Perkins®

UENR0617
February 2012

Systems Operation Testing and Adjusting

1106A-70TA and 1106C-70TA Industrial Engines

PR (Engine)
PT (Engine)

Important Safety Information

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

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

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

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

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

⚠ WARNING

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

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

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 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 or parts with equivalent specifications including, but not limited to, physical dimensions, type, strength and material.

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

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

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General Information

The following model views show typical 1106A-70TA 1106C-70TA Industrial Engines. Due to individual applications, your engine may appear different from the illustrations.

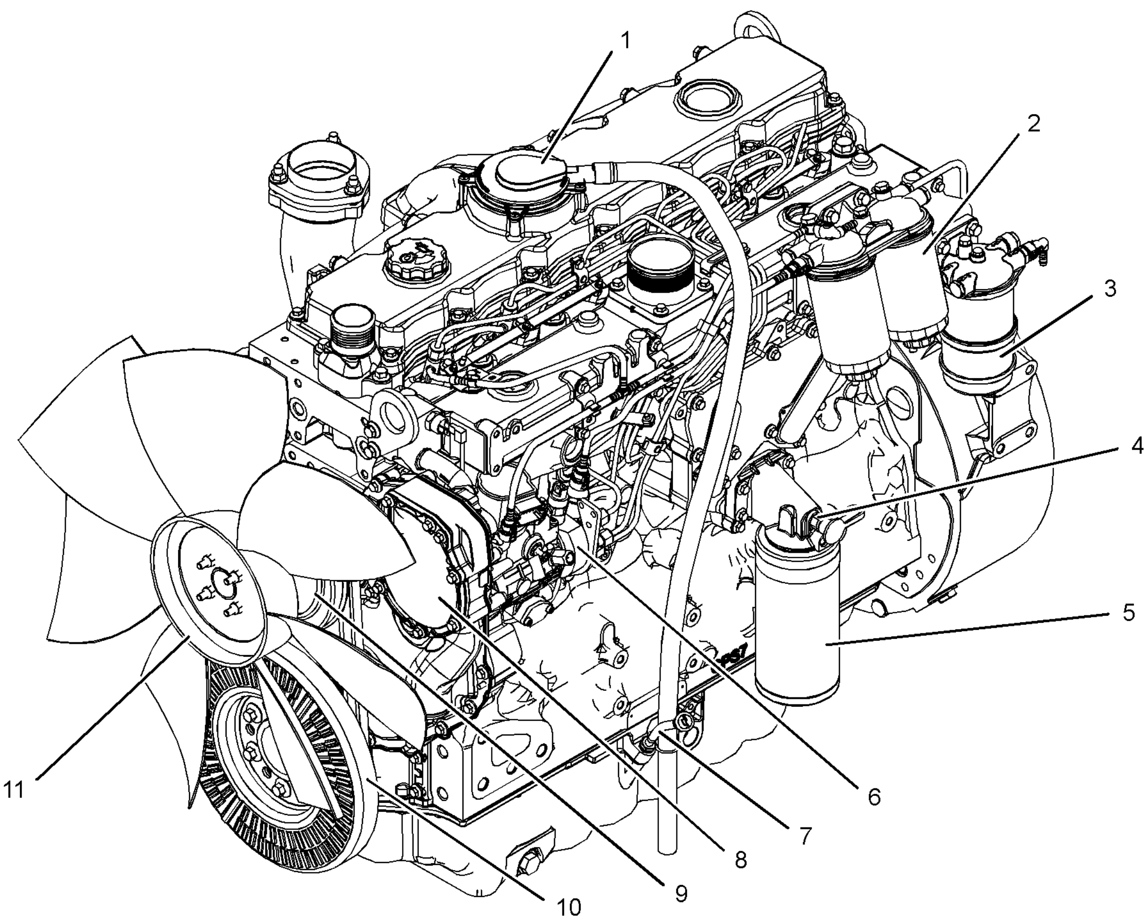

Illustration 1 g02344959

Typical example

(1) Crankcase breather
(2) Secondary fuel filters
(3) Primary fuel filter
(4) Oil sampling valve
(5) Oil filter
(6) Fuel injection pump
(7) Oil gauge (dipstick)
(8) Water pump
(9) Fan pulley
(10) Damper
(11) Fan

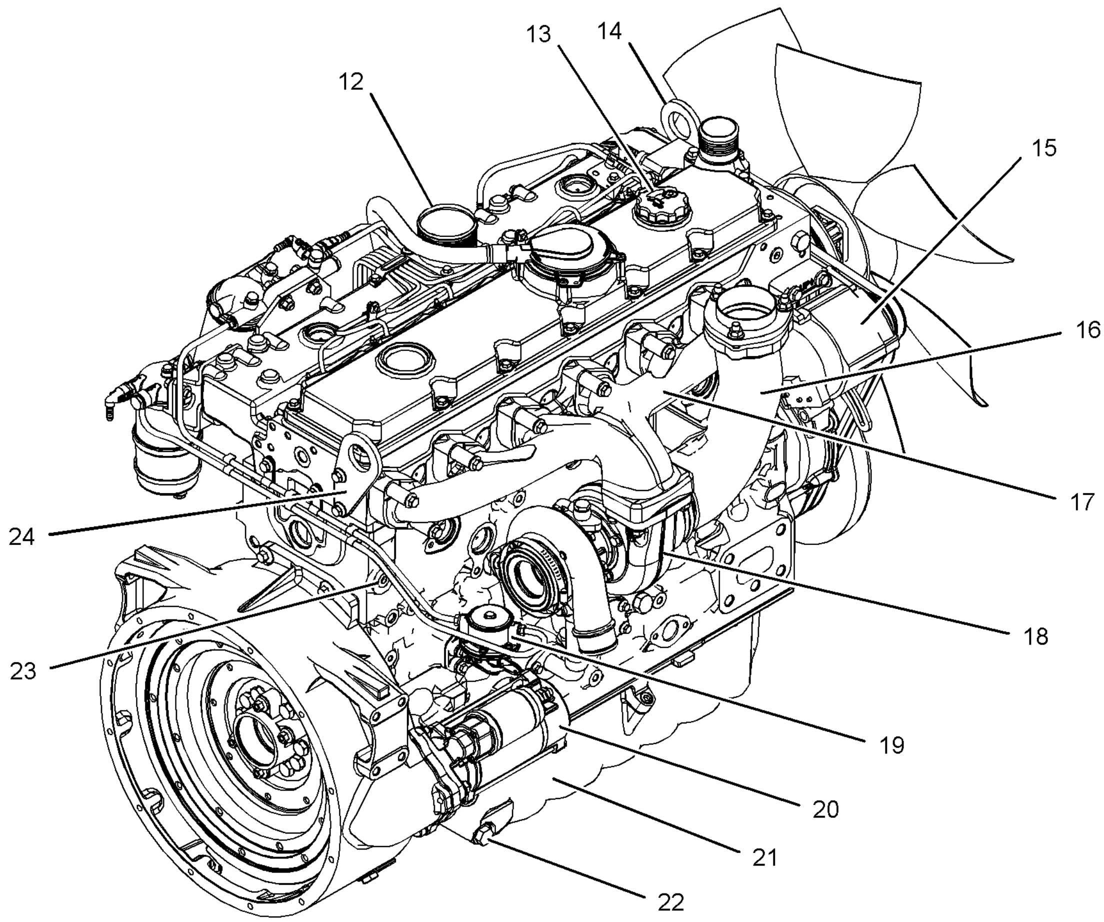

Illustration 2
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Typical example

(12) Air intake
(13) Oil filler
(14) Front lifting eye
(15) Alternator
(16) Exhaust elbow
(17) Exhaust manifold
(18) Turbocharger
(19) Fuel priming pump
(20) Starting motor
(21) Oil pan
(22) Drain plug (oil)
(23) Drain plug (coolant)
(24) Rear lifting eye

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

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

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

A piston and a connecting rod are matched to each cylinder. The piston height is controlled by the distance between the center of the big end bearing and the center of the small end bearing of the connecting rod. Three different lengths of connecting rods are available in order to attain the correct piston height. The three different lengths of connecting rods are made by machining the blank small end bearing of each rod at three fixed distances vertically above the centerline of the big end bearing.

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

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

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

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

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

The fuel injection pump that is installed on the left side of the engine is gear-driven from the timing case.

The fuel transfer pump is located on the right-hand side of the cylinder block.

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Cleanliness of Fuel System Components

Cleanliness of the Engine

NOTICE
Extreme cleanliness must be maintained 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. The high-pressure water system will remove dirt and loose debris before starting a repair on the fuel system. Ensure that no high-pressure water is directed at the injectors.

Environment

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

New Components

The fuel injection lines are not reusable. New fuel injection lines are manufactured for installation in one position only. When a fuel injection 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.

The technician must wear suitable rubber gloves. The rubber gloves should be disposed of immediately after completion of the repair in order to prevent contamination of the system.

Refueling

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

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Fuel System

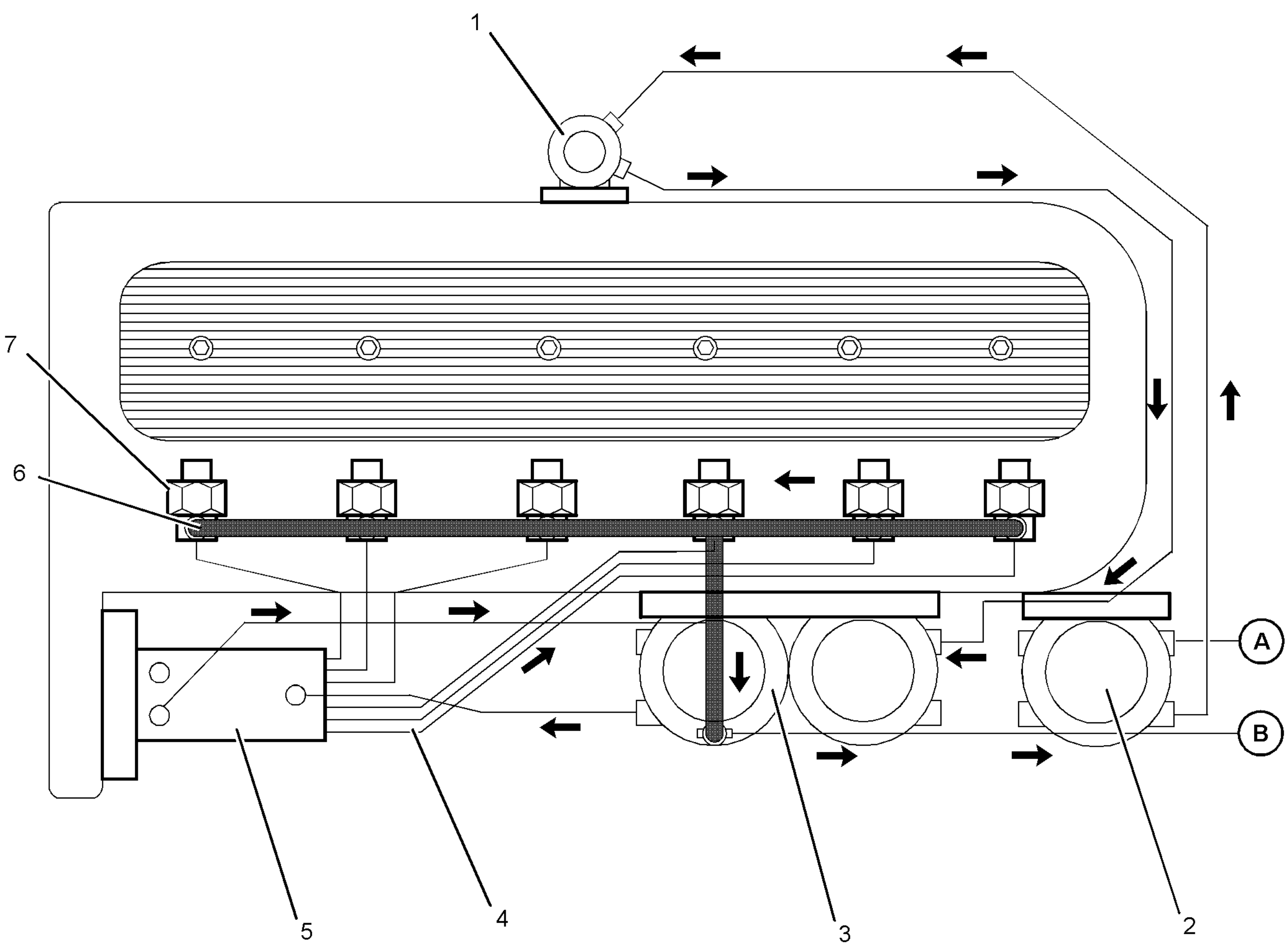

Illustration 3

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Typical example

Fuel from the tank (A) leaves the primary fuel filter (2) and then passes to the diaphragm type fuel transfer pump (1). The fuel transfer pump (1) is driven by an eccentric on the camshaft. Fuel leaves the fuel transfer pump (1) under pressure and passes through the secondary fuel filter (3) to the fuel injection pump (5). The secondary fuel filter (3) is a twin filter.

