CATERPILLAR®

RENR9968-02
July 2007

Systems Operation
Testing and Adjusting

C27 and C32 Generator Set Engines

DWB1-Up (Generator Set)
SXC1-Up (Generator Set)
MED1-Up (Power Module)
MEG1-Up (Power Module)
WDR1-Up (Generator Set)

i01658146

Important Safety Information

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

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

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

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

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

⚠ WARNING

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

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

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

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

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

⚠ WARNING

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

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

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Systems Operation Section

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General Information

SMCS Code: 1000

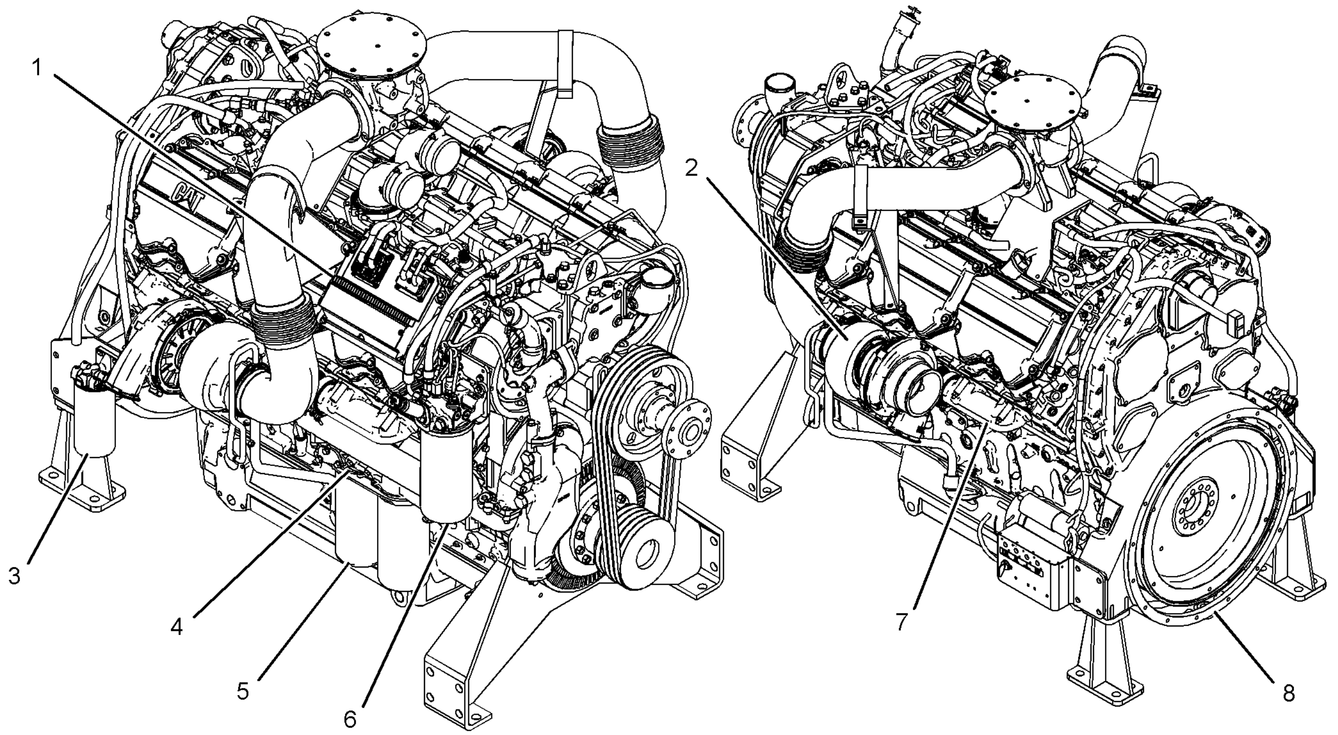

Illustration 1 g01205382

Typical example

(1) Electronic Control Module (ECM)
(2) Turbocharger
(3) Primary fuel filter and water separator
(4) Engine oil filter base
(5) Engine oil filters
(6) Secondary fuel filter and fuel priming pump
(7) Exhaust manifold
(8) Flywheel housing

The Mechanical Electronic Unit Injector (MEUI) fuel system is used on this engine. The MEUI fuel system eliminates many of the mechanical components that are used in a pump and lines. The electronic control and mechanical actuation provides increased control of the timing and increased control of the fuel injection pressure. The timing advance is achieved by precise control of the unit injector timing. Engine speed is controlled by adjusting the injection duration. A special speed-timing wheel provides information to the Electronic Control Module (ECM) for detection of cylinder position and engine speed.

