flows from the 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 a pressure of between 20 to 50 kPa (3 to 7 psi) when the engine is cranking until the engine speed is above 600 rpm.

The fuel then flows to the fuel transfer pump. The fuel transfer pump is part of the fuel injection pump.

At the fuel injection pump, the fuel is pumped at an increased pressure of up to 200 MPa (29000 psi) to the fuel manifold (rail). Fuel that is leak off from the electronic unit injectors flows to the return line.

Fuel that has too high a pressure from the fuel manifold (rail) returns through the pressure relief valve to the return line.

High-Pressure Fuel System

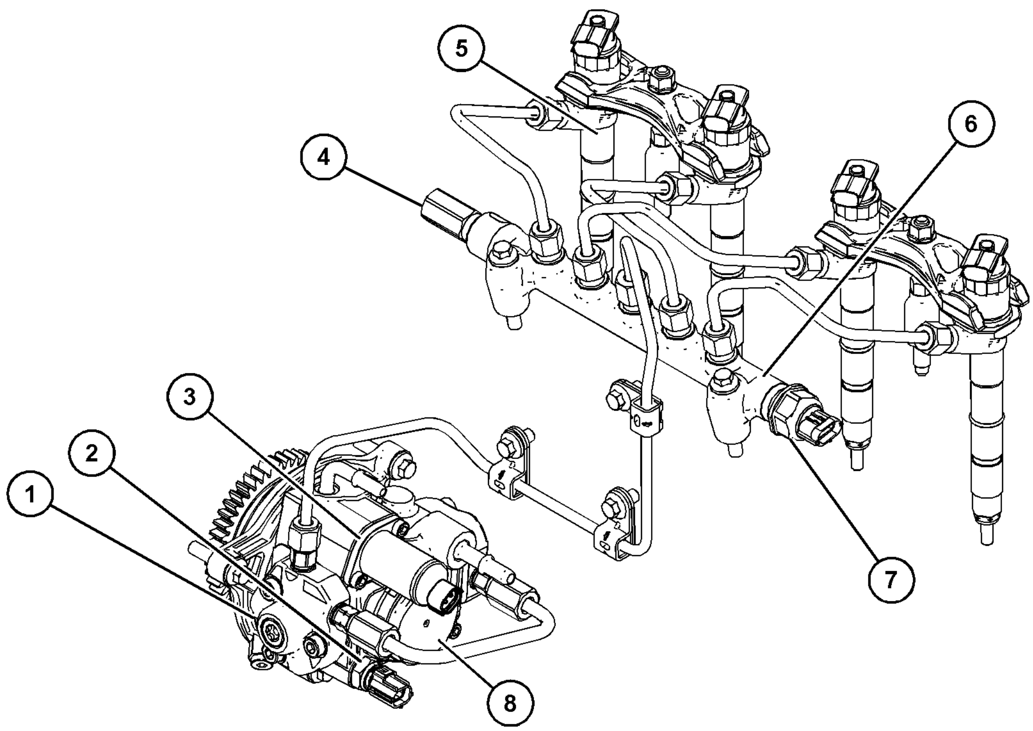

Illustration 48 g06148124

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 up to 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) 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 through fuel lines that are connected to the top of the electronic unit injectors. From the top of the electronic unit injectors, the fuel line is connected to the pressure relief valve. A fuel line is connected to the pressure relief valve to return the leakoff fuel to the fuel tank.

Components of the Fuel Injection System

The fuel injection system has the following mechanical components:

- Fuel filter/water separator
- 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.

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

Fuel Filter/Water Separator

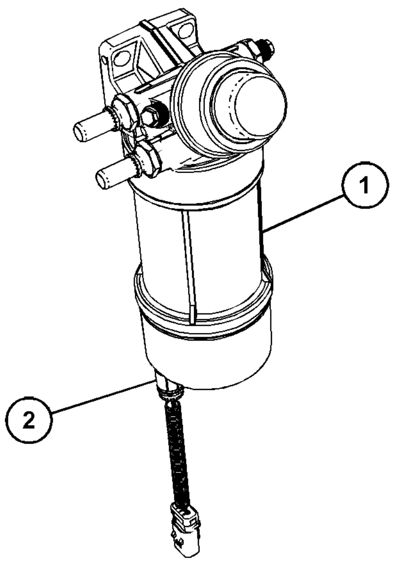

Illustration 49 g06359952

Typical example

The fuel filter/water separator (1) provides a 4 micron filtration level. The fuel filter/water separator is supplied with water in fuel sensor (2).

Fuel Pump Assembly

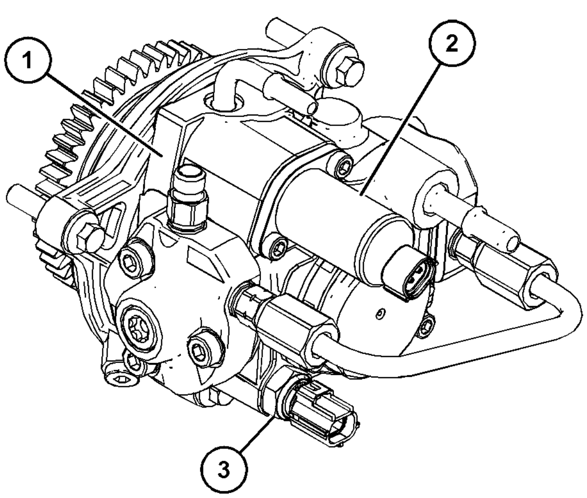

Illustration 50 g06148132

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 rear gear train at engine speed. The fuel injection pump (1) has two plungers that are driven by a camshaft. The fuel injection pump (1) delivers a volume of fuel two 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 (2) 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 (3) measures the temperature of the fuel. The ECM receives the signal from the fuel temperature sensor (3). 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

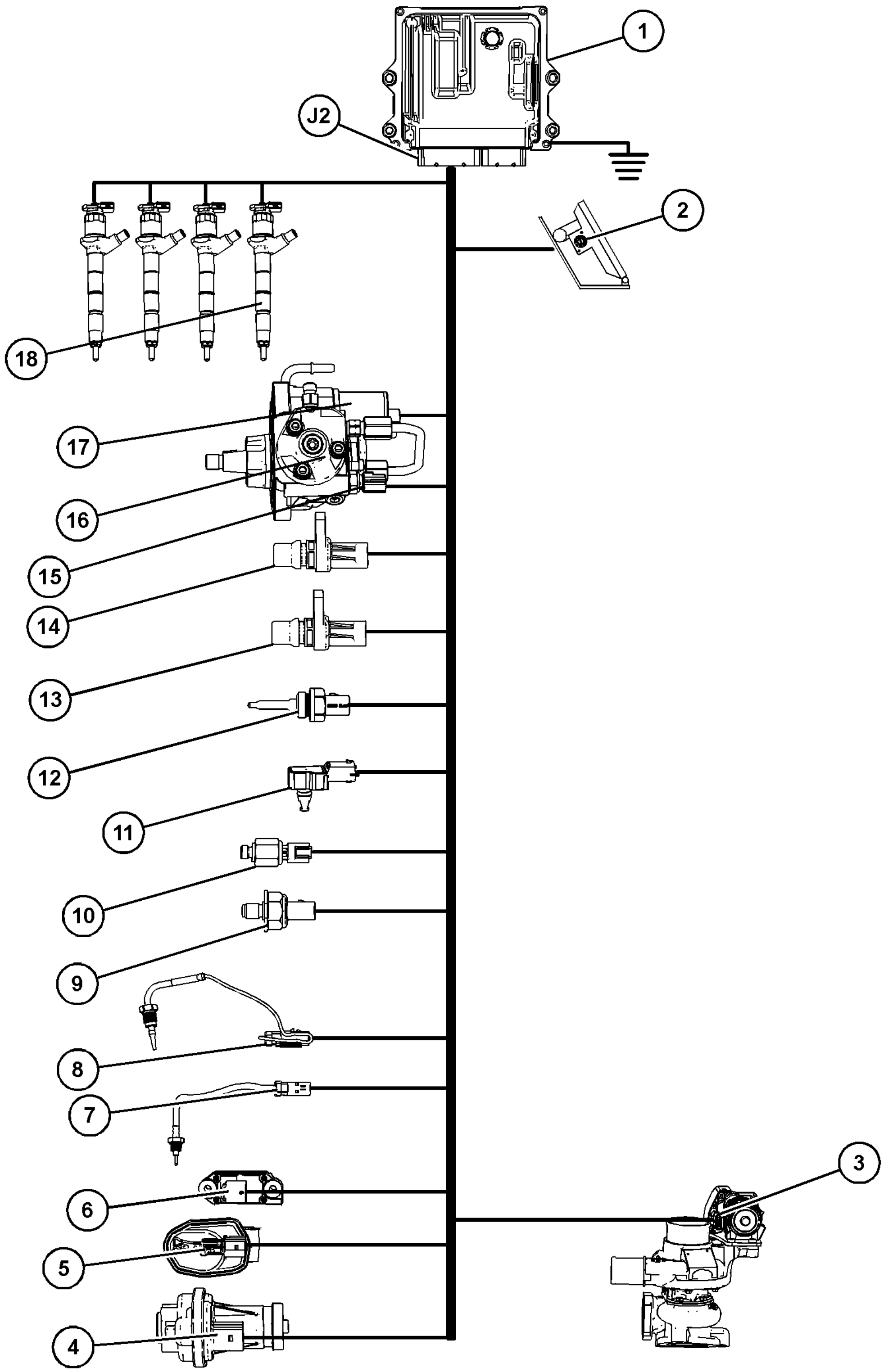

Illustration 51

g06359271

Typical example of the electrical control system for the fuel system

(1) Electronic Control Module (ECM)
(2) Throttle position sensor
(3) Turbocharger electronic wastegate
(4) Exhaust gas valve (NRS)
(5) Inlet throttle valve (NRS)
(6) Differential pressure sensor (NRS)

(7) Outlet temperature sensor (NRS)
(8) Inlet temperature sensor (NRS)
(9) Fuel pressure sensor
(10) Engine oil pressure switch
(11) Inlet manifold air pressure and temperature sensor
(12) Coolant temperature sensor
(13) Secondary speed/timing sensor
(14) Primary speed/timing sensor
(15) Fuel temperature sensor
(16) Fuel injection pump
(17) Suction control valve for the fuel injection pump
(18) Electronic unit injectors

The ECM determines the quantity, timing, and pressure of the fuel 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.

Electronic Unit Injectors

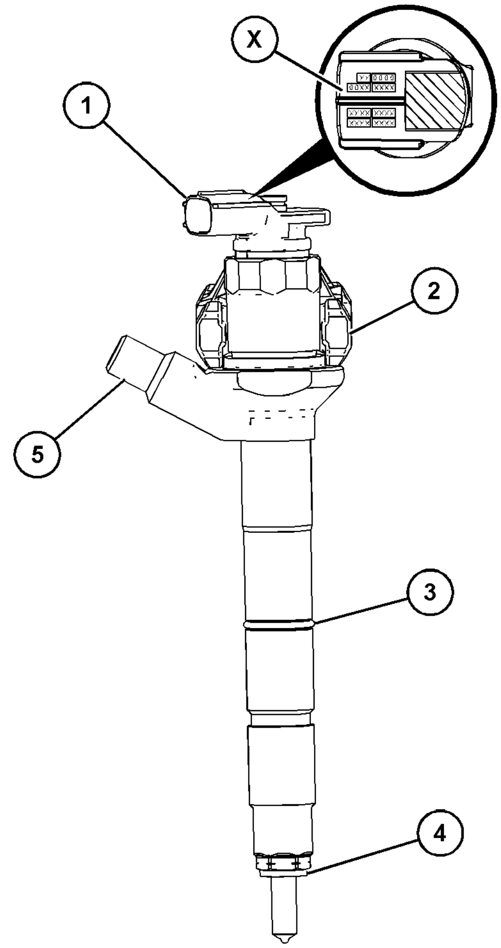

Illustration 52 g06148160

Typical example

(1) Electrical connections
(2) Clamp
(3) O-ring
(4) Combustion washer
(5) 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 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.

The pressurized fuel from the fuel manifold is injected into the combustion chamber by the electronic unit injector. The desired injection timing, injection quantity, and injection pattern are controlled by the ECM depending on engine operating conditions.

The injection process is controlled using a two-way valve. The supply of electrical current to the solenoid controls the two-way valve. When the two-way valve is not energized the out orifice is closed and there is no fuel leak. In this condition the pressure in the control chamber and the pressure at the nozzle needle are the same. In this condition the spring pressure on the command piston keeps the needle closed.

When an injection of fuel is required, the electrical current from the ECM charges the solenoid, which in turn energizes the two-way valve and lifts the valve. When the valve lifts the valve uncovers the out orifice. The fuel starts to flow and reduces the pressure in the control chamber. When the pressure difference at the nozzle needle exceeds the combined pressure of the control chamber pressure and the spring pressure, the nozzle lifts to start the injection process. The fuel coming out of the nozzle is atomized and injected as a very fine spray.

When the injection needs to be stopped, the electrical current to the solenoid is cut off and the pressure difference in the control chamber starts increasing. The increased pressure difference stops the injection process when the combined pressure exceeds the nozzle pressure.

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 (Rail)

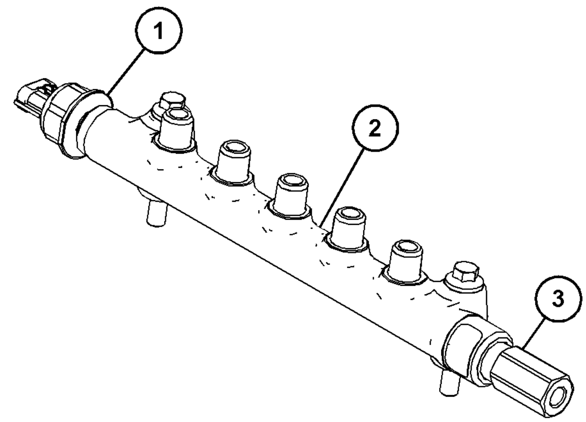

Illustration 53 g06148128

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 (1) measures the fuel pressure in the fuel manifold (3).

The pressure relief valve (3) 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.

i07561849

Fuel Injection
(Engines with Two Fuel Filters and Electric Fuel Priming Pump)

SMCS Code: 1251; 1252; 1253; 1254; 1281

Introduction

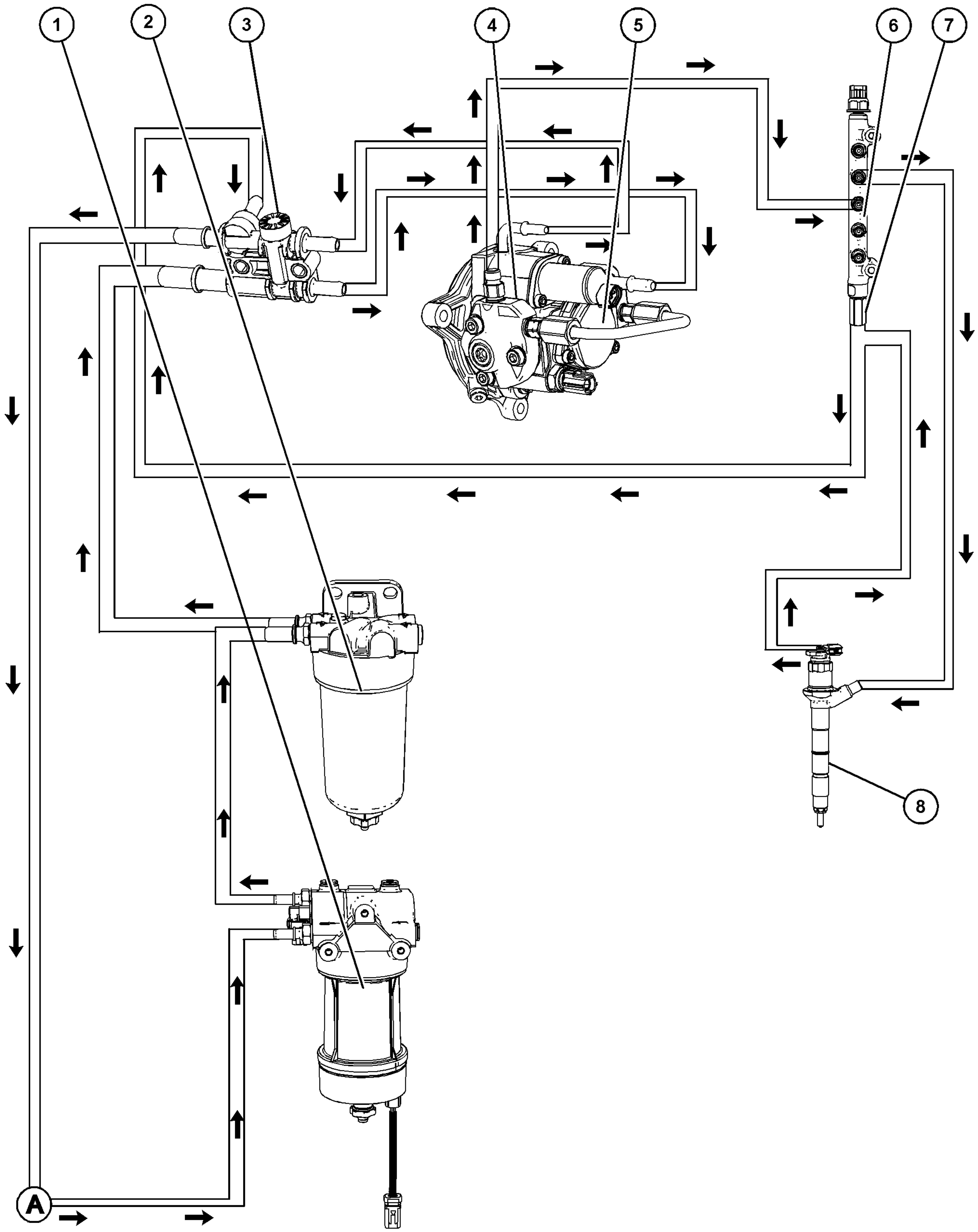

Illustration 54

g06367501

Typical example

(1) Primary fuel filter/water separator
(1) Secondary fuel filter
(3) Pressure regulator
(4) Fuel injection pump
(5) Fuel transfer pump
(6) Fuel manifold (rail)
(7) Pressure relief valve
(8) Electronic unit injector

Fuel is drawn from the fuel tank through a 10 micron primary fuel filter and a water separator with an integrated electric fuel priming pump.