Extra fuel is circulated through the injection pump (5). The extra fuel is then returned to the fuel tank.

A fuel heater or cooler may be installed between the filter head and filter canister.

The fuel injection pump (5) sends fuel through the fuel injection lines (4) to each of the fuel injection nozzles (7). The fuel injection lines (4) to the fuel injection nozzles (7) are equal lengths. This ensures even pressure and correct injection timing at each fuel injection nozzle (7). The fuel injection nozzle (7) sprays the fuel into the cylinder. Fuel that is not injected flows through the fuel return line (6) to the top of the secondary fuel filter. The fuel then flows back to the fuel tank (B).

The engine must not be started until the fuel injection pump is full of fuel that is free of air. The fuel injection pump requires fuel for lubrication. The precision parts of the pump are easily damaged without lubrication.

The fuel system must be primed when any of the following conditions occur:

- The fuel filter is changed.
- The fuel line is removed.
- The fuel injection pump is removed.

Fuel System Components

Fuel Injection Pump

General Operation

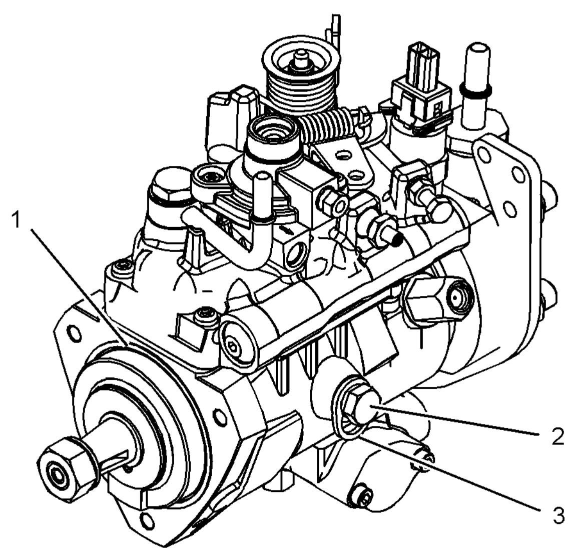

Illustration 4 g01352237

Typical example

(1) Fuel injection pump
(2) Locking screw
(3) Washer

The fuel injection pump is a pressurized system that is totally enclosed. The pump sends the correct amount of fuel under high pressure at the correct time through the fuel injection nozzles to the individual cylinders. The fuel injection pump regulates the amount of fuel that is delivered to the fuel injection nozzles. This action controls the engine rpm by the governor setting or the position of the throttle control.

The Delphi DP310 fuel injection pump must be serviced by an authorized Delphi technician. For repair information, contact your Perkins distributor.

High idle and low idle of the fuel injection pump are factory set. Idle adjustments cannot be made to the fuel pump. The fuel injection pump has a boost control and an engine stop solenoid. The Delphi DP310 fuel injection pump has a feature that vents air from the pump.

The fuel injection pump has a cold starting aid. The cold starting aid advances the timing of the pump when the engine is cold. The cold starting aid is electrically operated.

Cold Start Advance Unit (If equipped)

The cold start advance unit holds the timing of the fuel injection pump in an advance position when the engine is cold.

The coolant switch for the cold start advance unit is on the rear of the timing case on the left side of the engine.

When the engine is cold, the sender unit is energized in order to advance the fuel injection pump timing for the cold start operation. When the correct temperature is achieved the sender unit is de-energized and the fuel injection pump timing is returned to the normal operating position.

If the switch fails in the closed position, the engine will run with advanced fuel injection timing. The engine will have higher cylinder pressure and engine damage may result.

If the switch fails in the open position the engine will run with the fuel injection timing in the normal operating position. The engine will be more difficult to start. When the engine is cold the engine might emit white smoke.

Fuel filters

There is one type of fuel filter element that may be installed to the engine.

The canister type where the fuel filter element has an internal thread at the top and is fastened to a threaded adaptor in the fuel filter base.

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Air Inlet and Exhaust System

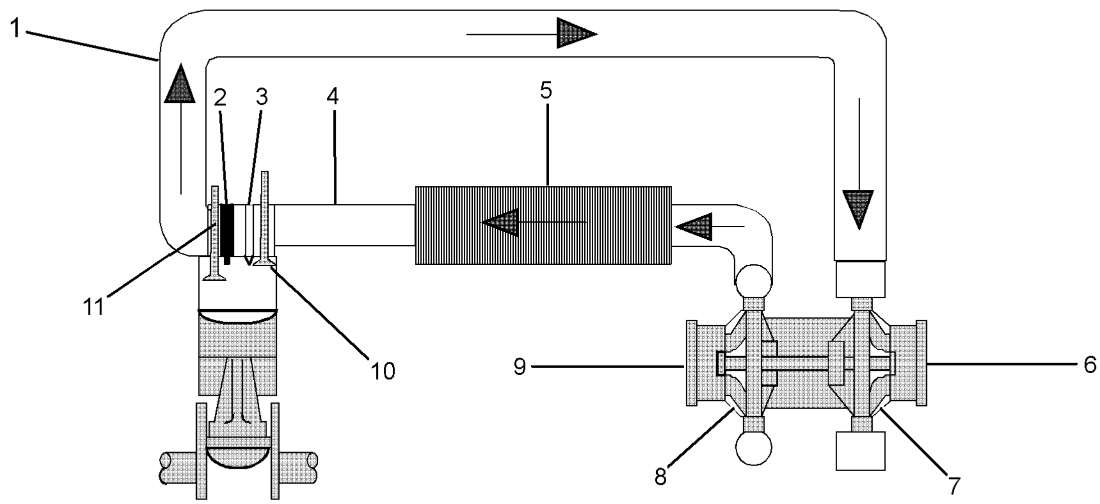

Illustration 5 g01205681

Air inlet and exhaust system

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

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

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

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

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

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

- Inlet
- Compression

- Power
- Exhaust

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

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

Just before the piston reaches the Top Center (TC) position, fuel is injected into the cylinder. The air/fuel mixture ignites. The ignition of the gases initiates the power stroke. Both the inlet and the exhaust valves are closed and the expanding gases force the piston downward toward the Bottom Center (BC) position.

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

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

Turbocharger

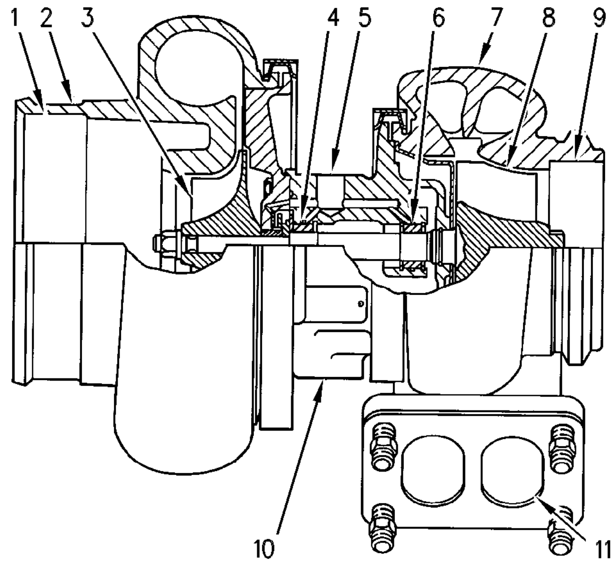

Illustration 6 g00302786

Turbocharger

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

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

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

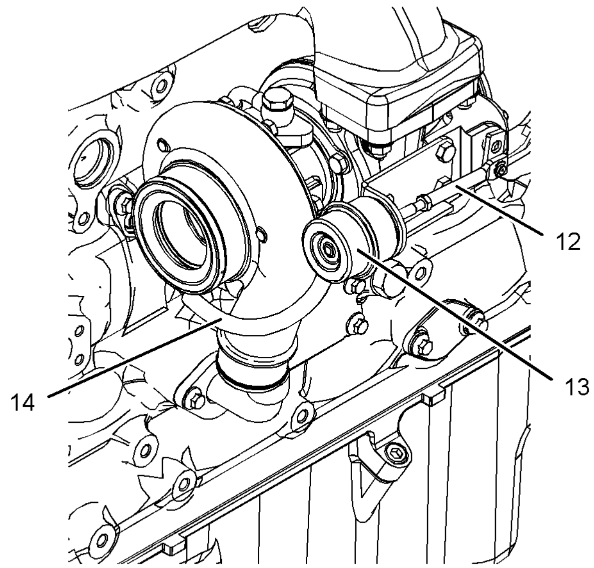

Illustration 7 g02269817

Turbocharger with the wastegate (if equipped)

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

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

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

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

Valve System Components

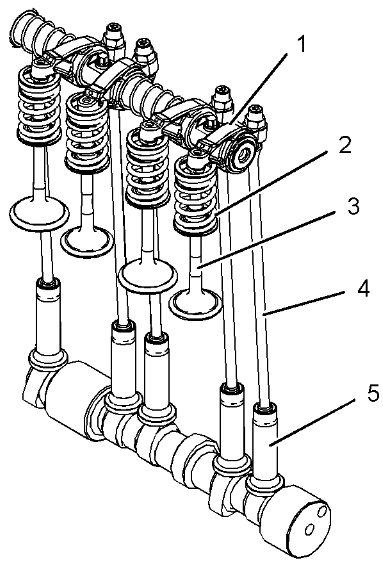

Illustration 8 g02263874

Valve system components

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

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

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

The camshaft has two camshaft lobes for each cylinder. The lobes operate the inlet and exhaust valves. As the camshaft turns, lobes on the camshaft cause the lifter (5) to move the pushrod (4) up and down. Upward movement of the pushrod against rocker arm (1) results in downward movement (opening) of valve (3). The opening of valve (3) compresses the valve spring (2). When the camshaft has rotated to the peak of the lobe, the valve is fully open. When the camshaft rotates further, the valve spring (2) under compression start to expand. The valve stems are under tension of the spring. The continued rotation of the camshaft causes the rocker arm (1), the pushrods (4) and the lifters (5) to move downward until the lifter reaches the bottom of the lobe. The valve (3) is now closed. The cycle is repeated for all the valves on each cylinder.

i02413834

Lubrication System

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

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

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

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

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

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

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

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

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

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

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

i02404368

Cooling System

Introduction (Cooling System)

The cooling system has the following components:

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

Coolant Flow

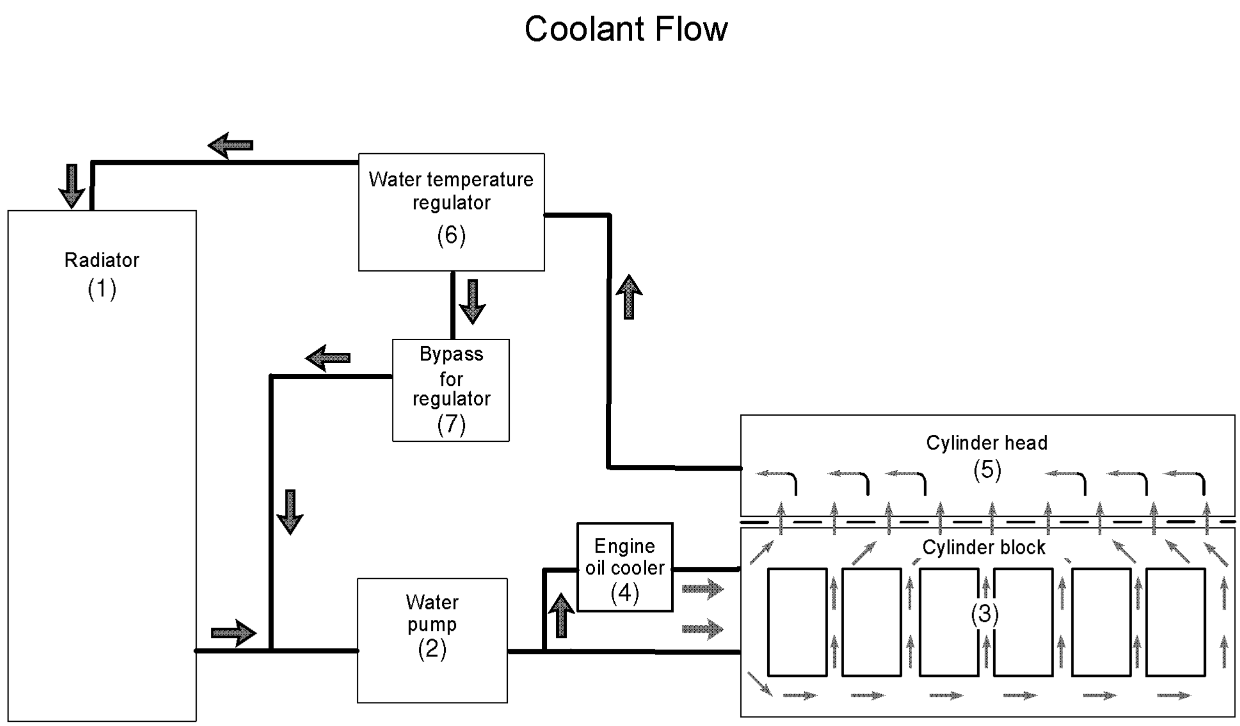

Illustration 9 g01206083

Coolant flow

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

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

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

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

i04476150

Basic Engine

Introduction

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

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

Cylinder Block

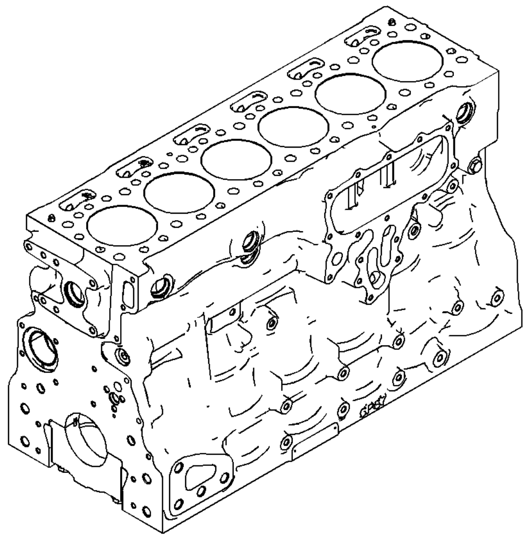

Illustration 10 g02323355

Typical example

The cast iron cylinder block for the 1106A-70TA and 1106C-70TA engines have six cylinders which are arranged in-line. The cylinder block is made of cast iron. The cylinder block provides support for the full length of the cylinder bores. The cylinder bores are machined into the block.

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

The cylinder block has seven main bearings which support the crankshaft. Thrust washers are installed on both sides of number 6 main bearing in order to control the end play of the crankshaft. The thrust washers can only be installed one way.

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

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

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

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

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

Cylinder Head

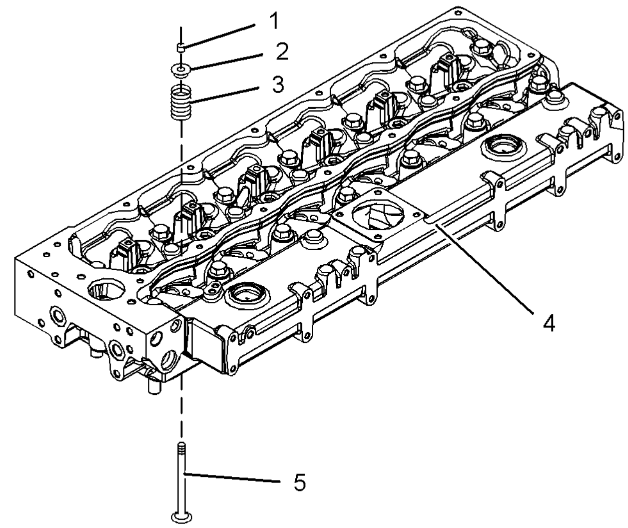

Illustration 11 g02260115

Typical example

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

The engine has a cast iron cylinder head (4). The lower part of the inlet manifold is integral within the cylinder head. There is one inlet valve and one exhaust valve (5) for each cylinder.

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

Pistons, Rings, and Connecting rods

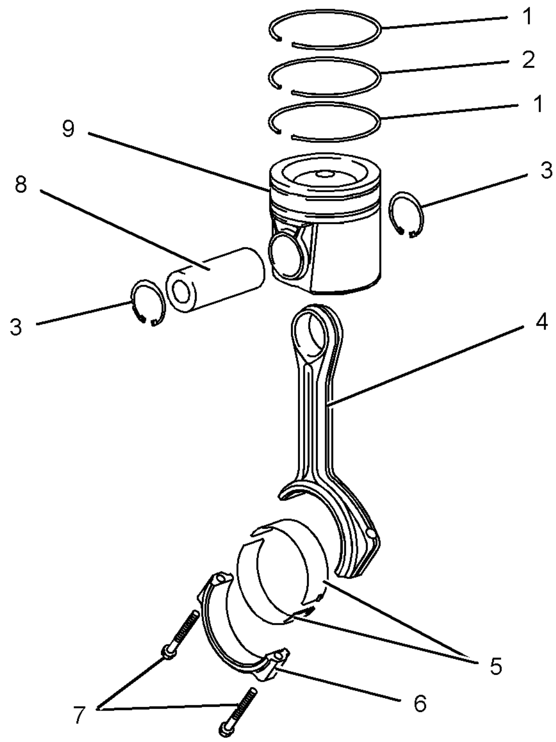

Illustration 12 g02212753

Typical example

The pistons (9) have a combustion chamber in the top of the piston in order to provide an efficient mix of fuel and air. The piston pin (8) is off-center in order to reduce the noise level. The position pin (8) is retained in the correct position by two circlips (3).

The pistons have two compression rings (1) and an oil control ring (2). The groove for the top ring has a hard metal insert in order to reduce wear of the groove. The piston skirt has a coating of graphite in order to reduce the risk of seizure when the engine is new.

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

The connecting rods (4) are machined from forged molybdenum 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

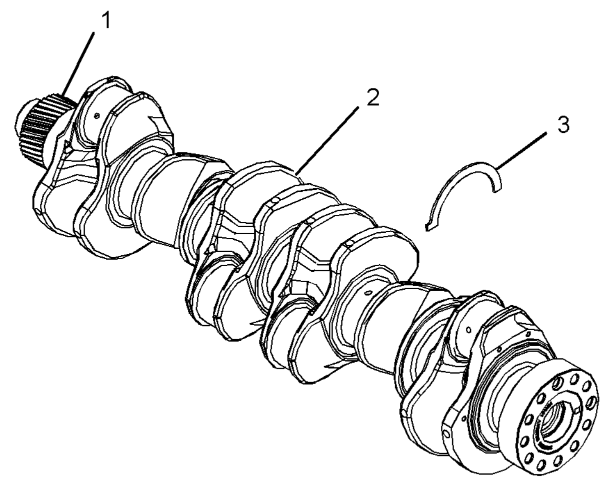

Illustration 13 g02260273

Typical example

(1) Crankshaft gear
(2) Crankshaft
(3) Thrust washer

The crankshaft is a chromium molybdenum steel forging. The crankshaft has seven main journals. Thrust washers are installed on both sides of number 6 main bearing in order to control the end play of the crankshaft.

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

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

- Camshaft gear
- Fuel injection pump
- The idler gear is driven by the crankshaft gear which turns the gear of the lubricating oil.

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

Vibration Damper

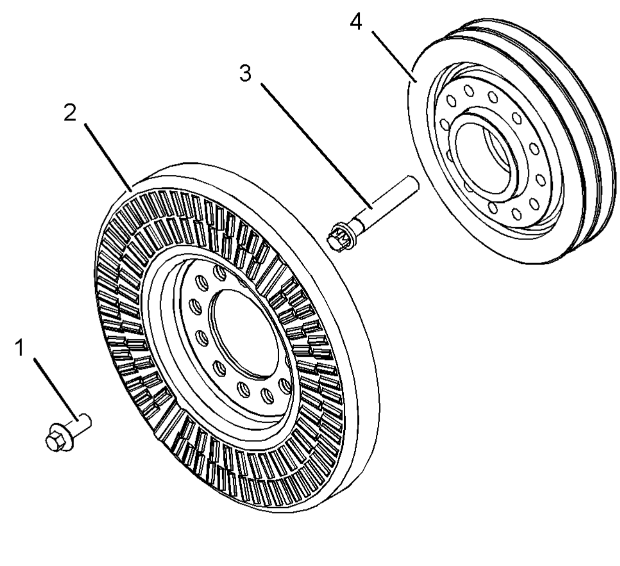

Illustration 14 g02260014

Typical example

(1) Damper setscrews
(2) Vibration damper
(3) Setscrews for the adapter
(4) Crankshaft adapter and pulley

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

Gears and Timing Gear Case

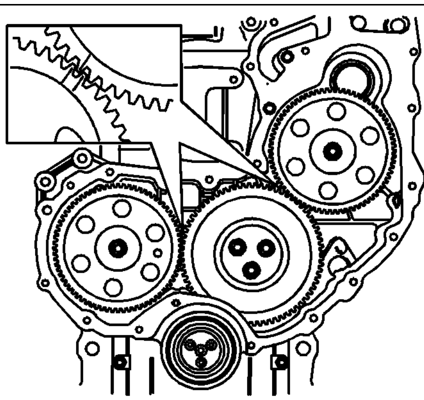

Illustration 15 g01334473

Typical example

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

The timing gears are made of steel.

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

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

Camshaft

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

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

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

i02403276

Electrical System

The electrical system is a negative ground system.