The engine has built-in diagnostics in order to ensure that all of the components are operating properly. In the event of a system component failure, the operator will be alerted to the condition via the diagnostic lamp that is located on the control panel. Caterpillar Electronic Technician (ET) can be used to read the numerical code of the faulty component or condition. Intermittent faults are also logged and stored in memory.

Starting the Engine

The engine's ECM will automatically provide the correct amount of fuel in order to start the engine. Do not hold the throttle down while the engine is cranking. If the engine fails to start in twenty seconds, release the starting switch. Allow the starting motor to cool for two minutes before using the starting motor again.

NOTICE

Excessive ether (starting fluid) can cause piston and ring damage. Use ether for cold weather starting purposes only.

Cold Mode Operation

The ECM will set the cold start strategy when the coolant temperature is below 20 °C (68 °F).

When the cold start strategy is activated, low idle rpm will be increased and engine power will be limited.

Cold mode operation will be deactivated when any of the following conditions have been met:

- Coolant temperature reaches 20 °C (68 °F).
- The engine has been running for twelve minutes.

Cold mode operation uses a modified control map, that is stored in the ECM, in order to adjust the fuel injection timing and the injection duration for white smoke cleanup. The engine will usually exit the cold mode operation before the walk-around inspection is completed. During cold mode operation, the engine will remain at the elevated rpm that has been specified for the engine.

After the cold mode is completed, the engine should be operated at low rpm until normal operating temperature is reached. The engine will reach normal operating temperature faster when the engine is operated at low rpm and low power demand.

Customer Specified Parameters

The engine is capable of being programmed for several customer specified parameters. For a brief explanation of each of the customer specified parameters, refer to the Operation and Maintenance Manual for your engine.

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Electronic Control System Components