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 a pressure of between 20 to 50 kPa (3 to 7 psi) when the engine is cranking until the engine speed is above 600 rpm.

The fuel then flows to the fuel transfer pump. The fuel transfer pump is part of the fuel injection pump.

At the fuel injection pump, the fuel is pumped at an increased pressure of up to 200 MPa (29000 psi) to the fuel manifold (rail). Fuel that is leak off from the electronic unit injectors flows to the return line.

Fuel that has too high a pressure from the fuel manifold (rail) returns through the pressure relief valve to the return line.

High-Pressure Fuel System

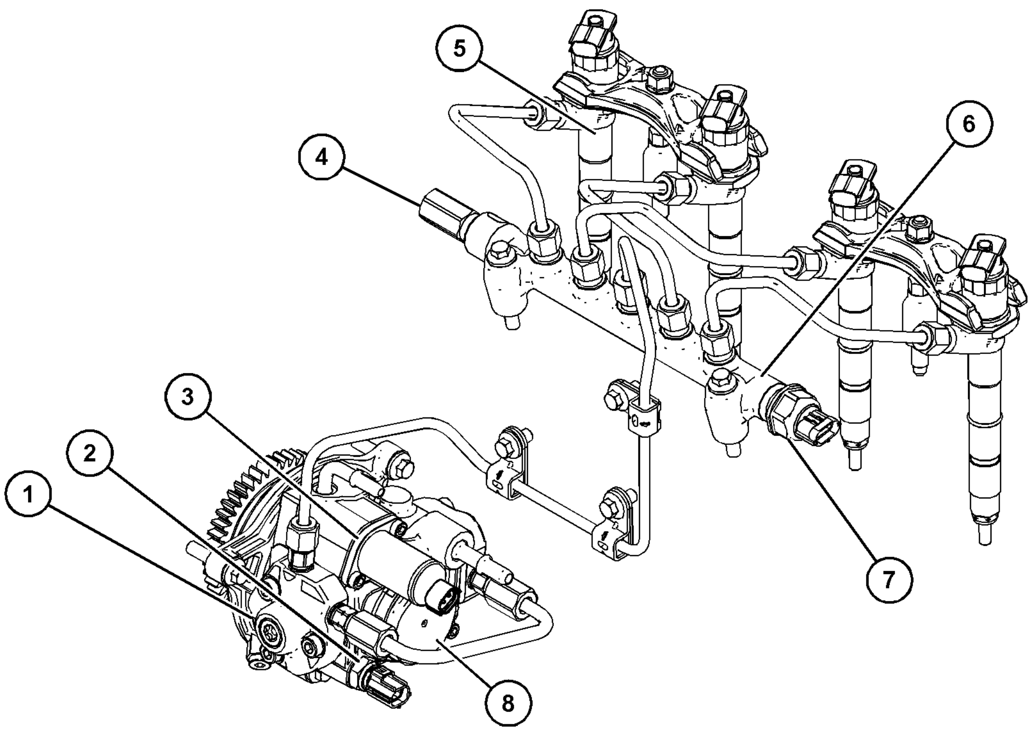

Illustration 55 g06148124

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 up to 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) 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 through fuel lines that are connected to the top of the electronic unit injectors. From the top of the electronic unit injectors, the fuel line is connected to the pressure relief valve. A fuel line is connected to the pressure relief valve 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 fuel filter/water separator
- 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.

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

Primary Fuel Filter/Water Separator

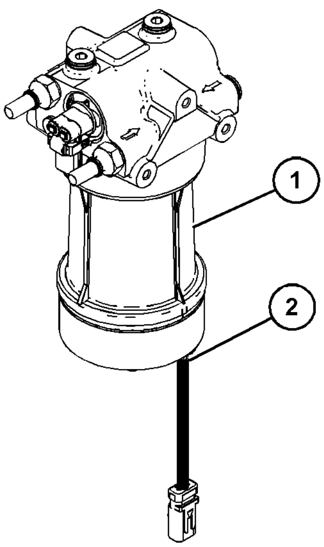

Illustration 56 g06148166

Typical example

The fuel filter/water separator (1) provides a 10 micron filtration level. The fuel filter/water separator is supplied with water in fuel sensor (2).

Secondary Fuel Filter

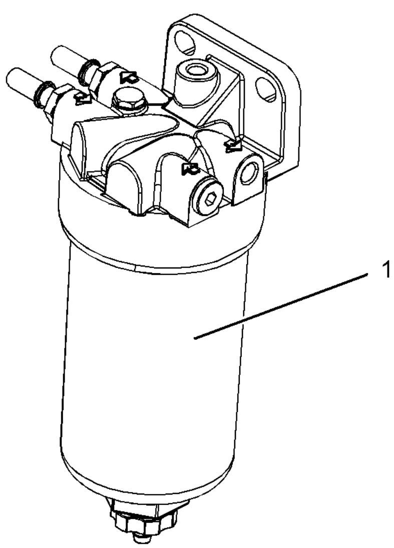

Illustration 57 g03723527

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

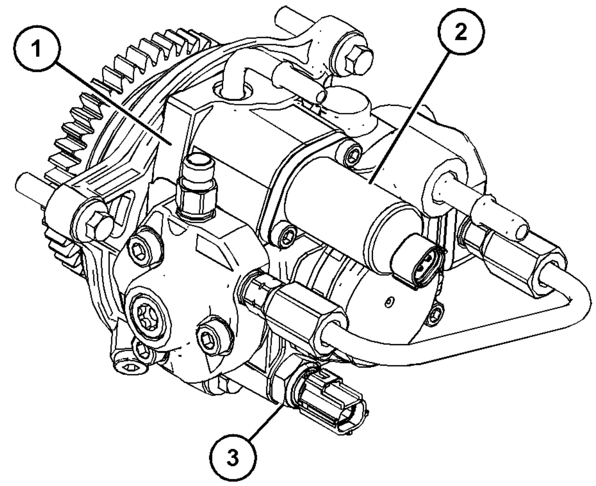

Illustration 58 g06148132

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 rear gear train at engine speed. The fuel injection pump (1) has two plungers that are driven by a camshaft. The fuel injection pump (1) delivers a volume of fuel two 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 (2) 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 (3) measures the temperature of the fuel. The ECM receives the signal from the fuel temperature sensor (3). 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

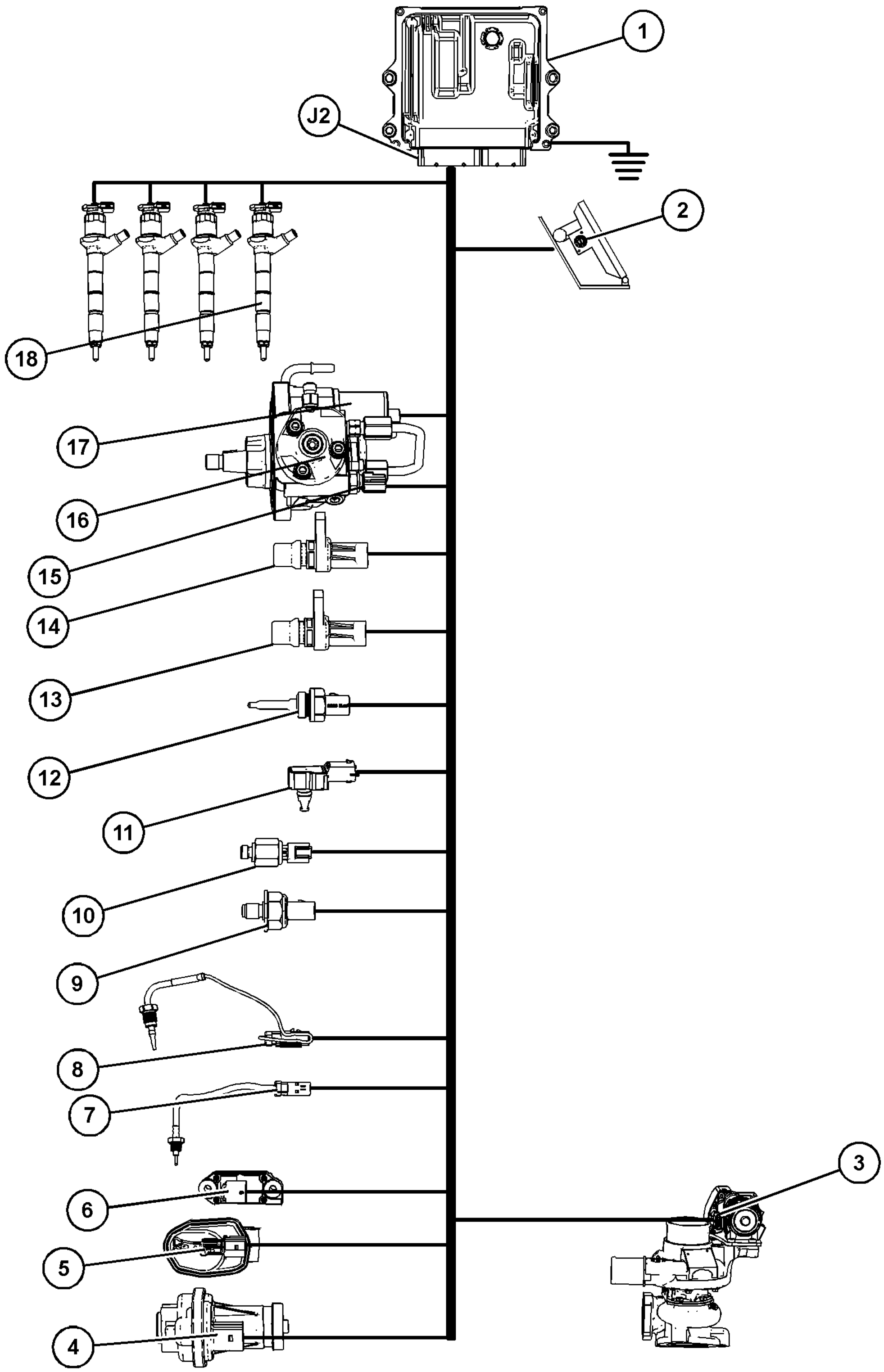

Illustration 59 g06359271

Typical example of the electrical control system for the fuel system

(1) Electronic Control Module (ECM)
(2) Throttle position sensor
(3) Turbocharger electronic wastegate
(4) Exhaust gas valve (NRS)
(5) Inlet throttle valve (NRS)
(6) Differential pressure sensor (NRS)

(7) Outlet temperature sensor (NRS)
(8) Inlet temperature sensor (NRS)
(9) Fuel pressure sensor
(10) Engine oil pressure switch
(11) Inlet manifold air pressure and temperature sensor
(12) Coolant temperature sensor
(13) Secondary speed/timing sensor
(14) Primary speed/timing sensor
(15) Fuel temperature sensor
(16) Fuel injection pump
(17) Suction control valve for the fuel injection pump
(18) Electronic unit injectors

The ECM determines the quantity, timing, and pressure of the fuel 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.

Electronic Unit Injectors

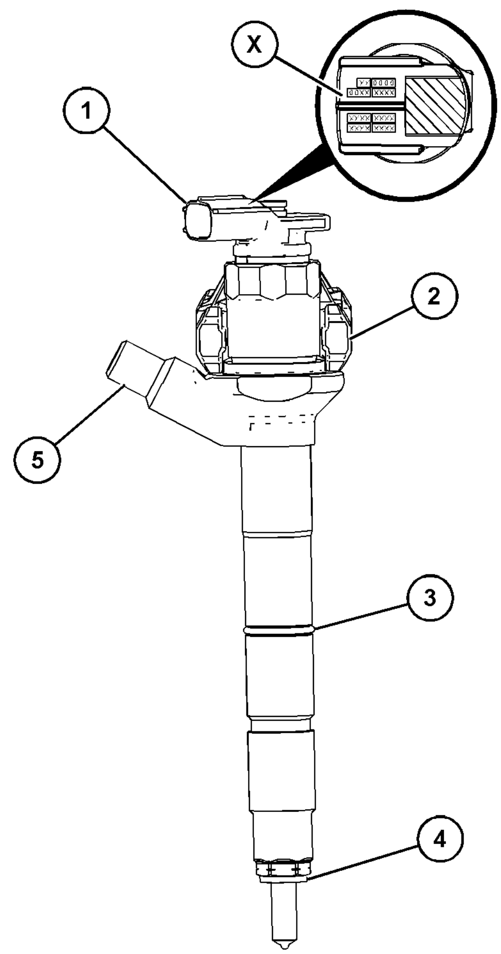

Illustration 60 g06148160

Typical example

(1) Electrical connections
(2) Clamp
(3) O-ring
(4) Combustion washer
(5) 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 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.

The pressurized fuel from the fuel manifold is injected into the combustion chamber by the electronic unit injector. The desired injection timing, injection quantity, and injection pattern are controlled by the ECM depending on engine operating conditions.

The injection process is controlled using a two-way valve. The supply of electrical current to the solenoid controls the two-way valve. When the two-way valve is not energized the out orifice is closed and there is no fuel leak. In this condition the pressure in the control chamber and the pressure at the nozzle needle are the same. In this condition the spring pressure on the command piston keeps the needle closed.

When an injection of fuel is required, the electrical current from the ECM charges the solenoid, which in turn energizes the two-way valve and lifts the valve. When the valve lifts the valve uncovers the out orifice. The fuel starts to flow and reduces the pressure in the control chamber. When the pressure difference at the nozzle needle exceeds the combined pressure of the control chamber pressure and the spring pressure, the nozzle lifts to start the injection process. The fuel coming out of the nozzle is atomized and injected as a very fine spray.

When the injection needs to be stopped, the electrical current to the solenoid is cut off and the pressure difference in the control chamber starts increasing. The increased pressure difference stops the injection process when the combined pressure exceeds the nozzle pressure.

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 (Rail)

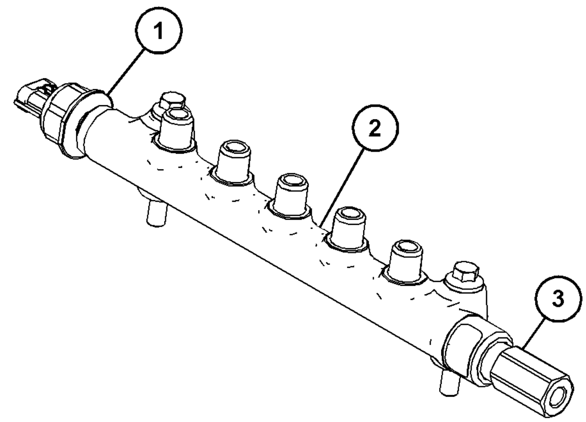

Illustration 61 g06148128

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 (1) measures the fuel pressure in the fuel manifold (3).