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

Starting Motor

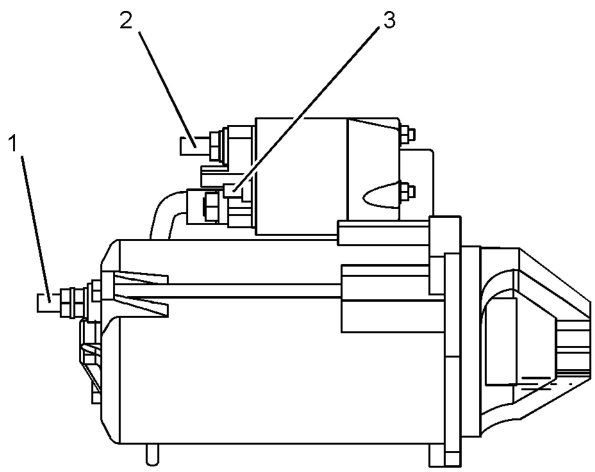

Illustration 16 g01216877

Typical example

12 Volt Starting Motor

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

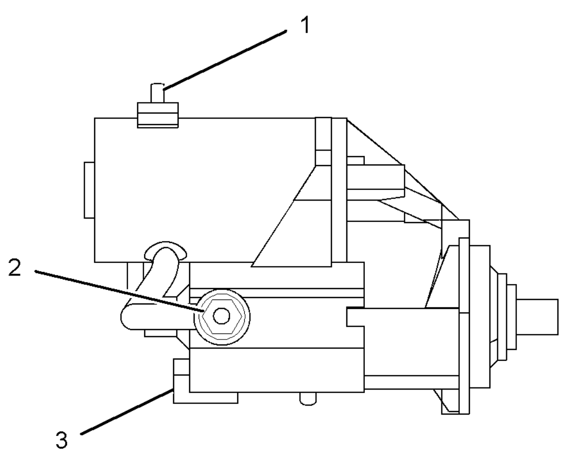

Illustration 17 g01200801

Typical example

24 Volt Starting Motor

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

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

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

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

Alternator

The electrical outputs of the alternator have the following characteristics:

- Three-phase
- Full-wave
- Rectified

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

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

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

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

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

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

Testing and Adjusting Section

Fuel System

i01804057

Fuel System - Inspect

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

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

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

3. Inspect the fuel filter for excess contamination. If necessary, install a new fuel filter. Determine the source of the contamination. Make the necessary repairs.

4. Service the primary fuel filter (if equipped).

5. Remove any air that may be in the fuel system. Refer to Testing and Adjusting, “Fuel System - Prime”.

i02780600

Air in Fuel - Test

This procedure checks for air in the fuel system. This procedure also assists in finding the source of the air.

1. Examine the fuel system for leaks. Ensure that the fuel line fittings are properly tightened. Check the fuel level in the fuel tank. Air can enter the fuel system on the suction side between the fuel transfer pump and the fuel tank.

⚠ WARNING

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

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

   - Elbows
   - Relief valves
   - Check valves
   - Connections

   Observe the fuel flow during engine cranking. Look for air bubbles in the fuel. If there is no fuel that is present in the sight gauge, prime the fuel system. Refer to Testing and Adjusting, “Fuel System - Prime” for more information. If the engine starts, check for air in the fuel at varying engine speeds. When possible, operate the engine under the conditions which have been suspect.

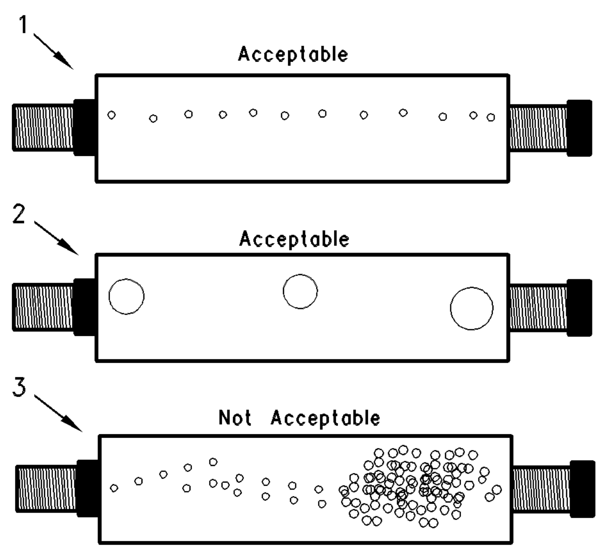

Illustration 18 g00578151

(1) A steady stream of small bubbles with a diameter of approximately 1.60 mm (0.063 inch) is an acceptable amount of air in the fuel.
(2) Bubbles with a diameter of approximately 6.35 mm (0.250 inch) are also acceptable if there is two seconds to three seconds intervals between bubbles.
(3) Excessive air bubbles in the fuel are not acceptable.

3. If excessive air is seen in the sight gauge in the fuel return line, install a second sight gauge at the inlet to the fuel transfer pump. If a second sight gauge is not available, move the sight gauge from the fuel return line and install the sight gauge at the inlet to the fuel transfer pump. Observe the fuel flow during engine cranking. Look for air bubbles in the fuel. If the engine starts, check for air in the fuel at varying engine speeds.

If excessive air is seen at the inlet to the fuel transfer pump, air is entering through the suction side of the fuel system.

WARNING

To avoid personal injury, always wear eye and face protection when using pressurized air.

NOTICE
To avoid damage, do not use more than 55 kPa (8 psi) to pressurize the fuel tank.

4. Pressurize the fuel tank to 35 kPa (5 psi). Do not use more than 55 kPa (8 psi) in order to avoid damage to the fuel tank. Check for leaks in the fuel lines between the fuel tank and the fuel transfer pump. Repair any leaks that are found. Check the fuel pressure in order to ensure that the fuel transfer pump is operating properly. For information about checking the fuel pressure, see Testing and Adjusting, "Fuel System Pressure - Test".

5. If the source of the air is not found, disconnect the supply line from the fuel tank and connect an external fuel supply to the inlet of the fuel transfer pump. If this corrects the problem, repair the fuel tank or the stand pipe in the fuel tank.

i04476411

Finding Top Center Position for No. 1 Piston

Table 1

Required Tools			
Tool	**Part Number**	**Part Name**	**Qty**
A	21825576	Crankshaft Turning Tool	1
A	27610291	Barring Device Housingl	1
	27610289	Gear	1
B	27610212	Camshaft Timing Pin	1
C	27610286	Crankshaft Timing Pin	1
	27610287	Adapter	1

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

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

2. Use Tooling (A) in order to rotate the crankshaft until the hole (X) in the camshaft gear (1) aligns with the hole in the front housing. Refer to illustration 19.

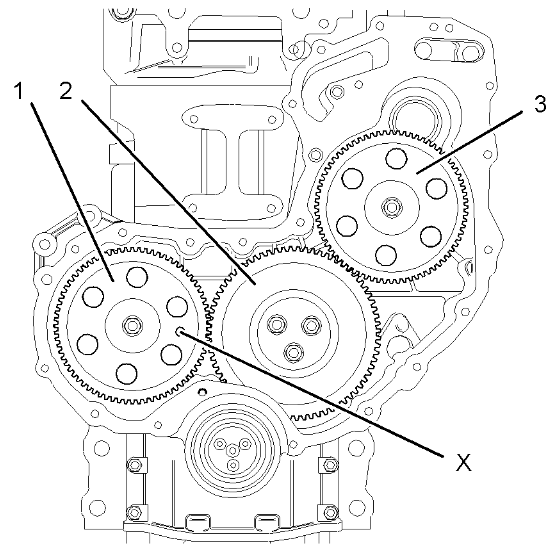

Illustration 19 g01194629

Typical example

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

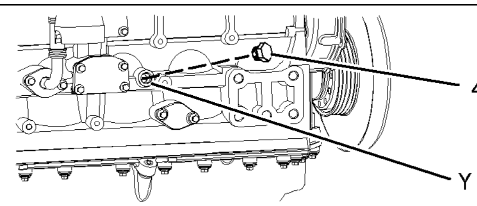

Illustration 20 g01195325

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

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

i01944302

Fuel Quality - Test

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

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

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

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

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

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

i04739290

Fuel System - Prime

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 is replaced.

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

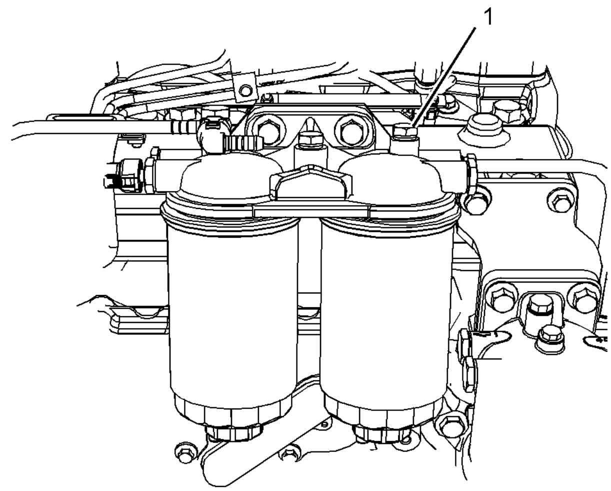

Illustration 21 g02791865

Typical example

1. Loosen the vent screw (1) on the secondary fuel filter base.

2. Operate the priming lever of the fuel priming pump to eliminate any air between the fuel priming pump and the fuel filters.

Note: The fuel priming pump is mechanically operated by the camshaft. If the lobe of the camshaft is acting upon the arm of the fuel priming pump, the ability to hand prime the fuel system will be reduced. If the resistance on the priming lever is low, rotate the crankshaft in order to move the camshaft lobe off the fuel priming pump arm.

3. Operate priming lever of the fuel priming pump by hand. Check that there is correct resistance on the fuel priming pump. Operate the fuel priming pump until fuel, free of air, comes from the vent screw.

4. Tighten the vent screw (1) to a torque of 20 N·m (15 lb ft)

5. Energize the stop solenoid on the fuel injection pump. Operate the priming lever of the fuel priming pump several times.

6. Crank the engine with the throttle lever in the CLOSED position until the engine starts.

7. Start the engine and run the engine at idle for 1 minute.

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.

8. Cycle the throttle lever from the low idle position to the high idle position three times. The cycle time for the throttle lever is one second to 6 seconds for one complete cycle.

Note: To purge air from the fuel injection pump on engines with a fixed throttle, the engine should be run at full load for 30 seconds. The load should then be decreased until the engine is at high idle. This should be repeated three times. This will assist in removing trapped air from the fuel injection pump.

9. Check for leaks in the fuel system.

i04051469

Fuel System Pressure - Test

1. Disconnect the fuel outlet pipe from the fuel transfer pump.

2. Install a pressure gauge that can measure a pressure of up to 70 kPa (10 psi) to the outlet of the fuel transfer pump.

3. Release the connection at the gauge and operate the priming lever of the fuel transfer pump to eliminate air from the pipe.

4. When fuel, free of air, flows from the pipe tighten the connection. Ensure that there are no leaks at the connections between the pump and the gauge.

5. Operate the starting motor for 10 seconds with the engine stop control in the stop position or with the stop solenoid disconnected.

6. If the pressure on the gauge indicated is less than 26 kPa (3.77 psi) repair or renew the fuel transfer pump.

7. Check the rate at which the pressure reduces to half the maximum pressure obtained. If the rate is less than 30 seconds, repair or renew the fuel transfer pump.

8. Remove the gauge and connect the outlet pipe to the transfer pump.

9. Release the vent screw on the fuel filter head. Operate the priming lever until fuel, free of air, flows from the vent screw. Tighten the vent screw.

10. Connect the engine stop solenoid.

Air Inlet and Exhaust System

i02281171

Air Inlet and Exhaust System - Inspect

Do a general visual inspection of 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 or there is a leak in the air inlet system or the exhaust system.

WARNING

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

WARNING

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

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

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

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

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

i04476171

Turbocharger - Inspect

WARNING

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

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

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

Dispose of all fluids according to local regulations and mandates.

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

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

- Inspection of the compressor wheel and the compressor housing

- Inspection of the turbine wheel and the turbine housing

- Inspection of the wastegate

Inspection of the Compressor Wheel and the Compressor Housing

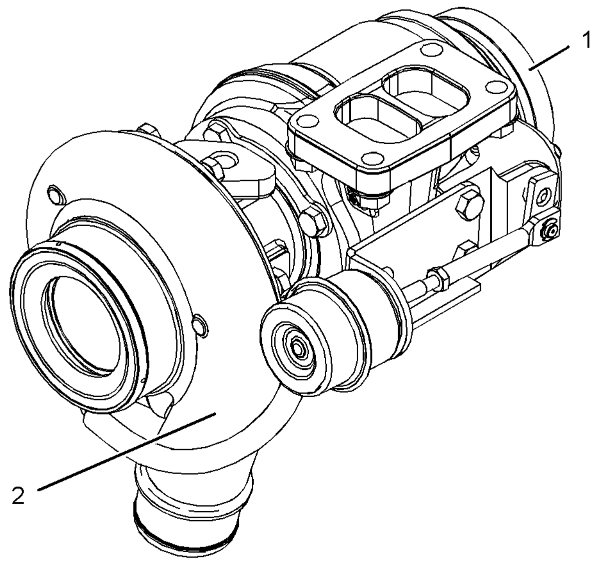

Illustration 22 g02269953

Typical example

(1) Turbine housing
(2) Compressor housing

1. Remove the air cleaner from the compressor inlet.

2. Inspect compressor wheel for damage from a foreign object. If there is damage, determine the source of the foreign object. As required, clean the inlet system and repair the intake system. Replace the turbocharger. If there is no damage, go to Step 4.

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

4. Inspect compressor wheel (2) and compressor housing (1) for oil leakage. An oil leak from the compressor wheel may deposit oil in the aftercooler (if equipped). Drain and clean the aftercooler if you find oil in the aftercooler.

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

    b. Inspect the air cleaner element for restriction. If restriction is found, correct the problem.

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

    d. Remove the oil drain tube. Inspect the oil drain hole and the oil drain tube for oil sludge. Inspect the area between the bearings of the rotating assembly shaft. If necessary, clean the rotating assembly shaft, the oil drain hole, and the oil drain tube.

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

Inspection of the Turbine Wheel and the Turbine Housing

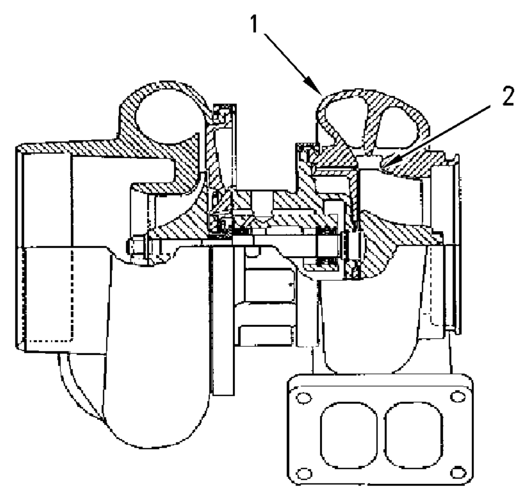

Illustration 23 g00922420

Typical example

(1) Turbine housing
(2) Turbine wheel

1. Remove the air piping from the turbine housing.

2. Inspect turbine wheel (2) 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 3.

3. Clean turbine wheel (2) and turbine housing (1) if you find buildup of carbon or foreign material. If there is no buildup of carbon or foreign material, go to Step 4.

4. Turn the rotating assembly by hand. While you turn the assembly, push the assembly sideways. The assembly should turn freely. Turbine wheel (2) should not rub turbine housing (1). Replace the turbocharger if the turbine wheel rubs the turbine housing. If there is no rubbing or scraping, go to Step 5.

5. Inspect turbine wheel (2) and turbine housing (1) for oil leakage and 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 5.a. Otherwise go to "Inspection of the Wastegate".

    a. Remove the oil drain tube. Inspect the oil drain hole and the oil drain tube for oil sludge. Inspect the area between the bearings of the rotating assembly shaft. If necessary, clean the rotating assembly shaft, the oil drain hole, and the oil drain tube.

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

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

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

    e. If Steps 5.a through 5.d did not reveal the source of the oil leakage, the turbocharger has internal damage. Replace the turbocharger.

Inspection of the Wastegate (If equipped)

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

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

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

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

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

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

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

Check the Wastegate for Proper Operation

Table 2

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

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

1. Remove the heat shield from the turbocharger. Remove the guard for the wastegate.

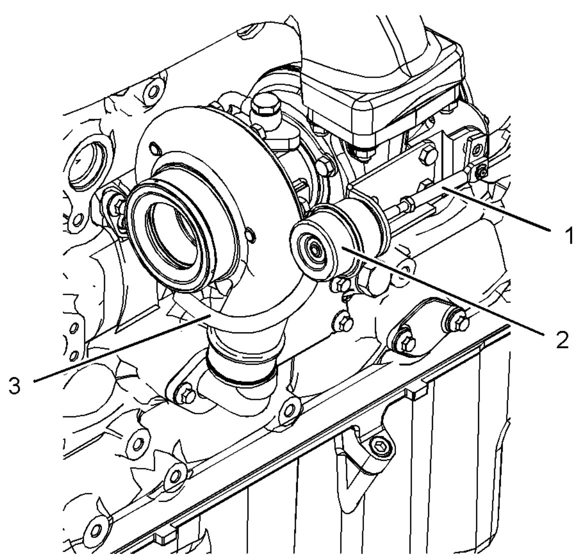

Illustration 24
g02269955

Typical example

2. Remove the boost line (3) from the wastegate (2). Connect an air supply to the wastegate that can be measured accurately.

3. Fasten a dial indicator to the turbocharger so that the end of the actuator rod (1) is in contact with the dial indicator. This will measure axial movement of the actuator rod.

4. Slowly apply air pressure to the wastegate (2) so that the actuator rod (1) moves 1.0 mm (0.039 inch). The air pressure should be within 107 to 117 kPa (15.5 to 17.0 psi). Ensure that the dial indicator returns to zero when the air pressure is released. Repeat the test several times. This will ensure that an accurate reading is obtained.

5. If the operation of the wastegate (2) is incorrect then the turbocharger must be renewed.

i04046710

Compression - Test

The cylinder compression test should only be used in order to compare the cylinders of an engine. If one or more cylinders vary by more than 350 kPa (51 psi), the cylinder and related components may need to be repaired.

A compression test should not be the only method which is used to determine the condition of an engine. Other tests should also be conducted in order to determine if the adjustment or the replacement of components is required.

Before the performance of the compression test, make sure that the following conditions exist:

- The battery is in good condition.
- The battery is fully charged.
- The starting motor operates correctly.
- The valve lash is set correctly.
- All glow plugs are removed.
- The fuel supply is disconnected.

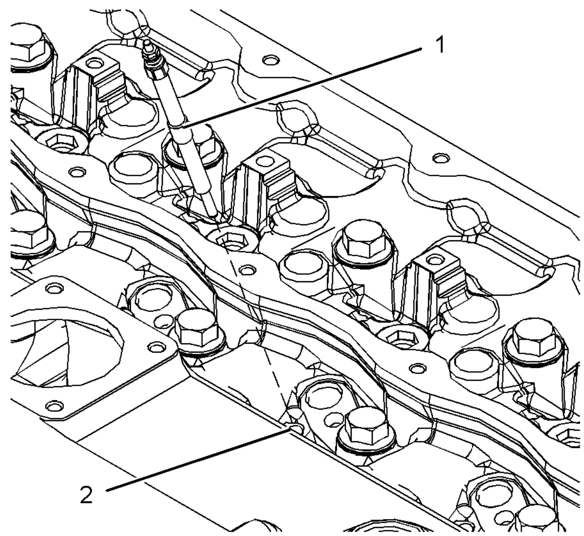

Illustration 25 g02260098

Typical example

1. Remove the glow plug (1). Refer to Disassembly and Assembly, “Glow Plugs - Remove and Install” for the correct procedure.

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

3. Remove the fuse for the glow plugs.

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

5. Repeat Steps 6 and 4 for all cylinders.

6. Install the fuse for the glow plugs.

i04046711

Engine Valve Lash - Inspect/Adjust

WARNING

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

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

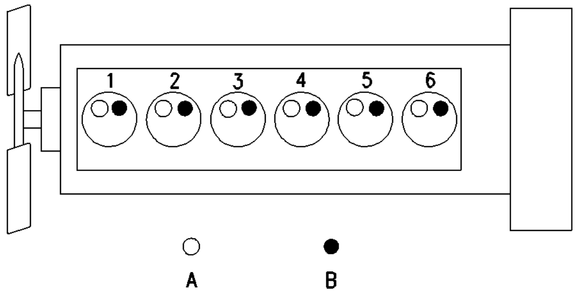

Illustration 26 g00939480

Cylinder and valve location

(A) Inlet valve
(B) Exhaust valve

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

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

Valves become worn due to the following causes:

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

Too much valve lash can cause broken valve stems, springs, and spring retainers. Too much valve lash can be an indication of the following problems:

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

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

Valve Lash Check

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

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

Valve Lash Adjustment

Table 3

	Inlet Valves	Exhaust Valves
Valve Lash	0.35 mm (0.014 inch)	0.45 mm (0.018 inch)
TC Compression Stroke	1-2-4	1-3-5
TC Exhaust Stroke(1)	3-5-6	2-4-6
Firing Order	1-5-3-6-2-4(2)	

(1) 360° from TC compression stroke
(2) The No. 1 Cylinder is at the front of the engine.

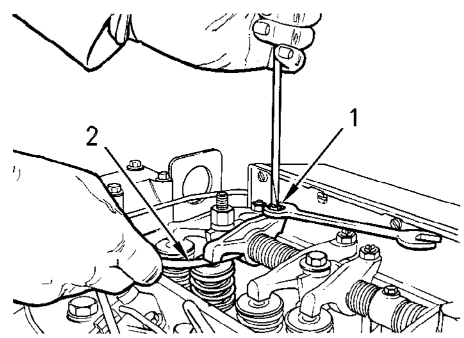

Illustration 27 g00323903

Setting the valve lash

(1) Adjustment screw
(2) Feeler gauge

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

2. Rotate the crankshaft in the direction of engine rotation until the inlet valve of the No. 6 cylinder has opened and the exhaust valve of the No. 6 cylinder has not completely closed. The engine is now at TC compression stroke.

Table 4

TC Compression Stroke	Inlet Valves	Exhaust Valves
Valve Lash	0.35 mm (0.014 inch)	0.45 mm (0.018 inch)
Cylinders	1-2-4	1-3-5

3. Measure the valve lash for the valve when the engine is at TC compression stroke according to Table 4. If necessary, make an adjustment to the valves according to Table 4.

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

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

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

4. Rotate the crankshaft in the direction of engine rotation to TC exhaust stroke (360° from TC compression stroke).

Table 5

TC Exhaust Stroke(1)	Inlet Valves	Exhaust Valves
Valve Lash	0.35 mm (0.014 inch)	0.45 mm (0.018 inch)
Cylinders	3-5-6	2-4-6

(1) 360° from TC compression stroke

5. Measure the valve lash for the valves when the engine is at TC exhaust stroke according to Table 5. If necessary, make an adjustment to the valves according to Table 5.