The pressure relief valve (3) 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.

i07925856

Electronic Control System

SMCS Code: 1900

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 these items are electronically controlled. There are also several engine sensors. The engine is equipped with an electronically controlled wastegate system 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 the operating maps and customer-selected parameters.

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
- Electronic actuated Turbocharger Wastegate (EWG)
- Electronic unit injectors
- Valve for the NOx Reduction System (NRS)
- Throttle valve for the NOx Reduction System (NRS)

Sensor Locations for the C3.6 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.

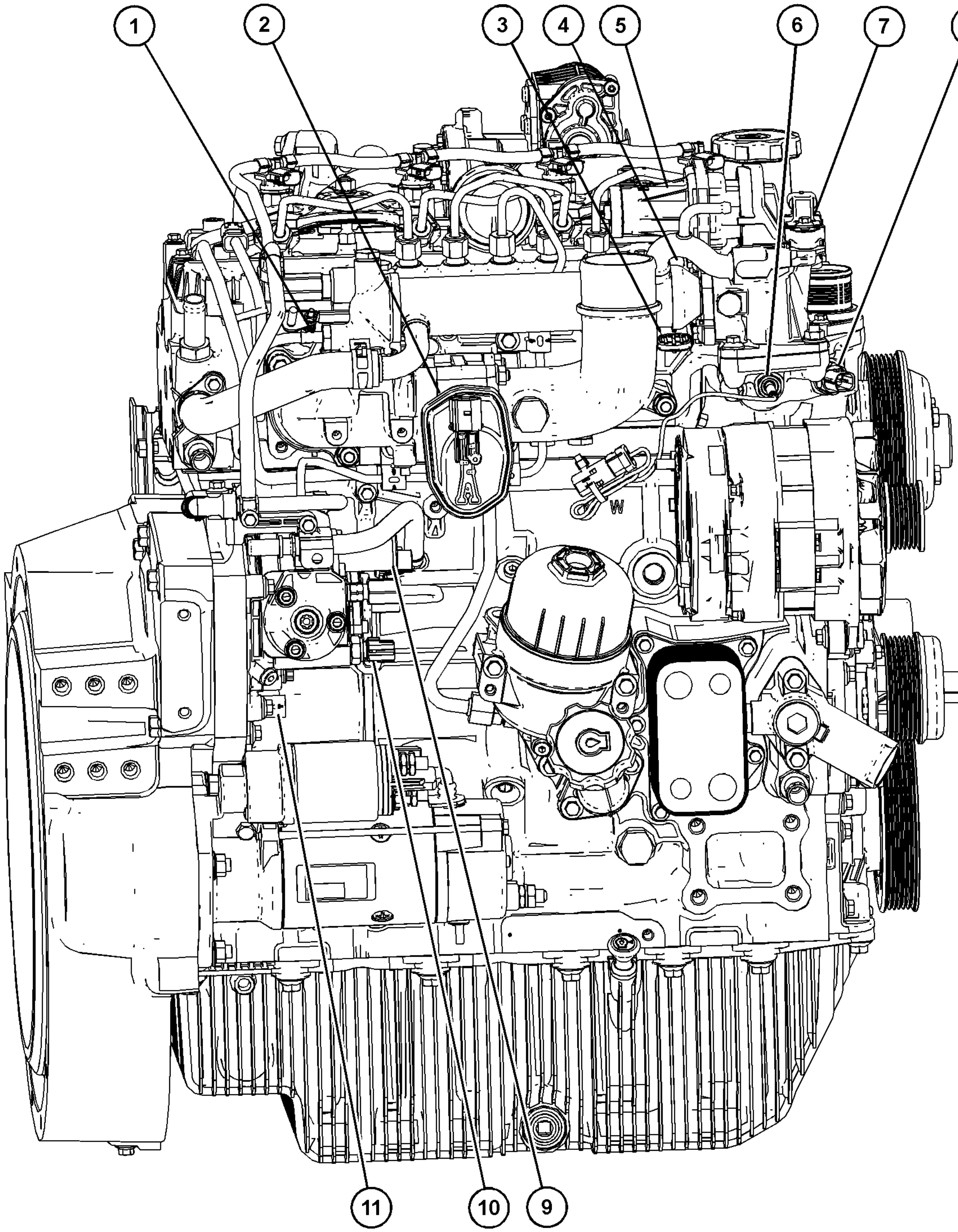

Illustration 62 g06163628

Typical example

(1) Temperature sensor for the NOx Reduction System (NRS)
(2) Throttle valve for the NOx Reduction System (NRS)
(3) Inlet manifold temperature and pressure sensor
(4) Fuel pressure sensor
(5) Exhaust gas valve for the NOx Reduction System (NRS)
(6) Temperature sensor for the NOx Reduction System (NRS)
(7) Differential Pressure Sensor for the NOx Reduction System (NRS)
(8) Coolant temperature sensor
(9) Suction control valve for the fuel injection pump

(10) Fuel temperature sensor
(11) Camshaft speed/timing sensor

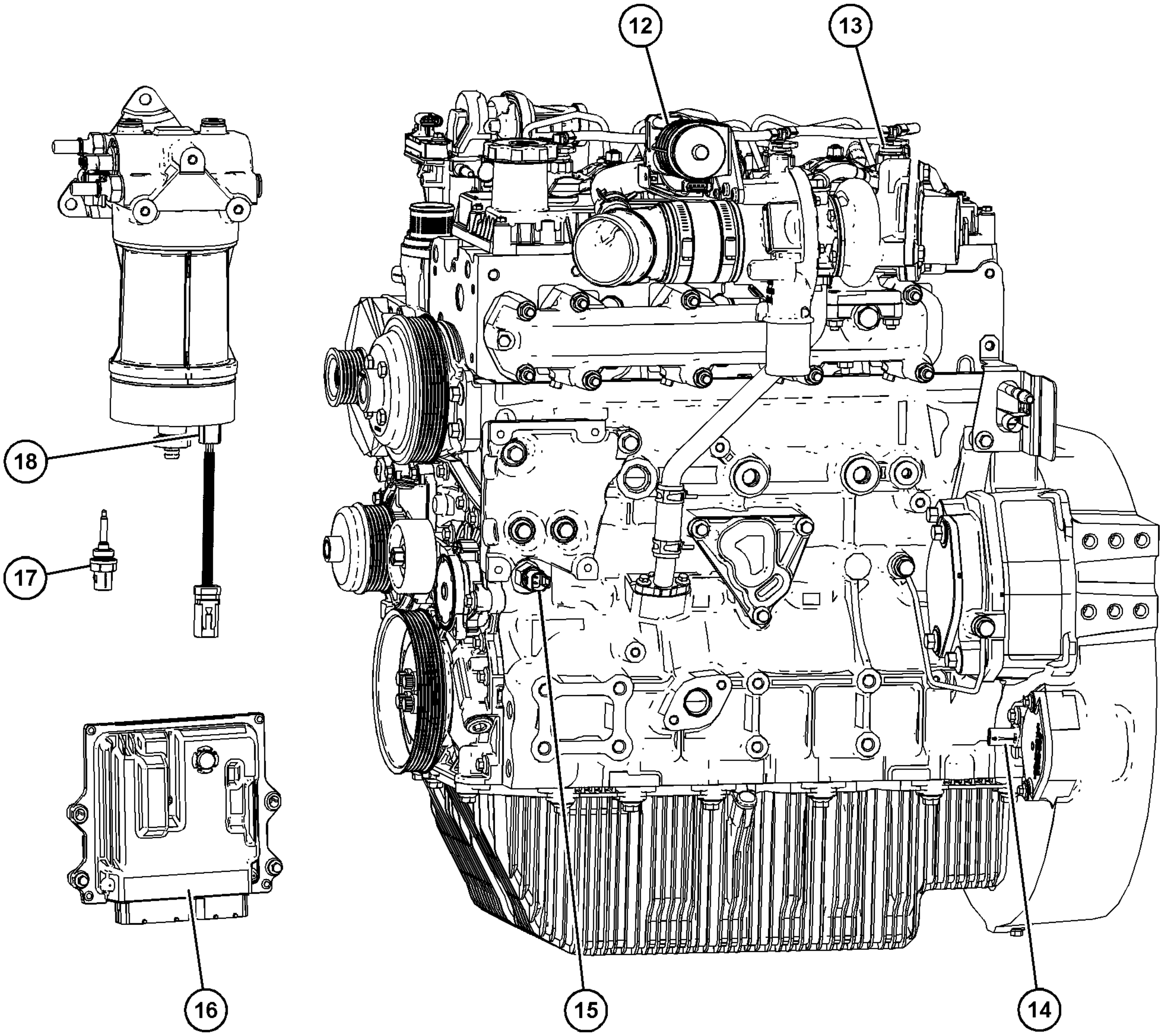

Illustration 63

g06163694

Typical example

(12) Electronic actuated Turbocharger Wastegate (EWG)
(13) Electronic unit injector
(14) Crankshaft speed/timing sensor
(15) Engine oil pressure switch
(16) Electronic Control Module (ECM)
(17) Inlet air temperature sensor
(18) Water in fuel switch

Sensor Locations for the C2.8 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.

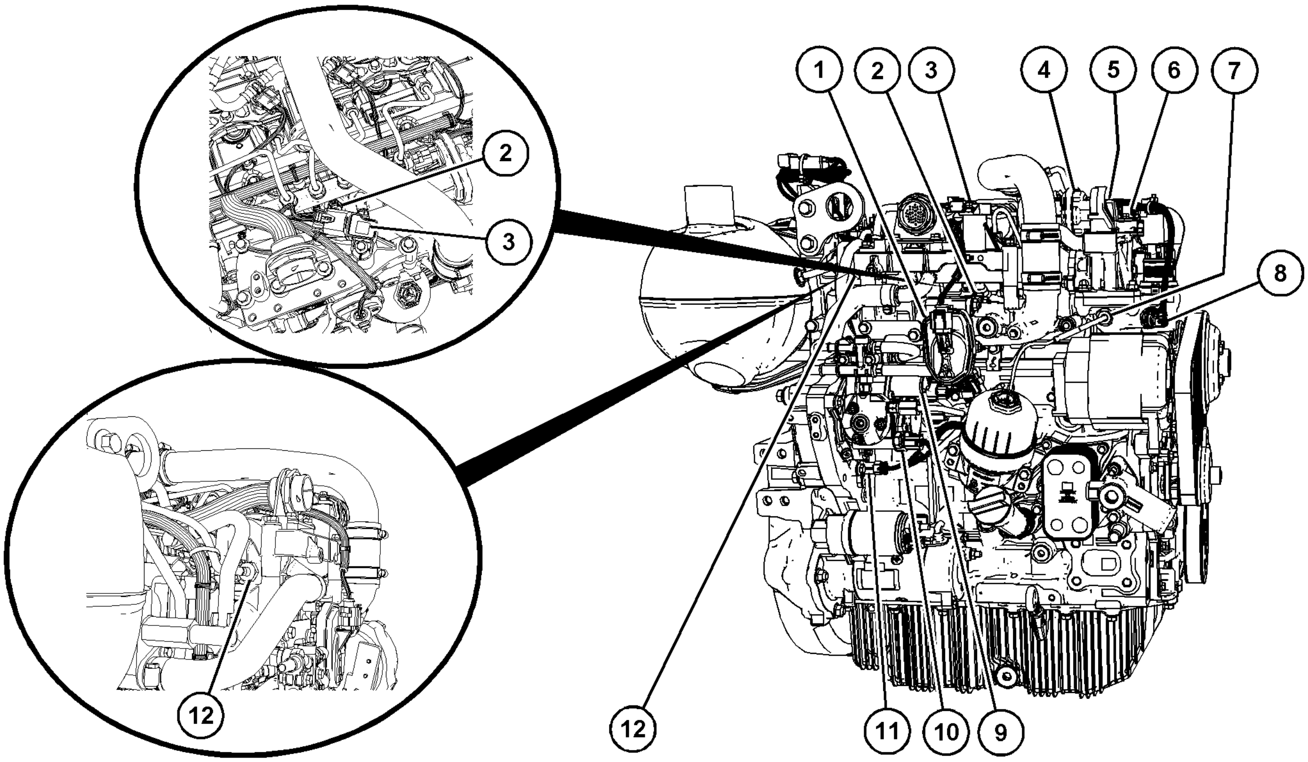

Illustration 64 g06481703

Typical example

(1) Throttle valve for the NOx Reduction System (NRS)
(2) Inlet manifold temperature sensor
(3) Inlet manifold pressure sensor
(4) Exhaust gas valve for the NOx Reduction System (NRS)
(5) Fuel pressure sensor
(6) Differential Pressure Sensor for the NOx Reduction System (NRS)
(7) Temperature sensor for the NOx Reduction System (NRS)
(8) Coolant temperature sensor
(9) Suction control valve for the fuel injection pump
(10) Fuel temperature sensor
(11) Camshaft speed/timing sensor
(12) Temperature sensor for the NOx Reduction System (NRS)

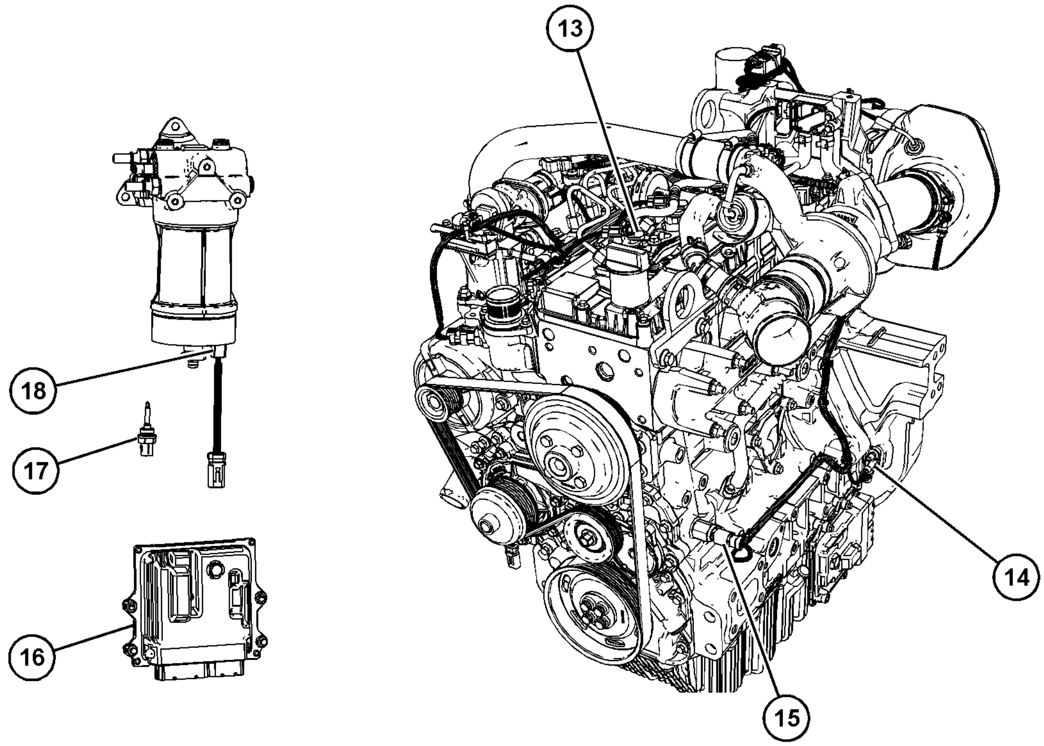

Illustration 65 g06481709

Typical example

(13) Electronic unit injector
(14) Crankshaft speed/timing sensor
(15) Engine oil pressure switch
(16) Electronic Control Module (ECM)
(17) Inlet air temperature sensor
(18) Water in fuel switch