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

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

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

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

i04103769

Valve Depth - Inspect

Table 6

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

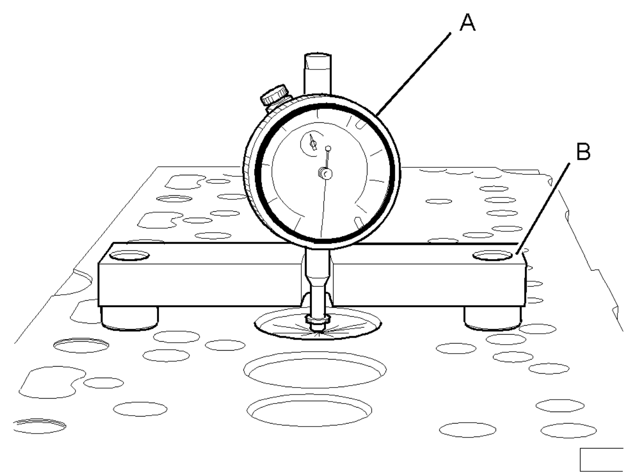

Illustration 28 g01201916

Typical example

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

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

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

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

   - Valves
   - Valve inserts

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

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

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

i04046714

Valve Guide - Inspect

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

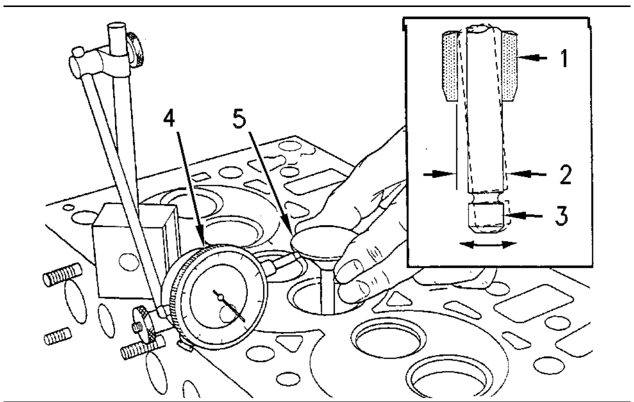

Illustration 29 g00314806

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. Refer to Specifications, "Cylinder Head Valves" for the clearances.

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.

Lubrication System

i02648880

Engine Oil Pressure - Test

Low Oil Pressure

The following conditions will cause low oil pressure.

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

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

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

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

High Oil Pressure

High oil pressure can be caused by the following conditions.

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

i02400036

Engine Oil Pump - Inspect

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

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

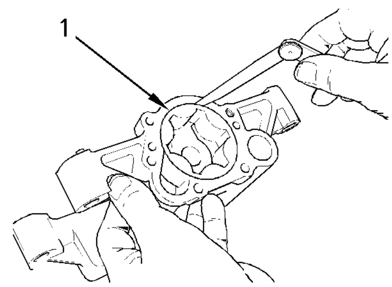

Illustration 30 g00938064

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

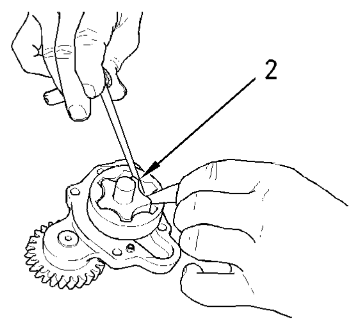

Illustration 31 g00938061

Clearance for the inner rotor body

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

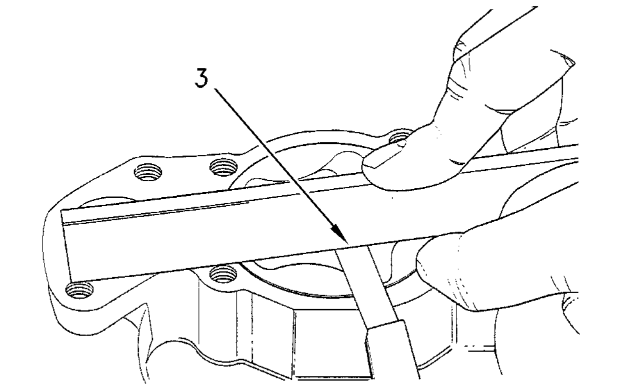

Illustration 32 g00938799

End play measurement of the rotor

5. Measure the end play of the rotor with a straight edge and a feeler gauge (3).

6. Clean the top face of the oil pump and the bottom face of the cover. Install the cover on the oil pump. Install the oil pump on the engine.

i01126690

Excessive Bearing Wear - Inspect

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

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

i02414692

Excessive Engine Oil Consumption - Inspect

Engine Oil Leaks on the Outside of the Engine

Check for leakage at the seals at each end of the crankshaft. Look for leakage at the gasket for the engine oil pan and all lubrication system connections. Look for any engine oil that may be leaking from the crankcase breather. This can be caused by combustion gas leakage around the pistons. A dirty crankcase breather will cause high pressure in the crankcase. A dirty crankcase breather will cause the gaskets and the seals to leak.

Engine Oil Leaks into the Combustion Area of the Cylinders

Engine oil that is leaking into the combustion area of the cylinders can be the cause of blue smoke. There are several possible ways for engine oil to leak into the combustion area of the cylinders:

- Failed valve stem seals
- Leaks between worn valve guides and valve stems
- Worn components or damaged components (pistons, piston rings, or dirty return holes for the engine oil)
- Incorrect installation of the compression ring and/or the intermediate ring
- Leaks past the seal rings in the turbocharger shaft
- Overfilling of the crankcase
- Wrong dipstick or guide tube
- Sustained operation at light loads

Excessive consumption of engine oil can also result if engine oil with the wrong viscosity is used. Engine oil with a thin viscosity can be caused by fuel leakage into the crankcase or by increased engine temperature.

i02414679

Increased Engine Oil Temperature - Inspect

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

Cooling System

i02419296

Cooling System - Check

Engine And Cooling System Heat Problems

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

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

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

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

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

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

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

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

a. Refer to "Testing The Radiator And Cooling System For Leaks" procedures.

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

a. Perform the "Testing The Water Temperature Regulator " procedures.

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

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

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

i01626003

Cooling System - Inspect

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

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

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

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

Visual Inspection Of The Cooling System

1. Check the coolant level in the cooling system.

2. Look for leaks in the system.

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

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

4. Inspect the drive belt for the fan.

5. Inspect the blades of the fan for damage.

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

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

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

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

i02414661

Cooling System - Test

Remember that temperature and pressure work together. When a diagnosis is made of a cooling system problem, temperature and pressure must be checked. The cooling system pressure will have an effect on the cooling system temperature. For an example, refer to Illustration 33. 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.

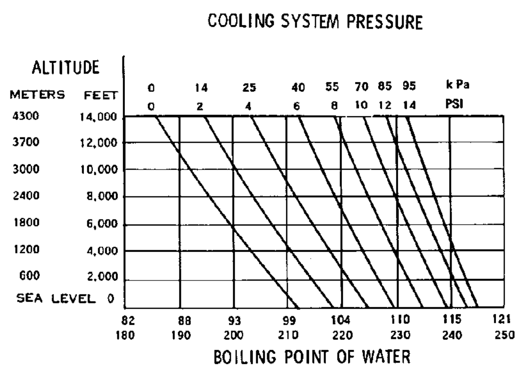

Illustration 33 g00286266

Cooling system pressure at specific altitudes and boiling points of water

⚠ WARNING

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

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

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

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

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

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

Making the Correct Antifreeze Mixtures

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

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

Checking the Filler Cap

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

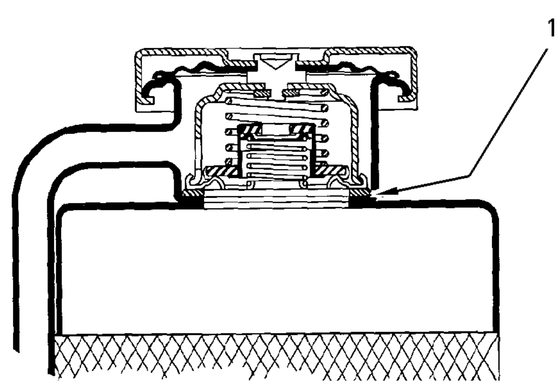

Illustration 34 g00296067

Typical schematic of filler cap

(1) Sealing surface between the pressure cap and the radiator

WARNING

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

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

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

To check for the amount of pressure that opens the filler cap, use the following procedure:

1. After the engine cools, carefully loosen the filler cap. Slowly release the pressure from the cooling system. Then, remove the filler cap.
2. Carefully inspect the filler cap. Look for any damage to the seals and to the sealing surface. Inspect the following components for any foreign substances:
   - Filler cap
   - Seal
   - Surface for seal

   Remove any deposits that are found on these items, and remove any material that is found on these items.
3. Install the pressure cap onto a suitable pressurizing Pump.
4. Observe the exact pressure that opens the filler cap.
5. Compare the pressure to the pressure rating that is found on the top of the filler cap.
6. If the filler cap is damaged, replace the filler cap.

Testing The Radiator And Cooling System For Leaks

Use the following procedure to test the radiator and the cooling system for leaks.

WARNING

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

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

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

1. When the engine has cooled, loosen the filler cap to the first stop. Allow the pressure to release from the cooling system. Then remove the filler cap.
2. Make sure that the coolant covers the top of the radiator core.
3. Put a suitable pressurizing Pump onto the radiator.
4. Use the pressurizing pump to increase the pressure to an amount of 20 kPa (3 psi) more than the operating pressure of the filler cap.
5. Check the radiator for leakage on the outside.
6. Check all connections and hoses of the cooling system for leaks.

   The radiator and the cooling system do not have leakage if all of the following conditions exist:

   - You do NOT observe any leakage after five minutes.
   - The dial indicator remains constant beyond five minutes.

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

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

   Make any repairs, as required.

i02652662

Engine Oil Cooler - Inspect

WARNING

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

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

Engine Oil Cooler with a Low Mounted Filter Base

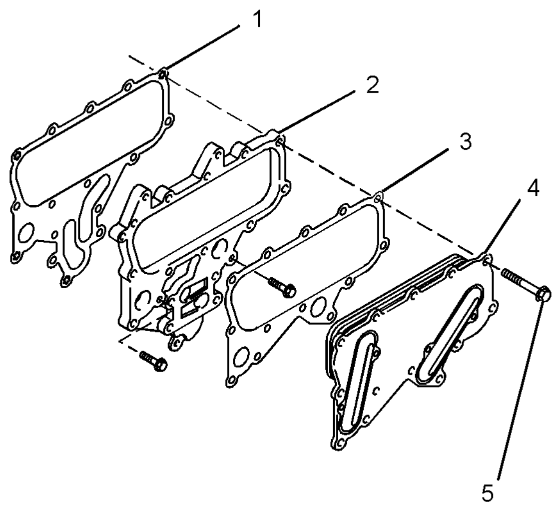

Illustration 35 g01332170

Typical example

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

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

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

2. Refer to Disassembly and Assembly, "Engine Oil Cooler - Remove" for removal of the engine oil cooler.

3. Thoroughly clean the oil cooler (1) and the cylinder block.

WARNING

Personal injury can result from air pressure.

Personal injury can result without following proper procedure. When using pressure air, wear a protective face shield and protective clothing.

Maximum air pressure at the nozzle must be less than 205 kPa (30 psi) for cleaning purposes.

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

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

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

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

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

   Check for oil or coolant leakage.

Engine Oil Cooler with a High Mounted Filter Base

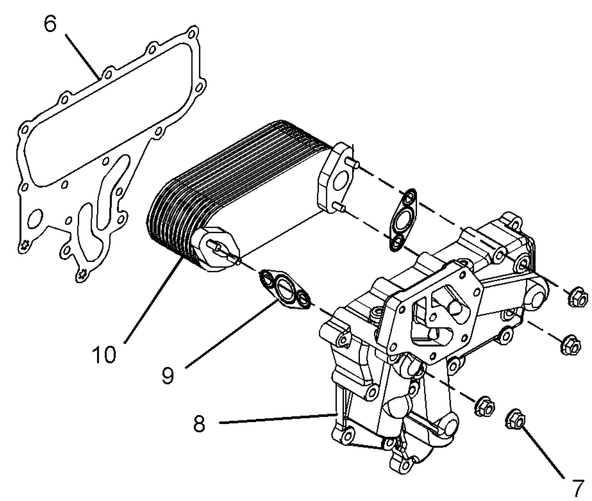

Illustration 36 g01322246

Typical example

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

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

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

2. Refer to Disassembly and Assembly, “Engine Oil Cooler - Remove” for removal of the engine oil cooler.

3. Thoroughly clean the oil cooler (1) and the cylinder block.

WARNING

Personal injury can result from air pressure.

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

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

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

Note: Refer to Operation And Maintenance Manual, “Refill Capacities” for additional information.

   Check for oil or coolant leakage.

i02414647

Water Temperature Regulator - Test

WARNING

Personal injury can result from escaping fluid under pressure.

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

1. Remove the water temperature regulator from the engine. Refer to Disassembly and Assembly Manual, “Water Temperature Regulator - Remove and Install”.

2. Heat water in a pan until the temperature of the water is equal to the fully open temperature of the water temperature regulator. Refer to Specifications, “Water Temperature Regulator” for the fully open temperature of the water temperature regulator. Stir the water in the pan. This will distribute the temperature throughout the pan.

3. Hang the water temperature regulator in the pan of water. The water temperature regulator must be below the surface of the water. The water temperature regulator must be away from the sides and the bottom of the pan.

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

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

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

Basic Engine

i02415240

Piston Ring Groove - Inspect

Inspect the Piston and the Piston Rings

1. Check the piston for wear and other damage.

2. Check that the piston rings are free to move in the grooves and that the rings are not broken.

Inspect the Clearance of the Piston Ring

1. Remove the piston rings and clean the grooves and the piston rings.

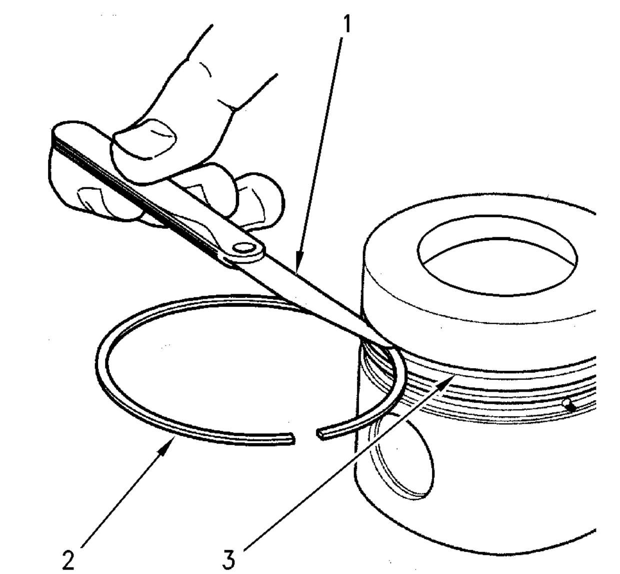

Illustration 37 g00905732

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

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

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

Inspect the Piston Ring End Gap

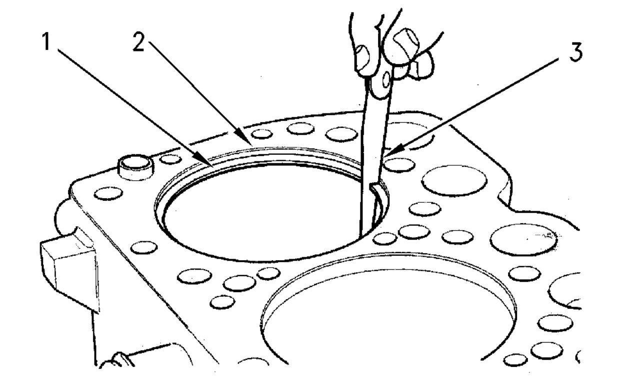

Illustration 38 g00782363

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

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

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

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

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

i04046797

Connecting Rod - Inspect

These procedures determine the following characteristics of the connecting rod:

- The length of the connecting rod

- The distortion of the connecting rod

- The parallel alignment of the bores of the connecting rod

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

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

- New connecting rod assemblies that are the correct grade of length must be installed. Refer to "Length Of The Connecting Rod".

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

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

Length of The Connecting Rod

The connecting rod length (CRL) is the length of the connecting rod. Refer to Table 7 for each grade of length of connecting rod.

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

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

If the connecting rod must be replaced, a new connecting rod assembly must be purchased and installed. Refer to Table 7 for more information.

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

Piston Pin Bearings

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

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

1. Determine the grade of length of the connecting rod. Use one of the following characteristics:

   - The mark

   - The color

   - Measuring the length

2. Ensure that the connecting rod is aligned parallel and that the connecting rod is not distorted. Refer to "Distortion Of A Connecting Rod" in this service module.

3. Remove the piston pin bearing from the connecting rod. Install a new bearing in the connecting rod. The new bearing is partially finished. The new bearing must be bored off-center to the correct diameter. This off-center position is determined by the grade of length of the connecting rod. Refer to Table 7. 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

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

5. If the grade of length of the connecting rod is changed, the letter that is stamped on the connecting rod must be removed. Etch a letter that is for the new grade of length on the side of the connecting rod.

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

Table 7 references the following information: Grade of letter of the connecting rod, the color code of the connecting rods, and the lengths of the connecting rods.

Table 7

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

Measure The Length Of The Connecting Rod

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

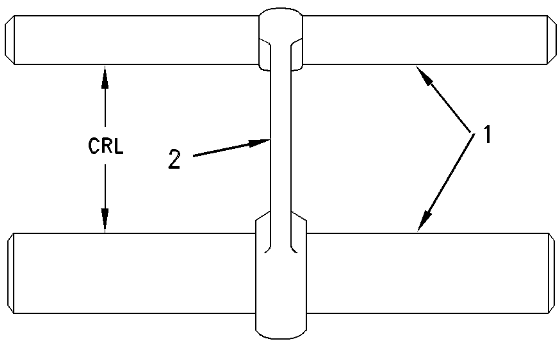

Illustration 39 g00326546

Measure the length of the connecting rod.

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

1. Refer to Illustration 39. Use the following tools in order to measure the length of the connecting rod:

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

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

   Measure "CRL". Compare the "CRL" that is given in Table 7. The grade of length of the connecting rod is determined by the "CRL". Refer to Table 7 for the correct grade of length.

Distortion of The Connecting Rod

1. Use the following tools in order to measure the distances for the connecting rod (2) which are specified in Illustration 39:

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

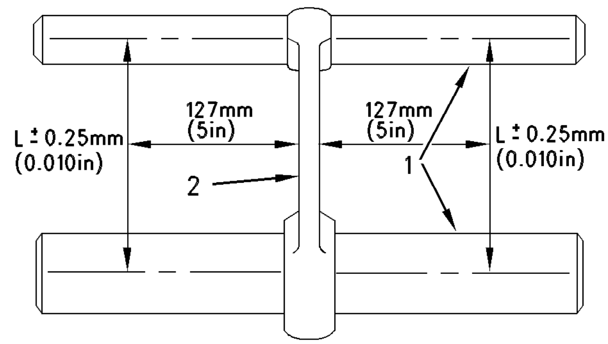

Illustration 40 g00326423

Measure the connecting rod for distortion.

(1) Measuring pins
(2) Connecting rod
(L) The length between the centers of the piston pin bearing and the crankshaft journal bearing is shown in Illustration 40.

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

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

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

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

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

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

4. Measure the clearance of the piston pin in the piston pin bearing. Refer to the Specifications, "Connecting Rod" for dimensions.

i04046730

Connecting Rod Bearings - Inspect

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

i04046790

Main Bearings - Inspect

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

i03191701

Cylinder Block - Inspect

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

2. Check the cylinder block for cracks and damage.

3. The top deck of the cylinder block must not be machined.

4. Check the front camshaft bearing for wear. Refer to Specifications, "Camshaft Bearings" for the correct specification of the camshaft bearing. If a new bearing is needed, use a suitable adapter to press the bearing out of the bore. Ensure that the oil hole in the new bearing faces the front of the block. The oil hole in the bearing must be aligned with the oil hole in the cylinder block. The bearing must be aligned with the face of the recess.

i04046732

Cylinder Head - Inspect

1. Remove the cylinder head from the engine.

2. Remove the water temperature regulator housing.

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

4. Remove the valve springs and valves.

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

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

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

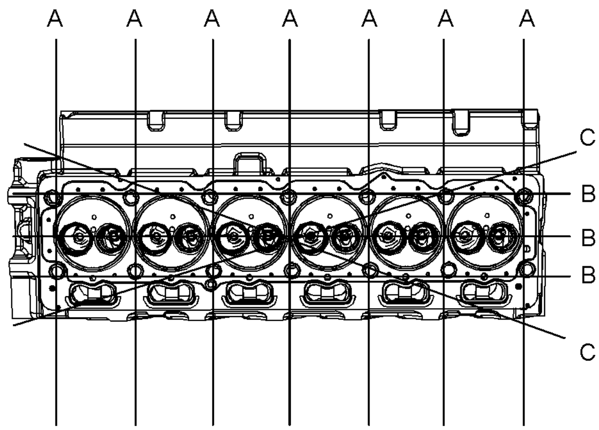

Illustration 41 g02260053

Flatness of the cylinder head (typical example)

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

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

    - Measure the cylinder head from one side to the opposite side (A).

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

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

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

Resurfacing the Cylinder Head

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

- The bottom face of the cylinder head is not flat within the specifications.

- The bottom face of the cylinder head is damaged by pitting, corrosion, or wear.

Note: The thickness of the cylinder head must not be less than 118 mm (4.64566 inch) after the cylinder head has been machined.

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

i02406197

Piston Height - Inspect

Table 8

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

If the height of the piston above the cylinder block is not within the tolerance that is given in the Specifications Module, “Piston and Rings”, the bearing for the piston pin must be checked. Refer to Testing and Adjusting, “Connecting Rod - Inspect”. If any of the following components are replaced or remachined, the piston height above the cylinder block must be measured:

- Crankshaft
- Cylinder head
- Connecting rod
- Bearing for the piston pin

The correct piston height must be maintained in order to ensure that the engine conforms to the standards for emissions.

Note: The top of the piston should not be machined. If the original piston is installed, be sure that the original piston is assembled to the correct connecting rod and installed in the original cylinder.

Three grades of length of connecting rods determine the piston height above the cylinder block. The grade of length of a connecting rod is identified by a letter or a color. The letter or the color is marked on the side of the connecting rod. Refer to Testing and Adjusting, “Connecting Rod - Inspect” and Specifications, “Connecting Rod” for additional information.

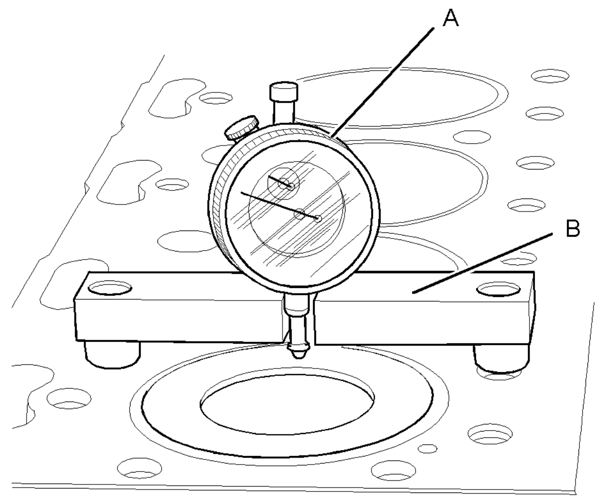

Illustration 42 g01201898

Typical example

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

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

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

i02636429

Flywheel - Inspect

Table 9

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

Alignment of the Flywheel Face

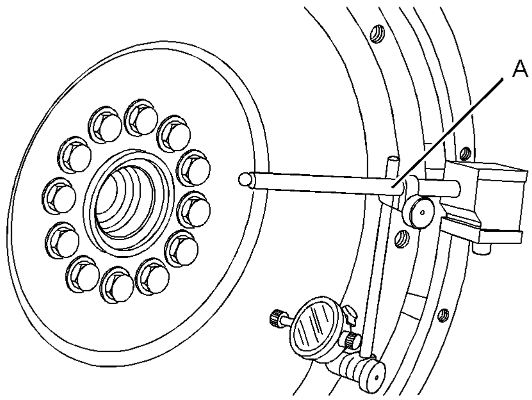

Illustration 43 g01332565

Typical example

1. Install Tooling (A) in illustration 43, as shown.
2. Set the pointer of the dial indicator to 0 mm (0 inch).
3. Turn the flywheel. Read the dial indicator for every 45 degrees.