Sensor Locations for the Clean Emissions Module

DOC, DPF, and SCR

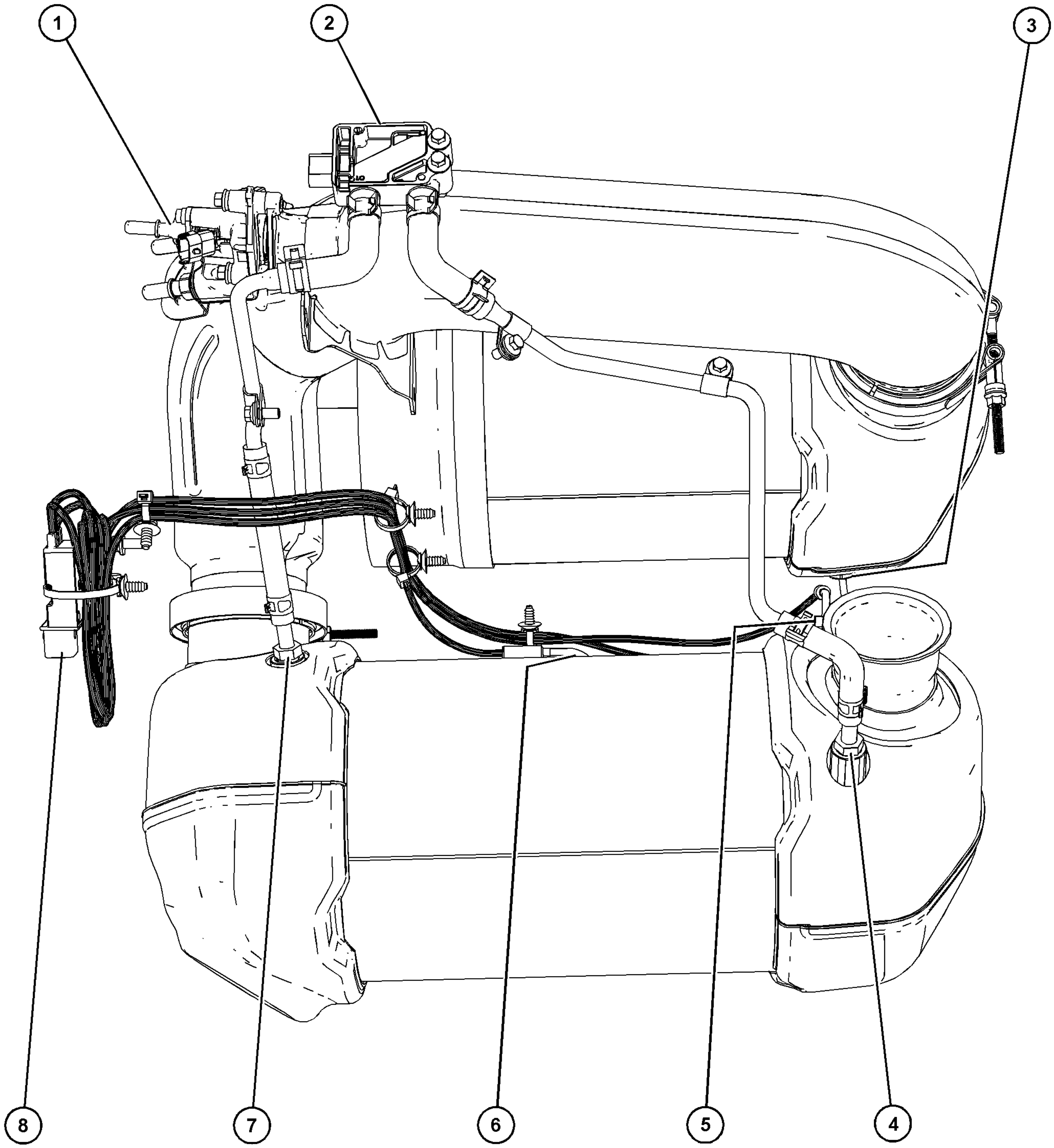

Illustration 66 g06163533

Typical example

(1) DEF Injector
(2) SCR temperature sensor probe
(3) DOC temperature sensor probe
(4) Delta pressure sensor connection
(5) DOC, DPF, and SCR temperature sensor
(6) DPF temperature sensor probe

(7) Delta pressure sensor (8) Delta pressure sensor connection

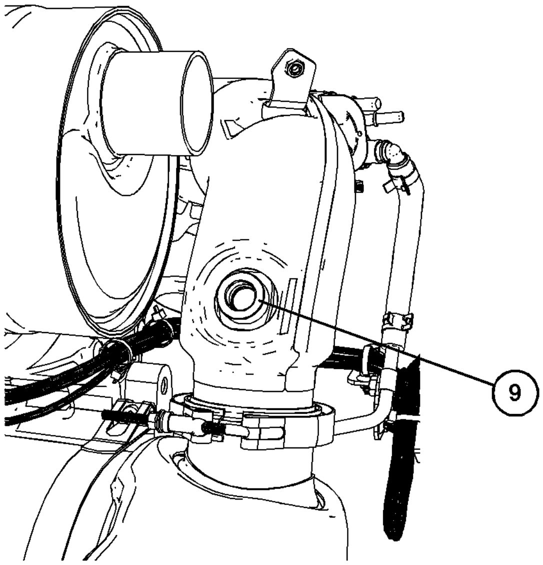

Illustration 67 g06163535

Typical example

(9) NOx sensor location

DOC and DPF

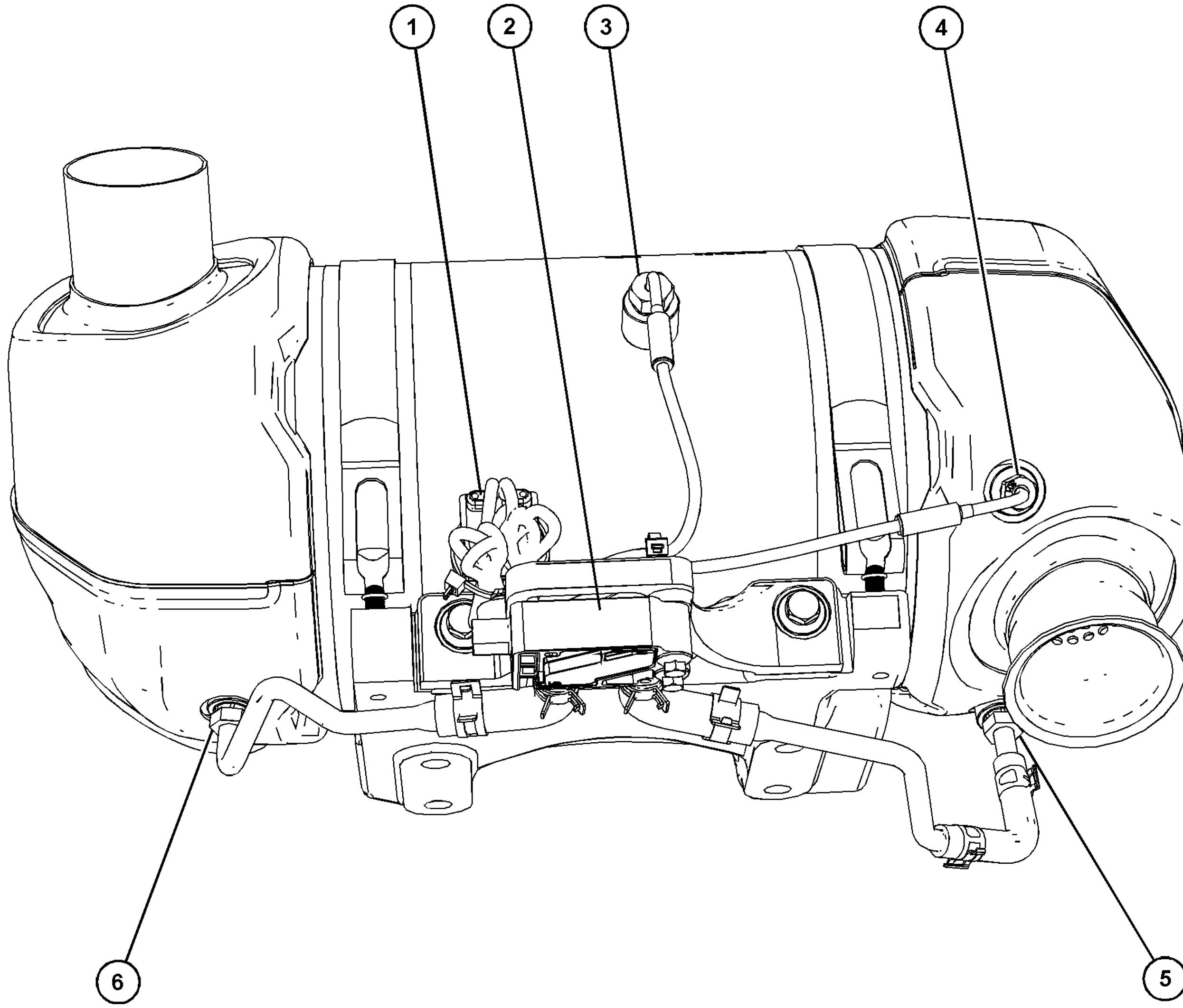

Illustration 68 g06367555

Typical example

(1) DOC and DPF temperature sensor
(2) Delta pressure sensor
(3) DPF temperature sensor probe
(4) DOC temperature sensor probe
(5) Delta pressure sensor connection
(6) Delta pressure sensor connection

ECM

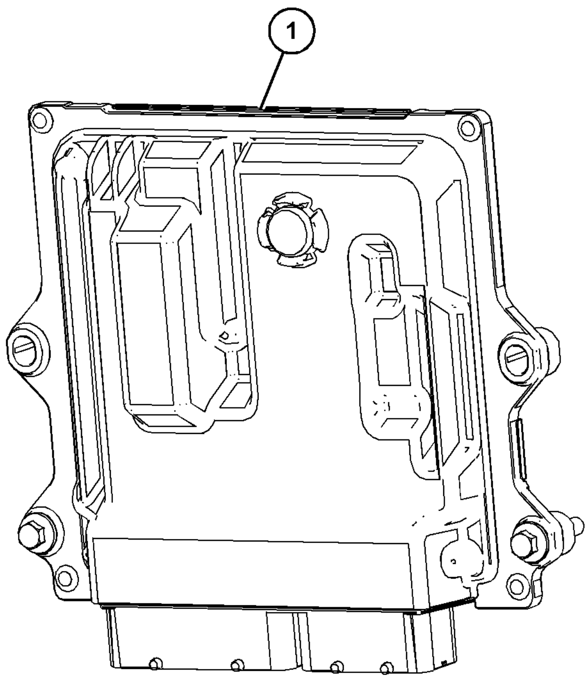

Illustration 69 g06163526

Typical example

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

The electronic system consists of the ECM, the engine sensors, and inputs from the parent machine. The ECM is the computer. The personality module is the software for the computer. The personality module contains the operating maps. The operating maps define the following characteristics of the engine:

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

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

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

Engine Speed

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

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

Timing Considerations

Once the ECM has determined the amount of fuel that is required, the software must determine the timing of the fuel injection. Fuel injection timing is determined by the ECM after considering input from the following components:

- Engine coolant temperature sensor
- The sensor for the inlet manifold temperature and pressure

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

The ECM adjusts injection timing and fuel pressure for the best engine performance, the best fuel economy, and the best control of exhaust emissions.

Fuel Injection

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

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

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

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

The ECM controls the following characteristics:

- Boost pressure
- Operation of the NOx reduction system

Diagnostic Codes

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

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

Event Codes

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

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 Caterpillar dealers. 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

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

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

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

The inlet manifold temperature and pressure sensor is an active sensor.

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

The operating range of the boost pressure sensor is 33 to 400 kPa (5 to 58 psi).

Temperature Sensors

The inlet manifold 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° to 150°C ((−72° to 270°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.

Pressure Switch

The engine oil pressure switch 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 engine oil pressure switch is operated when the pressure is between 62 to 90 kPa (9 to 13 psi).

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Glossary of Electronic Control Terms

SMCS Code: 1900

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 Code” in this glossary.

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

Air-To-Air Aftercooler – An air-to-air aftercooler is a device that is used on turbocharged engines 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.

Ammonia Oxidizing (AMOX) catalyst – The AMOX catalyst removes any residual ammonia from the exhaust gas stream after completion of the Selective Catalytic Reduction (SCR) process.

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

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

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

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

CAN Data Link (see also J1939 CAN Data Link) – The CAN Data Link is a serial communications port that is used for communication with other microprocessor-based devices.

Clean Emissions Module (CEM) – Refer to “Aftertreatment” .

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

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

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

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

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

Customer Specified Parameters – A customer specified parameter is a parameter that can be changed in the ECM with the Electronic Service Tool. A customer specified parameter 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 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 lamp. The diagnostic lamp is used to warn the operator of the presence of an active diagnostic code. The lamp may not be included in all applications.

Diesel Exhaust Fluid (DEF) – DEF is a mixture of urea and water that is injected into the exhaust stream. The heat in the exhaust gas releases the ammonia in the DEF. The ammonia reacts with the oxides of nitrogen (NOx) in the SCR filter to produce nitrogen and water vapor.

Diesel Oxidation Catalyst – 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 fractions (SOF) of particulate matter.

Diesel Particulate Filter – The Diesel Particulate Filter filters particulates from the exhaust gases. The hot exhaust gases burn off the particulates. This process prevents the DPF from becoming blocked with soot.

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 the engines. The connectors are manufactured by Deutsch .

Duty Cycle – Refer to “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.

Engine Control Module (ECM) – The ECM is the control computer of the engine. The ECM provides power to the electronics. The ECM monitors data that is input from the sensors of the engine. The ECM acts as a governor to control the speed and the power of the engine.

Electronic Service Tool – The electronic service tool allows a computer (PC) to communicate with the ECM.

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

Engine Oil Pressure Switch – The engine oil pressure switch provides a warning of low engine oil pressure. The switch controls a warning lamp at the operator position.

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 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 Rail Pump. This is a device that supplies fuel under pressure to the fuel rail (high-pressure fuel rail).

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

Fuel Manifold (Rail) Pressure Sensor – The fuel rail pressure sensor sends a signal to the ECM that depends on the pressure of the fuel in the fuel rail.

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

The 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 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.

Full Torque Setting (FTS) – The FTS is the parameter that represents the adjustment for the engine torque. This adjustment is made at the factory to fine-tune the fuel system. This adjustment is made with the FLS. 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 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 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 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 unit of frequency in cycles per second.

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

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

Injector Trim Codes – Injector trim codes are 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.

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 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 Code” for more information.

NOx Reduction System – The NOx Reduction System recycles a portion of the exhaust gases back into the inlet air. The recirculation reduces the oxides of nitrogen (NOx) in the exhaust gases. The recycled exhaust gas passes through a cooler before being introduced into the inlet air.

OEM – OEM is an abbreviation for the Original Equipment Manufacturer. This is the manufacturer of the 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.

Oxides of Nitrogen (NOx) – NOx is a component of the exhaust gases that are produced by the combustion process. NOx is reduced by the NRS system and is further reduced by the SCR component of the aftertreatment system.

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 to change some parameters (Factory Passwords). Refer to Troubleshooting, “Factory Passwords” for more information.

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.

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

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

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

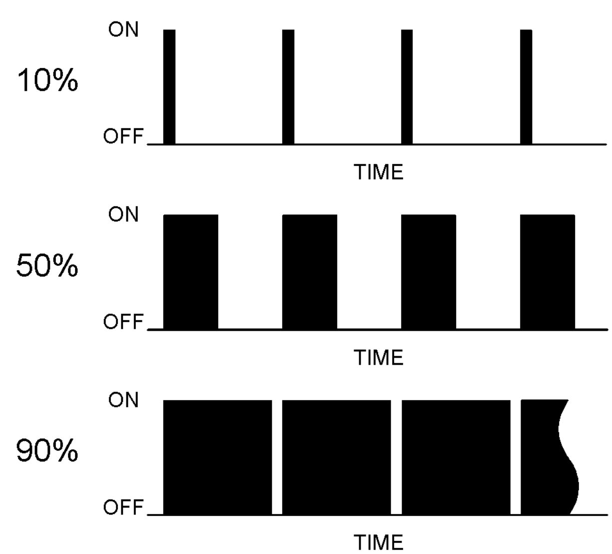

Illustration 70 g01858875

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 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.

Selective Catalytic Reduction (SCR) – SCR is a process for reducing the oxides of nitrogen (NOx) in the exhaust gases. Ammonia is introduced into the exhaust and reacts with the exhaust gases in the SCR catalyst to convert the NOx into nitrogen and water vapor.

Sensor – A sensor is a device that is used to detect the current value of pressure or temperature, or mechanical movement. The information that is detected is converted 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 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 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 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 – The wait to start lamp is a lamp that is included in the cold starting aid circuit to indicate when the wait to start period is active. The lamp will go off when the engine is ready to be started. The glow plugs may not have 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.

Testing And Adjusting Section

Fuel System

i04081693

Fuel System - Inspect

SMCS Code: 1250-040

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.

i07787861

Air in Fuel - Test

SMCS Code: 1280-081

Table 1

Required Tools			
Tool	Part Number	Part Description	Qty
A	2P-8278	Tube As (Sight Gauge)	1

NOTICE

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

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

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

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

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

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

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

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

5. Start the engine. Refer to Operation and Maintenance Manual, "Starting the Engine" for the correct procedure. Check if the problem has been resolved. Run the engine at low idle speed for 5 minutes.

6. Stop the engine. Refer to Operation and Maintenance Manual, "Stopping the Engine" for the correct procedure.

⚠ WARNING

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

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

- Elbows
- Relief valves
- Check valves
- Connections

8. Prime the fuel system. Refer to Operation and Maintenance Manual, “Fuel System - Prime” for the correct procedure.

9. Start the engine. Refer to Operation and Maintenance Manual, “Starting the Engine” for the correct procedure. Refer to steps 9a to 9h 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 gauge. 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. If excessive air is seen in the sight gauge in the fuel return line, install a second sight gauge at the inlet to the fuel filter/water separator. If a second sight gauge is not available, move the sight gauge from the fuel return line and install the sight gauge at the inlet to the fuel filter/water separator.

   e. Run the engine a low idle speed.

   f. Run the engine for 2 minutes. There should be no air in the fuel flow through the sight gauge. 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.

   g. The presence of large bubbles or a continuous stream of bubbles indicates a leak.

Note: If excessive air is seen at the inlet to the fuel filter/water separator, air is entering through the suction side of the fuel system.

   h. Investigate potential leaks and rectify any potential leaks in the low-pressure fuel system. If necessary, replace the low-pressure fuel lines.

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

11. Prime the fuel system. Refer to Operation and Maintenance Manual, “Fuel System - Prime” for the correct procedure.

i06909594

Finding Top Center Position for No. 1 Piston

SMCS Code: 1105-531

Table 2

Required Tools			
Tool	Part Number	Part Description	Qty
A(1)	-	Crankshaft Turning Tool	1
A(2)	-	Housing	1
	-	Engine Turning Tool	1
B	136-4632	Timing Pin (Camshaft)	1
	268-1966	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 plug from the cylinder block. The plug is located under the camshaft speed/timing sensor. If necessary, use Tooling (A) to rotate the engine in the normal direction of rotation.

2. Install Tooling (B) into the hole in the cylinder block. Use Tooling (B) to locate the camshaft gear in the correct position.

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

i06909500

Fuel Injection Timing - Check

SMCS Code: 1251-036

Table 3

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A(1)	-	Crankshaft Turning Tool	1
A(2)	-	Housing	1
	-	Engine Turning Tool	1
B	136-4632	Timing Pin (Camshaft)	1
	268-1966	Adapter	1
C	364-9107	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:

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

1. If necessary, install the fuel injection pump. Refer to Disassembly and Assembly, "Fuel Injection Pump - Install" for the correct procedure.

2. Remove the plug from the cylinder block. The plug is located under the camshaft speed/timing sensor. If necessary, use Tooling (A) to rotate the engine in the normal direction of rotation.

3. Install Tooling (B) into the hole in the cylinder block. Use Tooling (B) to locate the camshaft gear in the correct position.

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

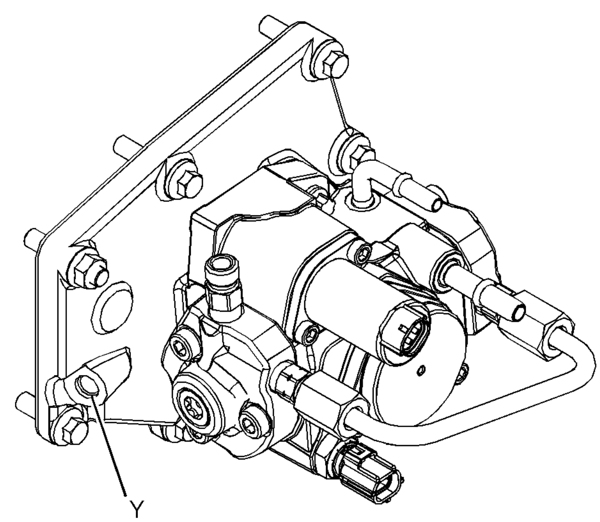

Illustration 71 g02337216

Typical example

4. Install Tooling (C) into hole in adapter plate at Position (Y). Use Tooling (A) to rotate the crankshaft until Tooling (C) locates into the slot in the gear for the fuel injection pump.

5. Remove Tooling (C) from the adapter plate.

6. Remove Tooling (B) from the cylinder block.

i04026058

Fuel Quality - Test

SMCS Code: 1280-081

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

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

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

1. Determine if water and/or contaminants are present in the fuel. Check the water separator. Drain the water separator, if necessary. A full fuel tank minimizes the potential for overnight condensation.

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

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

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

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

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

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

i06909604

Fuel System - Prime
(Electric Fuel Priming Pump)

SMCS Code: 1258-548

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 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 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 to purge air from the fuel system. This procedure is not required.**

After the engine has stopped, you must wait for 10 minutes to allow the fuel pressure to be purged from the high-pressure fuel lines before any service or repair is performed on the engine fuel lines. If necessary, perform minor adjustments. Repair any leaks from the low-pressure fuel system and from the cooling, lubrication, or air systems. Replace any high-pressure fuel line that has leaked. Refer to Disassembly and Assembly Manual, “Fuel Injection Lines - Install”.

If you inspect the engine in operation, always use the correct inspection procedure 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”.

i07552212

Fuel System - Prime (Mechanical Fuel Priming Pump)

SMCS Code: 1258-548

⚠ WARNING

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

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

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

NOTICE

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

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

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

Use the following procedures 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. Operate the hand priming pump. Count the number of operations of the pump. After approximately 80 depression of the pump stop.

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

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

4. 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 to purge air from the fuel system. This procedure is not required.**

After the engine has stopped, you must wait for 10 minutes 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 lines that have leaked. Refer to Disassembly and Assembly, “Fuel Injection Lines - Install”.

If you inspect the engine in operation, always use the correct inspection procedure 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”.

i06912989

Rear Gear Group - Time

SMCS Code: 1206-531

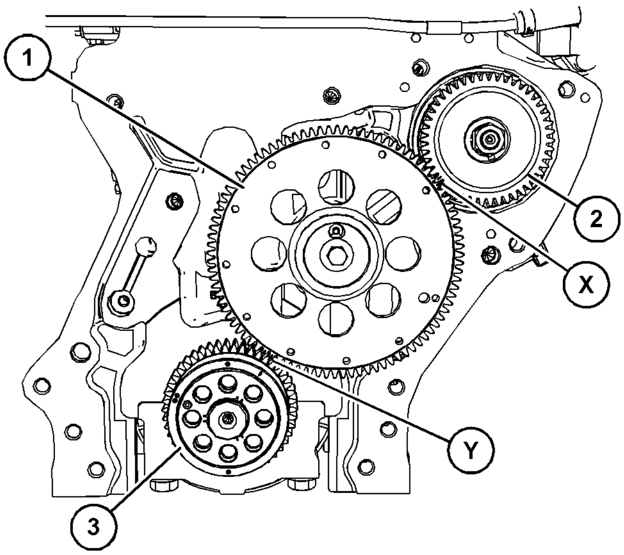

Illustration 72 g06357186

Typical example

Note: The flywheel housing has been removed for clarity.

1. If necessary, rotate the crankshaft in the normal direction of rotation.
2. Install the camshaft gear (1). Refer to Disassembly and Assembly, Gear Group (Rear) - Remove and Install for the correct procedure. Ensure timing marks on camshaft gear (1) in Position (Y) are correctly aligned with the timing mark on crankshaft gear (3).
3. Install the fuel injection pump and gear assembly (2). Refer to Disassembly and Assembly for the correct procedure. Ensure timing marks on camshaft gear (1) in Position (X) are correctly aligned with the timing mark on fuel injection pump gear (2).

Air Inlet and Exhaust System

i06910893

Air Inlet and Exhaust System - Inspect

SMCS Code: 1050-040

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 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) - 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

1. 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, 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 inside the valve mechanism cover for debris. Ensure that all debris is removed from the cover.

Note: Do not attempt to remove the separator from the cover.

i07851839

Turbocharger - Inspect

SMCS Code: 1052-040

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 (if equipped)

Inspection of the Compressor and the Compressor Housing

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

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

NOTICE

A high proportion of engine oil will be removed from the blow-by gas by the oil separator in the valve mechanism cover. In a closed breather system, the presence of some oil in the breather connection to the air induction systems and downstream of the compressor in air to air charge cooler connections after service is to be expected.

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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) - 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. Check that the outlet for the crankcase breather is clean and free of obstructions. If necessary, clean the outlet for the crankcase breather.

d. Remove the pipe for the oil drain. Inspect the drain opening. Inspect the oil drain line. Inspect the area between the bearings of the rotating assembly shaft. Look for the oil sludge. Inspect the oil drain hole for the oil sludge. Inspect the oil drain line for the oil sludge in the drain line. If necessary, clean the oil drain line. Replace the oil drain line if there is any sign of damage to the oil drain line.

e. If steps 3a through 3d did not reveal the source of the oil leakage, the turbocharger has internal damage. Replace the turbocharger. Refer to Disassembly and Assembly for the correct procedures.

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 the turbocharger. If there is no damage, go to step 2. Inspect the turbine wheel for the carbon and other foreign material. Inspect turbine housing for carbon and foreign material. Replace the turbocharger, if necessary. If there is no buildup of carbon or foreign material, 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 turbine wheel should not rub turbine wheel housing. Replace the turbocharger if the turbine wheel rubs turbine housing. If there is no rubbing or scraping, go to step 3.

3. Inspect the turbine and turbine housing for oil leakage. Inspect the turbine and turbine housing 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 3a. Otherwise go to “Check the Wastegate for Proper Operation”.

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

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

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

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

e. If steps 3a through 3d did not reveal the source of the oil leakage, turbocharger has internal damage. Replace the turbocharger. Refer to Disassembly and Assembly for the correct procedures.

Inspection of the Wastegate (If equipped)

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.

For more information about the operation of the wastegate actuator, refer to Systems Operation, Testing and Adjusting, Air Inlet and Exhaust System.

The following levels of boost pressure indicate a potential problem with the wastegate actuator or wastegate regulator:

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

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

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

Check the Wastegate for Proper Operation

Table 4

Required Tools			
Tool	Part Number	Part Description	QTY
A	8T - 5096	Dial Indicator Group	1

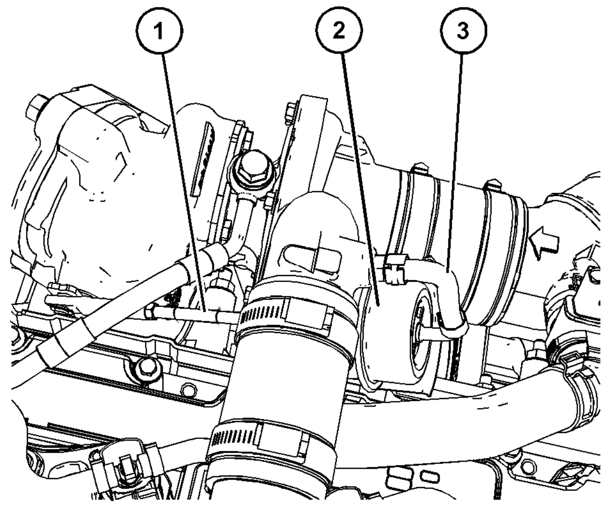

Illustration 73 g06457169

Typical example

1. Disconnect the air line (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 3 to repeat the pressure test.

6. If the air pressure is correct, remove the air supply. Remove Tooling (A). Connect the air line (3).

i07788510

Exhaust Cooler (NRS) - Test

SMCS Code: 1061; 1087; 108C-081

Table 5

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	1U-5470	Engine Pressure Gp	1

Refer to Special Instruction, SEHS8907, "Using The 1U-5470 Engine Pressure Group".

Air Under Water Leak Test Procedure.

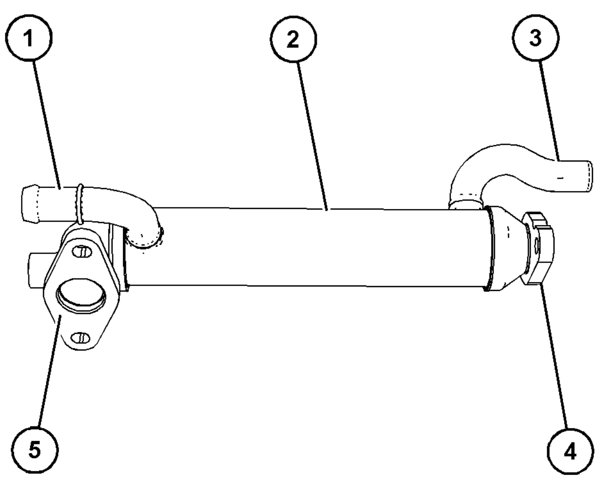

Illustration 74 g06357792

Typical example

1. Follow steps 1a to 1i to test the coolant side of the exhaust gas cooler (NRS).

a. Plug the coolant inlet (3) of the exhaust gas cooler (NRS) (2).

b. Plug the coolant outlet port (1) 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 Tooling (A) 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 to check for leakage. If the exhaust gas cooler (NRS) does leak, the exhaust gas cooler (NRS) should be replaced.

2. Follow steps 2a to 2i to test the gas side of the exhaust gas cooler (NRS).

a. Plug the gas inlet (4) of the exhaust gas cooler (NRS) (2).

b. Plug the gas outlet port (5) 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 Tooling (A) 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 to check for leakage. If the exhaust gas cooler (NRS) does leak, the exhaust gas cooler

(NRS) should be replaced.

i07552526

Compression - Test

SMCS Code: 1215

The cylinder compression test should only be used 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 be conducted 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.

1. Remove the glow plug. Refer to Disassembly and Assembly, “Glow Plugs - Remove and Install” for the correct procedure.
2. Electrically disconnect the electronic unit injectors. Alternatively, use the electronic service tool to enable the “Injector Disable Override” to disable the electronic unit injectors from activating.
3. Install a suitable gauge for measuring the cylinder compression in the hole for the glow plug.
4. Remove the fuse for the glow plugs.
5. Operate the starting motor to turn the engine. Record the maximum pressure which is indicated on the compression gauge.
6. Repeat steps 3 and 5 for all cylinders.
7. Electrically connect the electronic unit injectors. Alternatively, use the electronic service tool to disable the “Injector Disable Override” to enable the electronic unit injectors.
8. Install the fuse for the glow plugs.

i07788514

Engine Valve Lash - Inspect

SMCS Code: 1102-040

Table 6

Required Tools			
Tool	Part Number	Part Description	Qty
A(1)	-	Crankshaft Turning Tool	1
A(2)	-	Housing	1
	-	Engine Turning Tool	1
B	136-4632	Timing Pin (Camshaft)	1
	268-1966	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.

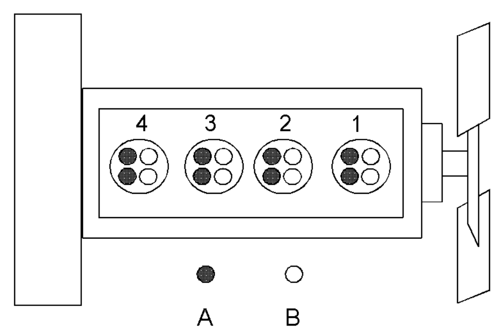

Illustration 75 g03692044

Cylinder and valve location

(A) Exhaust valves
(B) Inlet valves

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

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

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

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

- Issues with the hydraulic lash adjusters

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

Valve Lash Check

WARNING

Accidental engine starting can cause injury or death to personnel.

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

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

2. Use Tooling (A) to rotate the crankshaft until the number one piston is at the top center position. Refer to Systems Operation, Testing and Adjusting, Finding Top Center Position for No. 1 Piston for the correct procedure.

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

4. If there is an 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 against the pushrod. The rocker arm should rotate as the pushrod is pushed up by the recovery of the hydraulic lifter. Once all motion has ceased test again for an engine valve lash. There should be no engine valve lash.

5. Remove Tooling (B) from the camshaft. Use Tooling (A) to rotate the crankshaft in a clockwise direction. The crankshaft should be rotated 360 degrees. Install Tooling (B) to the camshaft.

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

7. If there is an 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 against the pushrod. Monitor the rocker arm for movement. The rocker arm should rotate as the pushrod is pushed up by the recovery of the hydraulic lifter. Once all motion has ceased test again for an engine valve lash. There should be no engine valve lash.