Note: During the check, keep the crankshaft pressed toward the front of the engine in order to remove any end clearance.

4. Calculate the difference between the lowest measurement and the highest measurement of the four locations. This difference must not be greater than 0.03 mm (0.001 inch) for every 25 mm (1.0 inch) of the radius of the flywheel. The radius of the flywheel is measured from the axis of the crankshaft to the contact point of the dial indicator.

Flywheel Runout

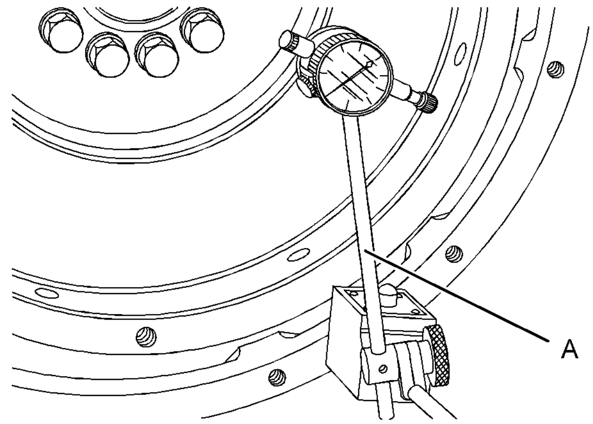

Illustration 44 g01321858

Typical example

1. Install Tooling (A) in illustration 44, as shown.
2. Set the pointer of the dial indicator to 0 mm (0 inch).
3. Turn the flywheel. Read the dial indicator for every 45 degrees.
4. Calculate the difference between the lowest measurement and the highest measurement of the four locations. This difference must not be greater than 0.30 mm (0.012 inch).

i02406200

Flywheel Housing - Inspect

Table 10

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

Concentricity of the Flywheel Housing

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

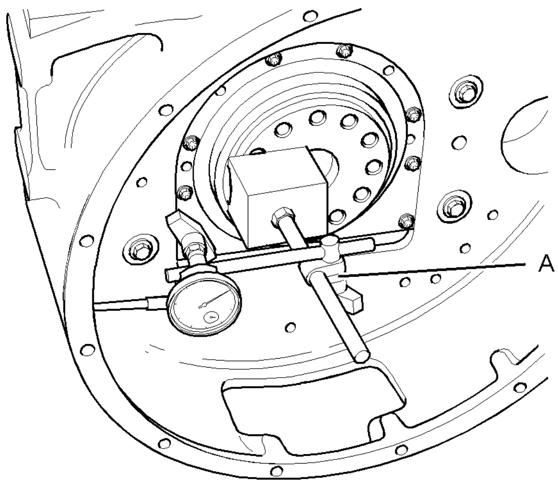

Illustration 45 g01199468

Typical example

1. Install Tooling (A). See illustration 45.

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

3. Check the concentricity at intervals of 45 degrees around the flywheel housing.

4. Calculate the difference between the lowest measurement and the highest measurement. This difference must not be greater than the limit that is given in Table 11.

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

Alignment of the Flywheel Housing

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

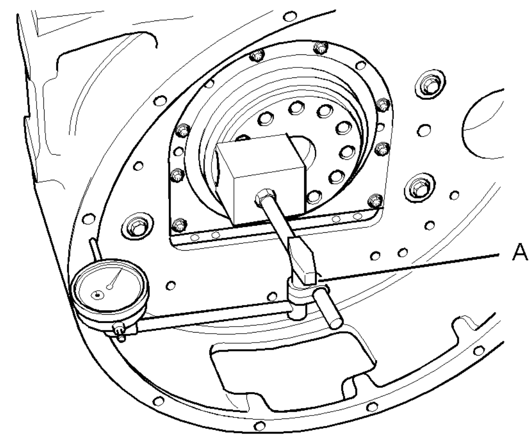

Illustration 46 g01199467

Typical example

1. Install Tooling (A). See illustration 46.

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

3. Check the alignment at intervals of 45 degrees around the flywheel housing.

4. Calculate the difference between the lowest measurement and the highest measurement. This difference must not be greater than the limit that is given in Table 11.

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

Table 11

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

i02652636

Gear Group - Inspect

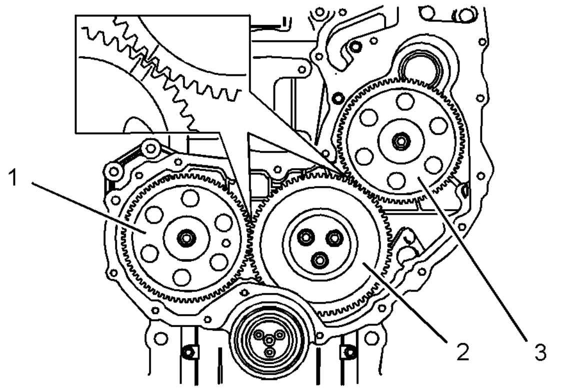

Illustration 47 g01332563

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

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

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

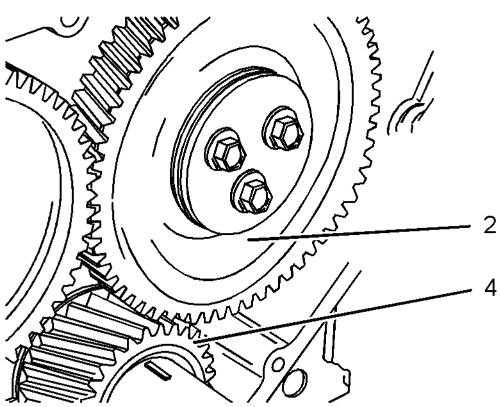

Illustration 48 g01332564

2. Measure the backlash between the camshaft gear (1) and the idler gear (2). Refer to Specifications, "Gear Group (Front)" for the backlash measurement.
3. Measure the backlash between the idler gear (2) and the crankshaft gear (4). Refer to Specifications, "Gear Group (Front)" for the backlash measurement.
4. Measure the backlash between the fuel injection pump gear (3) and the idler gear (2). Refer to Specifications, "Gear Group (Front)" for the backlash measurement.
5. Measure the end play on idler gear (2). Refer to Disassembly and Assembly, "Idler Gear - Install" for the correct procedure. Refer to Specifications, "Gear Group (Front)" for the end play measurement.

i04047270

Vibration Damper - Check

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

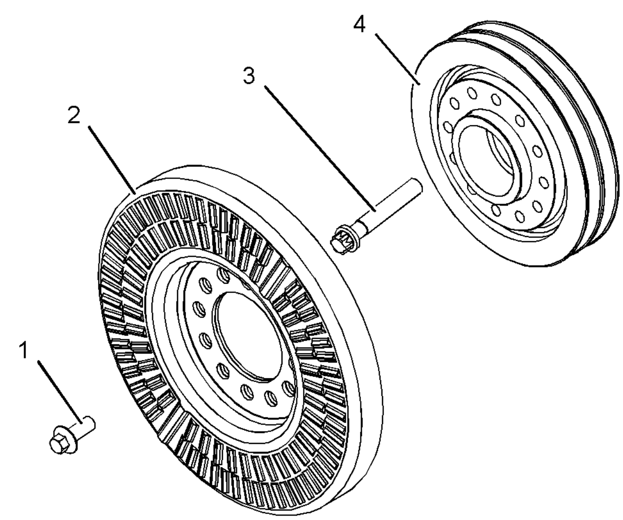

Illustration 49 g02260014

Vibration damper with hub assembly

(1) Damper setscrews
(2) Vibration damper
(3) Setscrews for the adapter
(4) Crankshaft adapter and pulley

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

- There is any impact damage to the outer casing.
- There is leakage of the viscous fluid from the cover plate.

- There is movement of the pulley or the outer ring on the hub.

- There is a large amount of gear train wear that is not caused by lack of oil.

- Analysis of the engine oil has revealed that the front main bearing is badly worn.

- The engine has had a failure because of a broken crankshaft.

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

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

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

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

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

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

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

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

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

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

Electrical System

i02418531

Alternator - Test

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

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

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

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

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

Table 12

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

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

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 12.

i01899136

Battery - Test

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

WARNING

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

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

NOTICE

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

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

i01945632

Electric Starting System - Test

General Information

All electrical starting systems have four elements:

- Ignition switch
- Start relay
- Starting motor solenoid
- Starting motor

Start switches have a capacity of 5 to 20 amperes. The coil of a start relay draws about 1 ampere between test points. The switch contacts of the start relay for the starting motor are rated between 100 and 300 amperes. The start relay can easily switch the load of 5 to 50 amperes for the starting motor solenoid.

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

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

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

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

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

Table 13

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

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

Table 14

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 14 are caused most often by the following conditions:

- Loose connections
- Corroded connections
- Faulty switch contacts

Diagnosis Procedure

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

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

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

1. Measure the voltage of the battery.

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

a. If the voltage is equal or greater than the voltage in Table 13, then go to Step 2.

b. The battery voltage is less than the voltage in Table 13.

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 13.
- The large starting motor cables get hot.

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

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

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

3. Measure the voltage of the starting motor.

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

b. If the voltage is equal or greater than the voltage that is given in Table 13, 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 13. 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 14.

   b. Voltage drops are equal to the voltage drops that are given in Table 14 or the voltage drops are less than the voltage drops that are given in Table 14. Go to Step 5 in order to check the engine.

   c. The voltage drops are greater than the voltage drops that are given in Table 14. The faulty component should be repaired or replaced.

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.

i02404376

Glow Plugs - Test

Continuity Check of the Glow Plugs

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

1. Disconnect the power supply and the bus bar.

2. Use a suitable digital multimeter to check continuity (resistance). Turn the audible signal on the digital multimeter ON.

3. Place one probe on the connection for the glow plug and the other probe to a suitable ground. The digital multimeter should make an audible sound. Replace the glow plug if there is no continuity.

4. Check the continuity on all the glow plugs.

Checking The Operation of The Glow Plug

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

1. Disconnect the power supply and the bus bar.

2. Connect the power supply to only one glow plug.

3. Place a suitable ammeter on the power supply wire.

4. Connect a suitable digital multimeter to the terminal on the glow plug and to a suitable ground.

5. Turn the switch to the ON position in order to activate the glow plugs.

Table 15

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

Table 16

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

6. Check the reading on each of the glow plugs.

7. If there is no reading on the ammeter check the electrical connections. If the readings on the ammeter are low replace the faulty glow plug. If there is still no reading replace the faulty glow plug.

i04538676

V-Belt - Test

Table 17

Required Tools			
Tool	**Part Number**	**Part Description**	**Qty**
A	-	Belt Tension Gauge	1

Table 18

Belt Tension Chart			
Size of Belt	**Width of Belt**	**Gauge Reading**	
		Initial Belt Tension(1)	**Used Belt Tension**(2)
1/2	13.89 mm (0.547 In)	535 N (120 lb)	355 N (80 lb)
Measure the tension of the belts.			

(1) Initial Belt Tension refers to a new belt.
(2) Used Belt Tension refers to a belt that has been in operation for 30 minutes or more at the rated speed.

Install Tooling (A) at the center of the longest free length of belt and check the tension on both belts. Check and adjust the tension on the tightest belt. To adjust the belt tension, refer to Disassembly and Assembly, “Alternator - Install”.

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