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

i03996952

Valve Depth - Inspect

SMCS Code: 1105-040

Table 7

Required Tools			
Tool	Part Number	Part Description	Qty
A	8T-0455	Liner Projection Tool Group	1

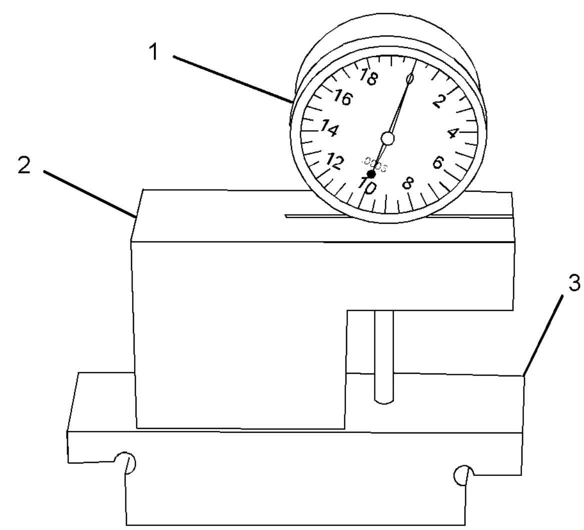

Illustration 76 g01343897

(1) Dial indicator
(2) Gauge body
(3) Gauge block

1. Use the Tooling (A) to check the depths of the inlet valves and the exhaust valves below the face of the cylinder head. Use the gauge block (3) to zero the dial indicator (1).

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

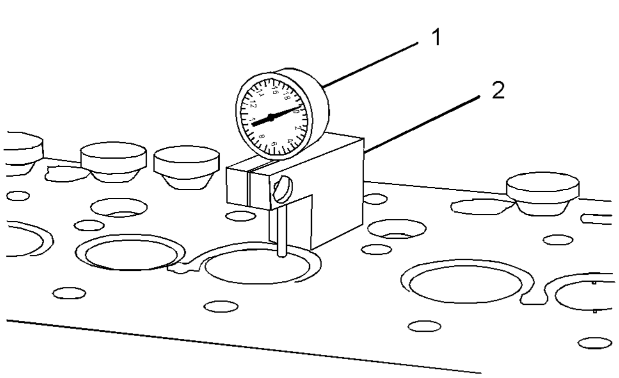

Illustration 77 g01343900

Typical example

Measurement of the valve depth

(1) Dial indicator
(2) Gauge body

3. Position gauge body (2) and dial indicator (1) in order to measure the valve depth. Measure the depth of the inlet valve and the exhaust valve before the valve springs are removed.

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

5. 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".

6. 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.

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

i07552211

Valve Guide - Inspect

SMCS Code: 1104-040

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

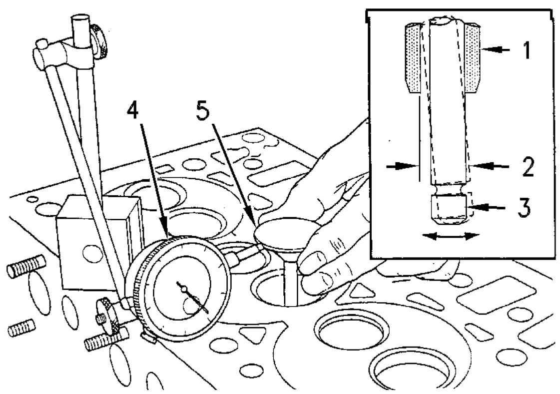

Illustration 78 g00314806

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 pressed into the cylinder head. When new valve guides(1) are installed, new valves and new valve seat inserts must be installed. For more information, contact your distributor or your dealer.

i06832352

Diesel Exhaust Fluid Quality - Test

SMCS Code: 108K-081

Required Tooling

Table 8

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	431-7087	Refractometer (DEF)	1
B	162-5791	Towel	1
C	169-8373	Fluid Sampling Bottle	2
D	1U-5718	Vacuum Pump	1
E	4C-4600	Container	1
F	1U-7648	Tube Cutter	1
G	466-8796	Test Strip	1
H	1U-8757	Tube	Length as needed
J	457-6144	Tool As - Pliers	1

Test Procedure

DEF Removal Procedure

Note: For Diesel Exhaust Fluid (DEF) handling and storage procedures, refer to Operation and Maintenance Manual, Fluid Recommendations for more information.

1. Clean the DEF tank of all debris prior to removal of any component. Contamination of the DEF can affect results of testing.

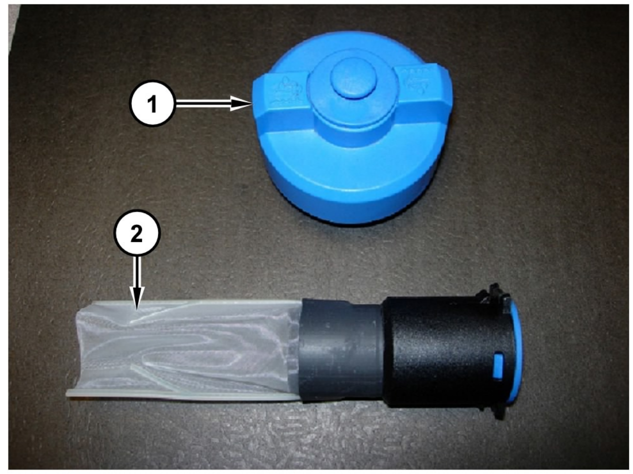

Illustration 79 g03706721

Typical example

(1) DEF tank fill cap
(2) Filter screen

2. Remove fill cap (1) from the Diesel Exhaust Fluid (DEF) tank.

3. Use Tooling (J) to press and release the tabs. With the tabs released, remove the filter screen (2) from DEF tank neck adapter.

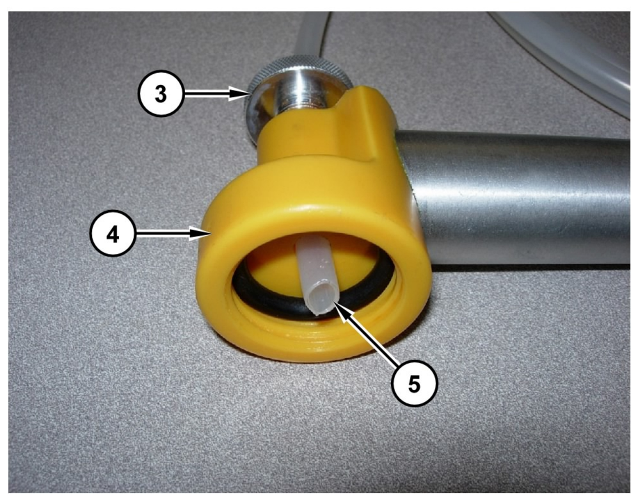

Illustration 80 g03706724

Typical example

(3) Vacuum pump nut
(4) Tooling (D)
(5) Tooling (H)

Note: To ensure that the DEF sample is not contaminated during extraction, use a new piece of Tooling (H) every time this procedure is performed.

4. Remove Tooling (H) from the plastic bag and install into Tooling (D).

a. Loosen nut (3) in order to install Tooling (H).

b. Install Tooling (H) all the way through the cap of the vacuum pump as shown in Illustration 80 .

c. Tighten the nut on top of the vacuum pump down completely to prevent DEF leaks.

5. Remove Tooling (C) from the plastic bag. Remove the cap and install Tooling (C) onto Tooling (D).

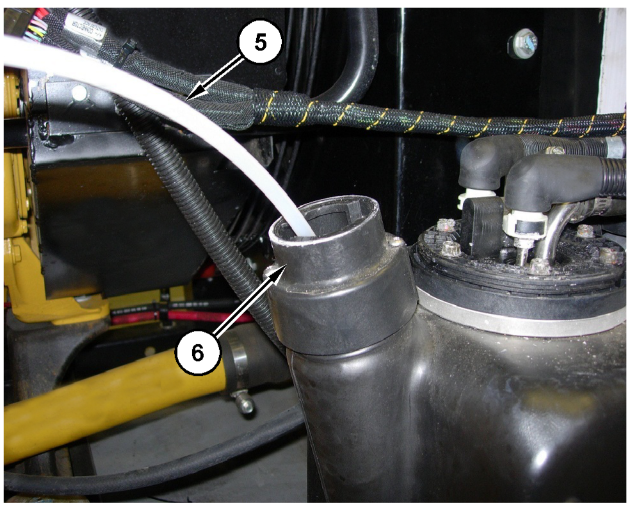

Illustration 81 g03706727

Typical example

(5) Tooling (H)
(6) DEF tank filler neck

Note: The DEF sample must only be taken from the top level of fluid that is contained in the DEF tank. The top level of the DEF is where the contaminants will be located.

6. Place the other end of Tooling (H) into the filler neck of DEF tank (6).

7. Extract DEF from the top level of fluid in the tank using Tooling (D). Fill Tooling (C) to the “Fill Line” that is on the bottle.

8. Proceed to“Test Procedure For DEF Contamination” to begin contamination testing.

Test Procedure For DEF Contamination

1. Place Tooling (G) into Tooling (C) for 5 seconds.

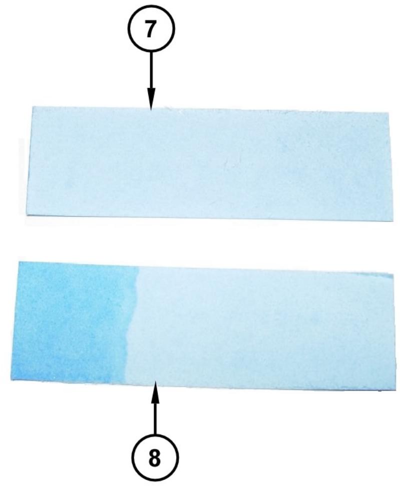

Illustration 82 g03707382

(7) Negative test result
(8) Positive test result

2. Remove Tooling (G) and look for discoloring as shown in Illustration 82 . Any discoloring of Tooling (G) indicates DEF contamination by an oil-based fluid. Contact the Dealer Solution Network (DSN) for further information.

Note: If the test strips indicate no DEF contamination, proceed to “Test Procedure For DEF Concentration”.

Test Procedure For DEF Concentration

Illustration 83 g03370564

A typical example of Tooling (A)

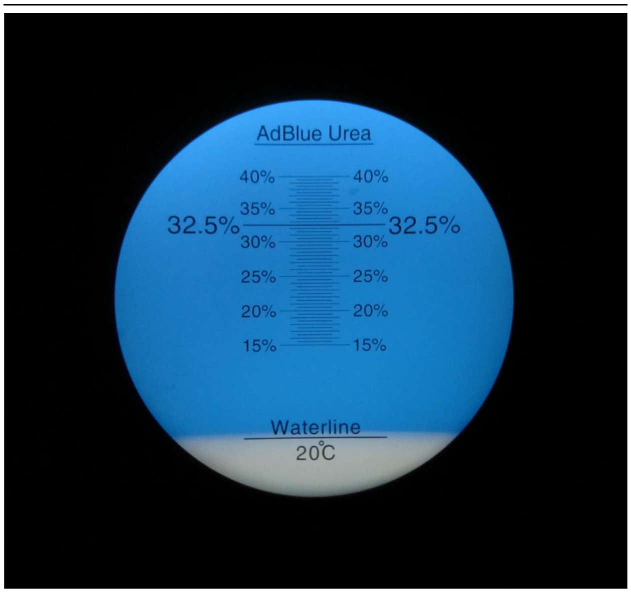

Illustration 84 g03370553

Calibration point for distilled water

1. Follow the instructions included with Tooling (A) to calibrate the waterline of the meter.
2. Clean Tooling (A) and apply two drops of Diesel Exhaust Fluid (DEF) collected from the DEF tank.

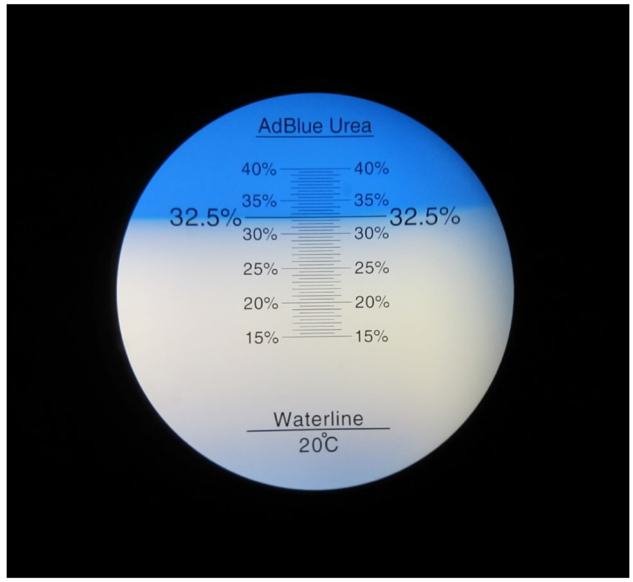

Illustration 85 g03370573

Typical reading for DEF in good condition

3. Inspect the DEF in Tooling (A). The DEF quality must measure between 29 and 35 percent. If the DEF does not meet specification, replace the DEF in the tank with new DEF. Refer to Operation and Maintenance Manual for more information. The new DEF must meet ISO 22241 standards.

Note: Dispose of the DEF removed as per local regulations and mandates.

i07788516

Aftertreatment SCR System Dosing - Test

SMCS Code: 108K-081; 775E-081

Required Tooling

Table 9

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	441-0451	Test Kit (DEF)	1

Test Procedure

1. Remove the Diesel Exhaust Fluid (DEF) injector from the Clean Emissions Module (CEM). Refer to Disassembly and Assembly, “DEF Injector and Mounting - Remove and Install” for the correct procedure.

Note: Leave the DEF line and electrical connector connected to the DEF injector. Where possible, the coolant line may also be left connected if the hose has sufficient free length.

Illustration 86 g03370846

A typical example of the DEF injector bolted to measuring container lid

Illustration 87 g03370910

A typical example of Tooling (A) assembled for the test procedure

2. Assemble the DEF collection container from Tooling (A). Three bolts and wing nuts will connect the DEF injector to the lid for the collection container.

Note: In Tooling (A) there are extensions for the DEF line and the electrical connection if needed.

3. Turn the key switch to the ON position.

4. Connect to the electronic service tool.

5. Click “Diagnostics” in the main menu, then click “Diagnostic Tests” .

6. Proceed by clicking “DEF Dosing System Accuracy Test” .

7. Click “Start” to proceed with the test.

Note: With the DEF injector dosing, inspect the spray pattern. The injector spray pattern should be finely atomized and conical.

Illustration 88 g03370954

Typical example

8. After the test has completed on each occasion, dispose of the collected DEF as per local regulations and mandates.

9. **Repeat the test procedure.** Document the quantity of DEF collected.

Specification for DEF sprayed during dosing test . . . . 100 mL to 130 mL

10. Install the DEF injector assembly. Refer to Disassembly and Assembly, “DEF Injector and Mounting - Remove and Install” for the correct procedure.

Note: Use de-ionized water, distilled water, or Diesel Exhaust Fluid (DEF) to lubricate the O-ring seals of the connections of the diesel exhaust fluid lines before installation of the diesel exhaust fluid lines.**If DEF has been used to lubricate the O-ring seals of the connections of the diesel exhaust fluid lines. The excess DEF must be cleaned from the connections of the diesel exhaust fluid lines.**

i07788527

Diesel Exhaust Fluid Tank - Flush

SMCS Code: 108T-046

Required Tools

Table 10

Required Tools			
Tool	Part Number	Part Description	Qty
A	385-1861	Plugs	2

Flushing Procedure

1. Turn the key switch to the OFF position. The key switch must be OFF to allow the DEF pump to purge, ensuring the system is free of pressurized DEF.

Note: Allow the full 2 minutes after turning the key switch to the OFF position before turning the battery disconnect switch to the OFF position. Refer to Operation and Maintenance Manual, “Battery Disconnect Switch” for more information.

2. Drain the existing DEF from the DEF tank.

Note: All DEF drained or flushed during this procedure must be disposed of as per local regulations and mandates.

3. Drain the engine coolant to an appropriate level that will allow the coolant lines to be removed from the tank header. Refer to Operation and Maintenance Manual for more information.

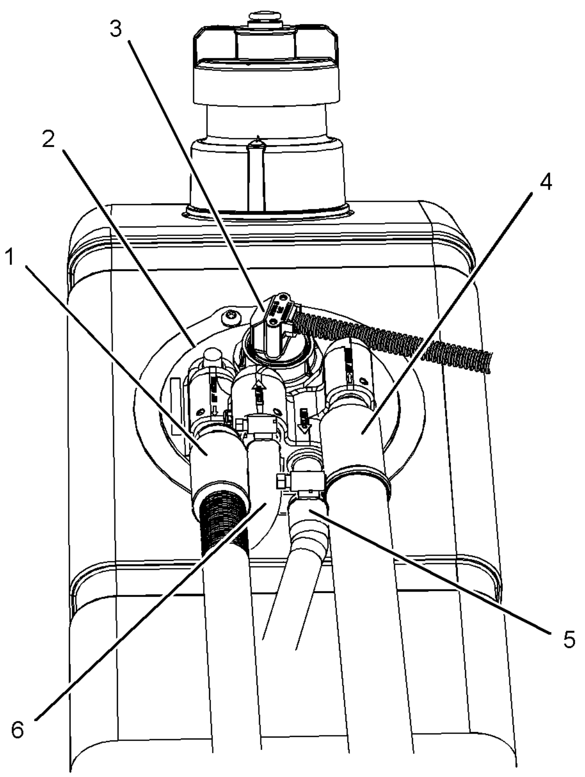

Illustration 89 g03708638

Typical example

(1) DEF suction line
(2) Manifold (DEF heater)
(3) Harness assembly
(4) DEF backflow line
(5) Coolant return to the engine
(6) Coolant supply to manifold (DEF heater)

4. Remove the manifold (DEF heater) from the DEF tank. Refer to Disassembly and Assembly, "Manifold (DEF Heater) - Remove and Install" for the correct procedure.

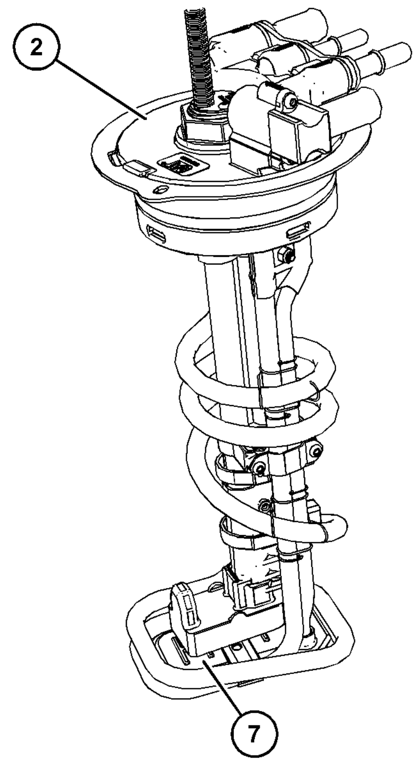

Illustration 90 g06357825

Typical example

(2) Manifold (DEF heater)
(7) Filter

5. Remove the filter from the manifold (DEF heater). Refer to Disassembly and Assembly, "Manifold (DEF Heater) - Remove and Install" for the correct procedure.

6. Flush the DEF suction and backflow connections on the manifold (DEF heater) using distilled water. Install a new filter onto the manifold (DEF heater). Refer to Disassembly and Assembly, "Manifold (DEF Heater) - Remove and Install" for the correct procedure.

7. Position the suitable container under the DEF tank drain and flush the DEF tank thoroughly.

8. Reinstall the manifold (DEF heater) into the DEF tank. Refer to Disassembly and Assembly, "Manifold (DEF Heater) - Remove and Install" for the correct procedure.

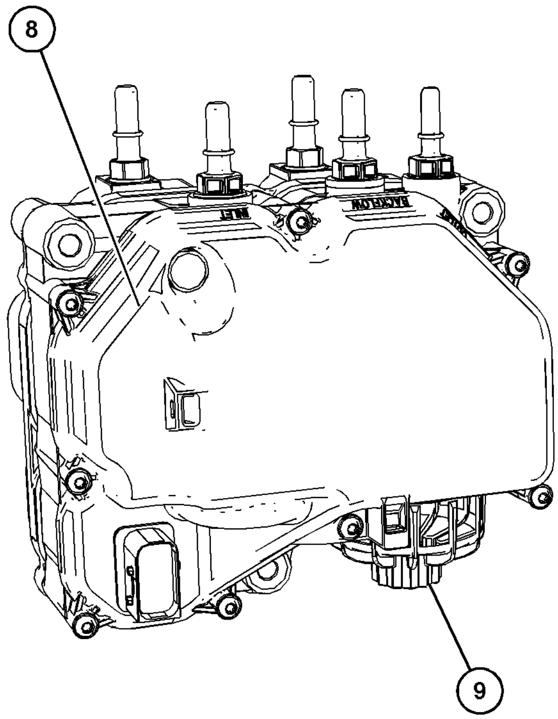

Illustration 91 g06357828

Typical example

(8) DEF pump
(9) DEF filter cap

9. Replace the Diesel Exhaust Fluid (DEF) filter. Refer to Operation and Maintenance Manual for the correct procedure.

10. Flush the DEF suction and backflow lines into a suitable container using distilled water. The minimum quantity of distilled water that is required is 7.57 L (2 US gal).

11. Reconnect all lines to the DEF pump and to the manifold (DEF heater). Refer to Disassembly and Assembly for the correct procedures.

12. Fill the DEF tank to the appropriate level with new DEF. Operation and Maintenance Manual for more information. The new DEF must meet ISO 22241 standards.

13. Start the engine. Refer to Operation and Maintenance Manual for the correct procedure.

14. Connect to the electronic service tool.

15. Perform the “Aftertreatment System Functional Test” in the electronic service tool. This test will verify that the DEF system is working correctly following the flush and filter replacement.

Lubrication System

i06910589

Engine Oil Pressure - Test

SMCS Code: 1304-081

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.

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.

Test Procedure

1. Remove the engine oil pressure switch. Refer to Disassembly and Assembly for the correct procedure.

2. Install a suitable adaptor into the cylinder block.

3. Install a suitable pressure gauge to the adaptor to test the pressure of the lubrication system.

The minimum oil pressure at an operating speed of between 1800 rpm and 2400 rpm and at normal operating temperature is 375 kPa (54 psi).

i04027269

Excessive Bearing Wear - Inspect

SMCS Code: 1203-040; 1211-040; 1219-040

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

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

Refer to Specifications for more information regarding component wear limits.

i02414692

Excessive Engine Oil Consumption - Inspect

SMCS Code: 1348-040

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

SMCS Code: 1348-040

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

i05355811

Cooling System - Check

SMCS Code: 1350-535

Engine And Cooling System Heat Problems

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

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

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

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

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

a. Run the engine at medium idle, which is approximately 1200 rpm, for 3 minutes after the high idle shuts off. Running the engine at medium idle will allow the engine to cool before the engine is stopped.

b. Inspect the poly v-belt for contamination, wear, or damage as this may affect the fan speed hence the efficiency of the cooling system. 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

SMCS Code: 1350-040

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

SMCS Code: 1350-040; 1350-081

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 92 . 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.

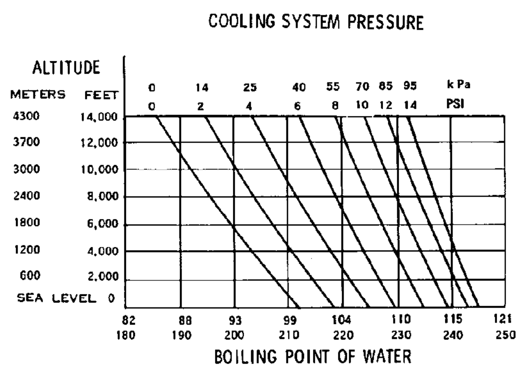

Illustration 92 g00286266

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.

i06909666

Engine Oil Cooler - Inspect

SMCS Code: 1378-040

WARNING

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

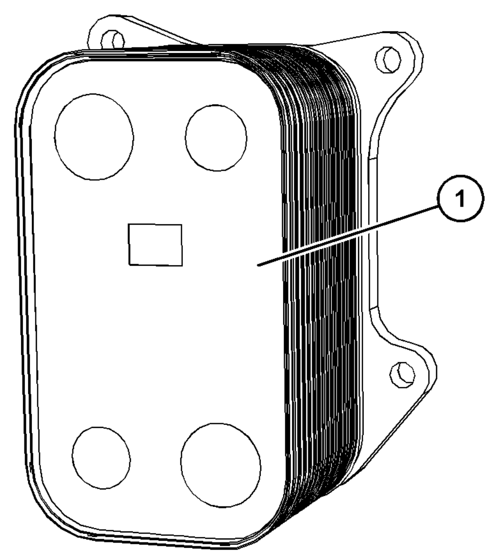

Illustration 93 g06354800

Typical example

Perform the following procedure to inspect the engine oil cooler.

1. Place a container under the oil cooler 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 for cracks and dents. Replace the oil cooler if cracks or dents exist. Ensure that no restrictions for the flow of lubricating oil exist in the oil cooler.

   Dry the oil cooler with low-pressure air. Flush inside the oil cooler 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 for additional information.

Check for oil or coolant leakage.

i02414647

Water Temperature Regulator - Test

SMCS Code: 1355-081-ON; 1355-081

⚠ 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

SMCS Code: 1361-040

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

i06909511

Position the Valve Mechanism Before Maintenance Procedures

SMCS Code: 1102; 1121; 1123; 1209

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

Table 11

Required Tools			
Tool	Part Number	Part Description	Qty
A[1]	-	Crankshaft Turning Tool	1
A[2]	-	Housing	1
	-	Engine Turning Tool	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.

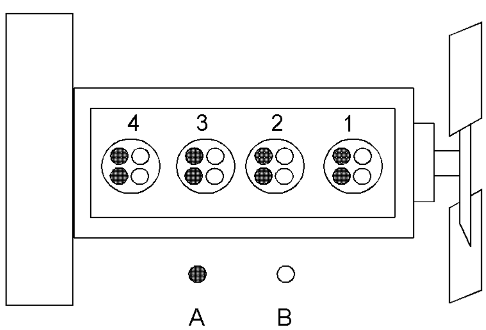

Illustration 94 g03692044

Cylinder and valve location

(A) Exhaust valves
(B) Inlet valves

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 exhaust rocker arm. The exhaust rocker arm can be on any cylinder.

4. Use Tooling (A) to rotate the crankshaft in the normal direction of rotation until the hydraulic lifter starts to open the exhaust valve. Continue to rotate the crankshaft until the valve has opened to the maximum extent. This is the safe position.

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

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

i03633934

Piston Ring Groove - Inspect

SMCS Code: 1214-040

Table 12

Required Tools			
Tool	Part Number	Part Description	Qty
A	8H-8581	Feeler Gauge	1

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 (2). Refer to Disassembly and Assembly, “Pistons and Connecting Rods - Disassemble” for the correct procedure. Clean the grooves (1) and the piston rings (2).

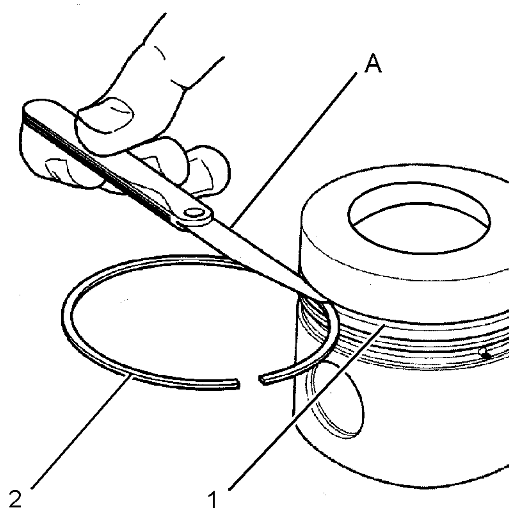

Illustration 95 g01200845

Typical example

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

2. Install new piston rings (2) in the piston grooves (1). Refer to Disassembly and Assembly Manual, "Pistons and Connecting Rods - Assemble" for the correct procedure.

3. Check the clearance for the piston ring by placing Tooling (A) between piston groove (1) 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

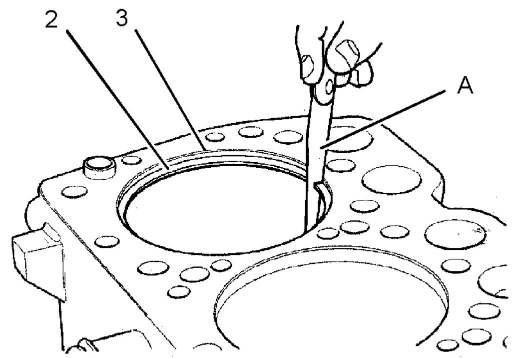

Illustration 96 g01344283

(A) Feeler Gauge
(2) Piston ring
(3) Cylinder ring ridge

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

2. Place each piston ring (2) in the cylinder bore just below the cylinder ring ridge (3).

3. Use Tooling (A) 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.

i07544982

Connecting Rod - Inspect

SMCS Code: 1218-040

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

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

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

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. Measure the grade length of the connecting rod. Refer to Specifications, “Connecting Rod”for more information.

2. 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. 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

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

i07544971

Cylinder Block - Inspect

SMCS Code: 1201-040

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

2. Check the cylinder block for cracks and damage.

i07544929

Cylinder Head - Inspect

SMCS Code: 1100-040

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).

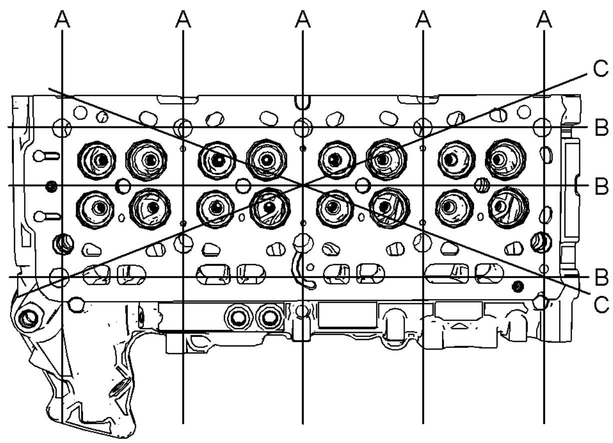

Illustration 97 g06227964

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.

Note: The thickness of the cylinder head must not be less than 120 mm (4.72440 inch).

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.

i04156268

Piston Height - Inspect

SMCS Code: 1214-040

Table 13

Required Tools			
Tool	Part Number	Part Description	Qty
A	1P-2403	Dial Indicator	1
B	1P-2402	Gauge Body	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.

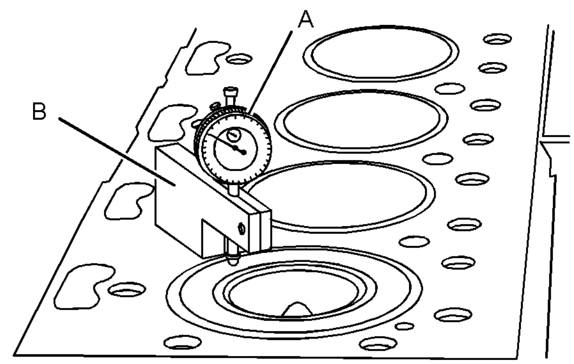

Illustration 98 g01334423

Typical example

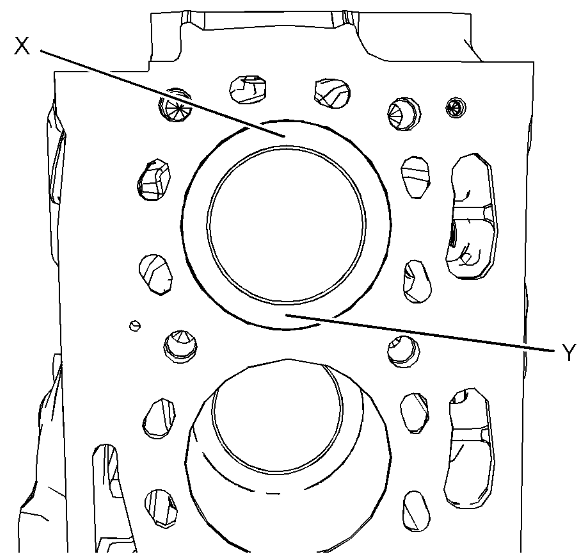

Illustration 99 g02351060

Typical example

1. Use Tooling (A) and Tooling (B) in order to measure the piston height above the cylinder block. Use the cylinder block face to zero Tooling (A).
2. Rotate the crankshaft until the piston is at the approximate top center.

3. Position Tooling (B) and Tooling (A) in order to measure the piston height above the cylinder block. The piston height should be measured at positions (X) or (Y). Slowly rotate the crankshaft in order to determine when the piston is at the highest position. Record this dimension. Compare this dimension with the dimensions that are given in Specifications, “Piston and Rings”.

i07788542

Flywheel - Inspect

SMCS Code: 1156-040

Table 14

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	8T-5096	Dial Indicator	1
	-	Magnetic Base and Stand	1

Alignment of the Flywheel Face

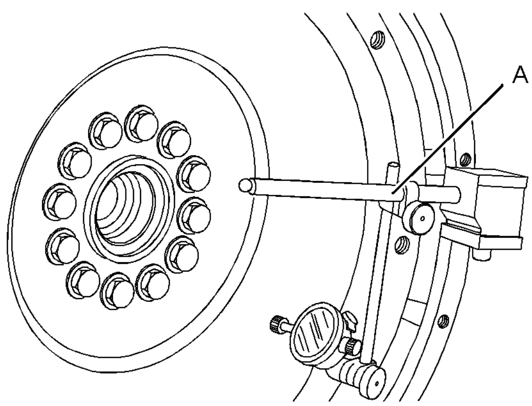

Illustration 100 g01332565

Typical example

1. Install Tooling (A) in illustration 100 , 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 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 0.025 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

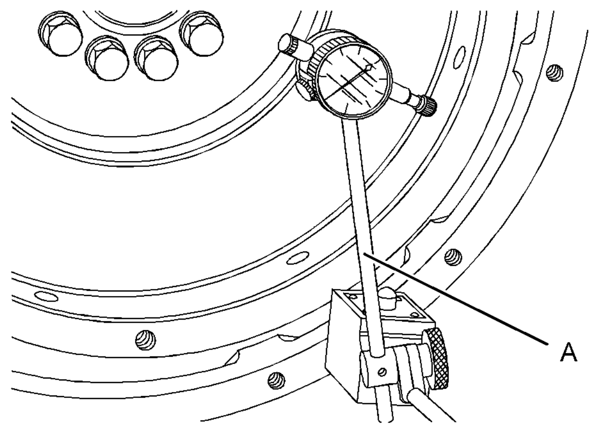

Illustration 101 g01321858

Typical example

1. Install Tooling (A) in illustration 101 , 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).

i06910608

Gear Group - Inspect

SMCS Code: 1206-040

Table 15

Required Tools			
Tool	Part Number	Part Description	Qty
A(1)	-	Crankshaft Turning Tool	1
A(2)	-	Housing	1
	-	Engine Turning Tool	1
B	136-4632	Timing Pin (Camshaft)	1
	268-1966	Adapter	1
C	8T-5096	Dial Indicator	1
	-	Magnetic Base and Stand	1
	-	Finger attachment	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.

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

Note: If one or more of the gears need to be removed for repair, refer to Disassembly and Assembly to remove the gears. Refer to the Disassembly and Assembly to install the gears.

Backlash Between the Crankshaft Gear, the Camshaft Gear, and the Fuel Injection Pump Gear

Table 16

Record Backlash Measurement	Crankshaft Gear Tooth	Crankshaft Gear / Fuel Injection Pump Gear Angle (Degrees)	Camshaft Gear Angle (Degrees)
1	0	0	0
2	11	90	45
3	23	180	90
4	34	270	135
5	46	360	180
6	57	450	225
7	69	540	270
8	80	630	315
9	96	720	360

Backlash Between the Crankshaft Gear and the Camshaft Gear

1. Use Tooling (A) to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, Finding Top Center Position for No.1 Piston for the correct procedure.

2. Make a temporary mark on the top tooth of the crankshaft gear. Refer to illustration. Move in a counterclockwise direction and make a temporary mark in the next tooth (number “11”). Make a temporary mark in the next tooth (number “23”). Make a temporary mark in the next tooth (number “34”).

Note: The top tooth of the crankshaft gear is number “0” and number “46” . Make a note of the starting point and the direction of rotation.

3. Mount Tooling (C) on a suitable flat surface to measure the backlash between the crankshaft gear and the camshaft gear. Ensure that the finger attachment is vertical. Ensure that the point of the finger attachment is in contact with the gear. The backlash measurement point is half way down the pitch circle diameter and along the relevant tooth.

4. Set the dial gauge indicator to zero. Gently rotate the camshaft gear backwards and forwards. Measure the backlash between the crankshaft gear and the camshaft gear. Refer to Specifications, “Gear Group (Rear)” for the backlash measurement.

5. Remove Tooling (B) from the camshaft.

6. Use Tooling (A) to rotate the crankshaft in a clockwise direction until the next crankshaft tooth (number “11”) is located between the camshaft gear teeth.

7. Gently rotate the camshaft gear backwards and forwards. Measure the backlash between the crankshaft gear and the camshaft gear. Refer to Specifications, “Gear Group (Rear)” for the backlash measurement.

8. Use Tooling (A) to rotate the crankshaft in a clockwise direction until the next crankshaft tooth (number “23”) is located between the camshaft gear teeth.

9. Gently rotate the camshaft gear backwards and forwards. Measure the backlash between the crankshaft gear and the camshaft gear. Refer to Specifications, “Gear Group (Rear)” for the backlash measurement.

10. Use Tooling (A) to rotate the crankshaft in a clockwise direction until the next crankshaft tooth (number “34”) is located between the camshaft gear teeth.

11. Gently rotate the camshaft gear backwards and forwards. Measure the backlash between the crankshaft gear and the camshaft gear. Refer to Specifications, “Gear Group (Rear)” for the backlash measurement.

12. Use Tooling (A) to rotate the crankshaft in a clockwise direction until the next crankshaft tooth (number “46”) is located between the camshaft gear teeth.

Note: At this point, the crankshaft gear has completed one revolution.

13. Gently rotate the camshaft gear backwards and forwards. Measure the backlash between the crankshaft gear and the camshaft gear. Refer to Specifications, “Gear Group (Rear)” for the backlash measurement.

14. Use Tooling (A) to rotate the crankshaft in a clockwise direction until the next crankshaft tooth with the temporary mark is in the correct position. Refer to table 16 for more information.

15. Use Tooling (A) to rotate the crankshaft in a clockwise direction until the crankshaft has completed two complete revolutions. If the first recorded backlash measurement is greater than 0.001 mm (0.00004 inch) of the value of the last recorded backlash measurement, repeat step 4 through step 14.

Backlash Between the Camshaft Gear and the Fuel Injection Pump Gear

1. Use Tooling (A) to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, Finding Top Center Position for No.1 Piston for the correct procedure.

2. If necessary, make a temporary mark on the top tooth of the crankshaft gear. Refer to illustration. Move in a counterclockwise direction and make a temporary mark in the next tooth (number “11”). Make a temporary mark in the next tooth (number “23”). Make a temporary mark in the next tooth (number “34”).

Note: The top tooth of the crankshaft gear is number “0” and number “46” . Make a note of the starting point and the direction of rotation.

3. Mount Tooling (C) on a suitable flat surface to measure the backlash between the camshaft gear and the fuel injection pump gear. Ensure that the finger attachment is vertical. Ensure that the point of the finger attachment is in contact with the gear. The backlash measurement point is half way down the pitch circle diameter and along the relevant tooth.

4. Set the dial gauge indicator to zero. Gently rotate the fuel injection pump gear backwards and forwards. Measure the backlash between the camshaft gear and the fuel injection pump gear. Refer to Specifications, “Gear Group (Rear)” for the backlash measurement.

5. Remove Tooling (B) from the camshaft.

6. Use Tooling (A) to rotate the crankshaft in a clockwise direction until the next crankshaft tooth (number “11”) is located between the camshaft gear teeth.

7. Gently rotate the fuel injection pump gear backwards and forwards. Measure the backlash between the camshaft gear and the fuel injection pump gear. Refer to Specifications, “Gear Group (Rear)” for the backlash measurement.

8. Use Tooling (A) to rotate the crankshaft in a clockwise direction until the next crankshaft tooth with the temporary mark is in the correct position. Refer to table 16 for more information.

9. Use Tooling (A) to rotate the crankshaft in a clockwise direction until the crankshaft has completed two complete revolutions. If the first recorded backlash measurement is greater than 0.001 mm (0.00004 inch) of the value of the last recorded backlash measurement, repeat step 4 through step 8.

Backlash Between the Crankshaft Gear and the Idler Gear

1. If necessary, install the idler gear and flywheel housing. Refer to Disassembly and Assembly, Flywheel Housing - Remove and Install for the correct procedure.

Note: Do not install the crankshaft rear seal at this time.

2. Use Tooling (A) to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, Finding Top Center Position for No.1 Piston for the correct procedure.
3. Use a suitable feeler gauge or mount Tooling (C) on a suitable flat surface to measure the backlash between crankshaft gear and the camshaft gear. Ensure that the finger attachment is vertical. Ensure that the point of the finger attachment is in contact with the gear. The backlash measurement point is half way down the pitch circle diameter and along the relevant tooth. Set the dial gauge indicator to zero.
4. Remove Tooling (B) from the camshaft.
5. Gently rotate the idler gear backwards and forwards. Measure the backlash between the crankshaft gear and the idler gear. Refer to Specifications, “Gear Group (Rear)” for the backlash measurement.
6. Use Tooling (A) to rotate the crankshaft one complete revolution.
7. Gently rotate the idler gear backwards and forwards. Measure the backlash between the crankshaft gear and the idler gear. Refer to Specifications, “Gear Group (Rear)” for the backlash measurement.
8. Install the crankshaft rear seal. Refer to Disassembly and Assembly, Crankshaft Rear Seal - Remove and Install for the correct procedure.

Backlash Between the Idler Gear and the Accessory Drive Gear (If Equipped)

Note: This procedure can be achieved by removing the flywheel housing. Refer to Disassembly and Assembly, Flywheel Housing - Remove and Install for the correct procedure.

1. Use Tooling (A) to rotate the crankshaft so that number one piston is at the top center position on the compression stroke. Refer to Systems Operation, Testing and Adjusting, Finding Top Center Position for No.1 Piston for the correct procedure.
2. Use a suitable feeler gauge to measure the backlash between the idler gear and the accessory drive gear (if equipped). Refer to Specifications, “Gear Group (Rear)” for the backlash measurement.

i07003030

Crankshaft Pulley - Check

SMCS Code: 1205-535

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

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

- There is movement of the crankshaft pulley.
- There is a large amount of gear train wear that is not caused by lack of oil.
- Analysis of the engine oil has revealed that the front main bearing is badly worn.
- The engine has had a failure because of a broken crankshaft.

Check the areas around the holes for the bolts in the crankshaft pulley for cracks or for wear and for damage.

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

1. Remove any debris from the front face of the crankshaft pulley. Remove any debris from the circumference of the crankshaft pulley.
2. Obtain a dial indicator with a suitable 2.5 mm (0.098 inch) diameter ball gauge. Mount the dial indicator on the front of the engine. Position the ball gauge in between the grooves of the crankshaft pulley.
3. Set the dial indicator to read 0.00 mm (0.00 inch).

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

5. On the faces of the grooves, 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 0.3 mm (0.01181 inch). On the diameters of the grooves, 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 0.25 mm (0.00984 inch).

If the reading on the dial indicator is more than the values stated, inspect the pulley for damage. If the pulley is damaged, use new parts for replacement.

Electrical System

i03578982

Alternator - Test

SMCS Code: 1405-081

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

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

Note: Cranking the engine for 30 seconds partially discharges the batteries in order to do a charging test. If the battery has a low charge, do not perform this step. Jump start the engine or charge the battery before the engine is started. For the correct procedure to jump start the engine, refer to Operation and Maintenance Manual, “Starting with Jump Start Cables”.

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

4. Check the output current of the alternator. The initial charging current should be equal to the minimum full load current or greater than the minimum full load current. The electrical load from the accessories may need to be added. Refer to Specifications, “Alternator” for the correct minimum full load current.

Table 17

Fault Conditions And Possible Causes			
Current At Start-up	**The Voltage Is Below Specifications After 10 Minutes.**	**The Voltage Is Within Specifications After 10 Minutes.**	**The Voltage Is Above Specifications After 10 Minutes.**
Less than the specifications	Replace the alternator. Check the circuit of the ignition switch.	Turn on all accessories. If the voltage decreases below the specifications, replace the alternator. Ensure that combined current of the accessories does not exceed the maximum output of the alternator.	-

(continued)

(Table 17, contd)

Fault Conditions And Possible Causes			
Decreases after matching specifications	Replace the alternator.	The alternator and the battery match the specifications. Turn on all accessories in order to verify that the voltage stays within specifications. Ensure that combined current of the accessories does not exceed the maximum output of the alternator.	Replace the alternator.
The voltage consistently exceeds specifications.	-	The alternator operates within the specifications. Test the battery.	Replace the alternator. Inspect the battery for damage.

5. After approximately ten minutes of operating the engine at full throttle, the output voltage of the alternator should be 14.0 ± 0.5 volts for a 12 volt system and 28.0 ± 1 volts for a 24 volt system. Refer to the Fault Conditions And Possible Causes in table 17 . Refer to Special Instruction, REHS0354, “Charging System Troubleshooting” for more information.

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

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

Refer to the Fault Conditions And Possible Causes in table 17 . Refer to Special Instruction, REHS0354, “Charging System Troubleshooting” for more information.

i01126605

Battery - Test

SMCS Code: 1401-081

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

WARNING

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

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

NOTICE

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

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

i03578983

Charging System - Test

SMCS Code: 1406-081

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 30 mL (1 oz) per cell per week or per every 100 service hours. There are no adjustments on maintenance free batteries.

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

Alternator Regulator

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

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

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

i07669475

V-Belt - Test

SMCS Code: 1357-081

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.

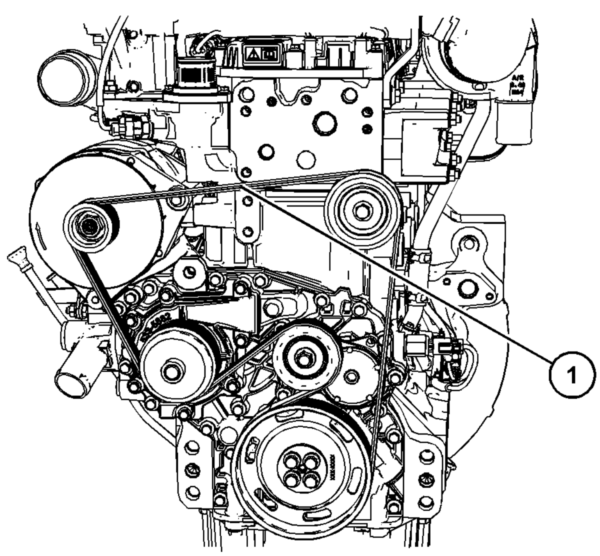

Illustration 102 g06301080

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.

i03578986

Electric Starting System - Test

SMCS Code: 1450-081

General Information

All electrical starting systems have four elements:

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

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

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

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

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

Power which is available during cranking varies according to the temperature and condition of the batteries. Table 18 shows the voltages which are expected from a battery at the various temperature ranges.

Table 18

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

Table 19 shows the maximum acceptable loss of voltage in the battery circuit. The battery circuit supplies high current to the starting motor. The values in the table are for engines which have service of 2000 hours or more.

Table 19

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

Voltage drops that are greater than the amounts in table 19 are caused most often by the following conditions:

- Loose connections
- Corroded connections
- Faulty switch contacts

Diagnosis Procedure

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

NOTICE

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

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

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

1. Measure the voltage of the battery.

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

a. If the voltage is equal to or greater than the voltage in table 18 , then go to step 2.

b. The battery voltage is less than the voltage in Table 18 .

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

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

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

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

- The voltage at the battery post is within 2 volts of the lowest value in the applicable temperature range of table 18 .
- The large starting motor cables get hot.

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

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

If the current is within the specification, proceed to step 3.

3. Measure the voltage of the starting motor.

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

b. If the voltage is equal to or greater than the voltage that is given in table 18 , then the battery and the starting motor cable that goes to the starting motor are within specifications. Go to step 5.

c. The starting motor voltage is less than the voltage specified in table 18 . The voltage drop between the battery and the starting motor is too great. Go to step 4.

4. Measure the voltage.

a. Measure the voltage drops in the cranking circuits with the multimeter. Compare the results with the voltage drops which are allowed in table 19 .

b. Voltage drops are equal to the voltage drops that are given in table 19 or the voltage drops are less than the voltage drops that are given in Table 19 . Go to step 5 in order to check the engine.

c. The voltage drops are greater than the voltage drops that are given in table 19 . The faulty component should be repaired or replaced.

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

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

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

6. Attempt to crank the starting motor.

a. The starting motor cranks slowly.

Remove the starting motor for repair or replacement.

b. The starting motor does not crank.

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

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

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