SMCS Code: 1900

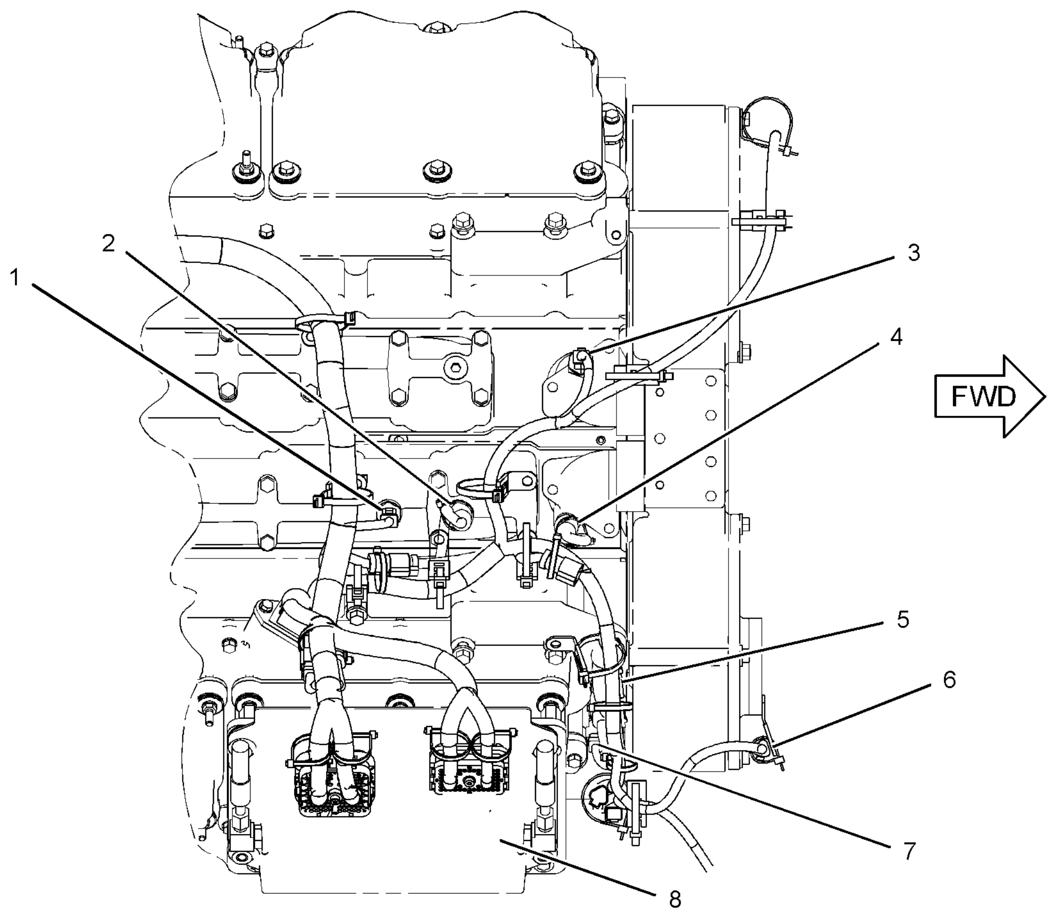

Illustration 2 g01205842

Top view

(1) Inlet air temperature sensor
(2) Inlet air pressure sensor
(3) Coolant temperature sensor
(4) Atmospheric pressure sensor
(5) Secondary engine speed/timing sensor
(6) Coolant level sensor
(7) Oil pressure sensor
(8) Electronic Control Module (ECM)

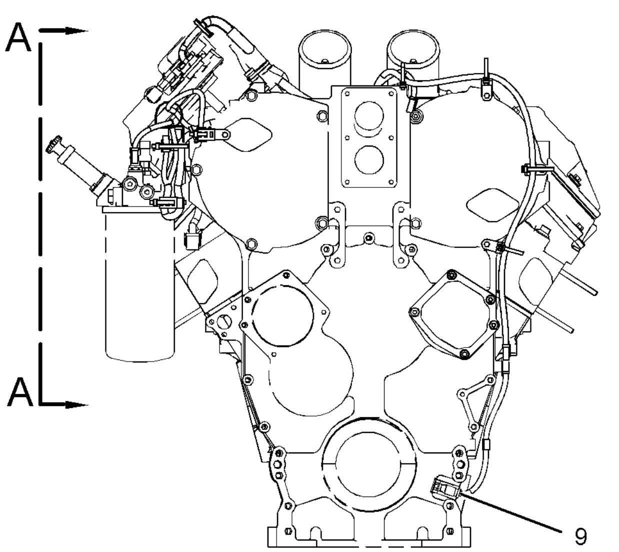

Illustration 3 g01387178

Front view

(9) Primary engine speed/timing sensor

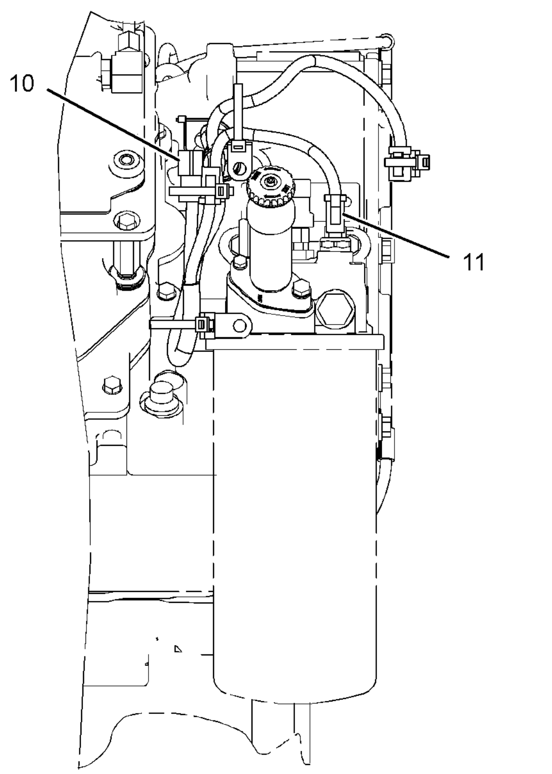

Illustration 4 g01387177

Section A-A

(10) Fuel pressure sensor
(11) Fuel temperature sensor

The electronic control system is integrally designed into the engine's fuel system and the engine's air inlet and exhaust system in order to electronically control the fuel delivery. The electronic control system provides better timing control and fuel air ratio control in comparison to conventional mechanical engines. Injection timing is achieved by the precise control of the fuel injectors. Engine speed is controlled by adjusting the injection duration. The Electronic Control Module (ECM) energizes the unit injector solenoids in order to start the injection of fuel. Also, the ECM de-energizes the unit injector solenoids in order to stop the injection of fuel.

Refer to Systems Operation/Testing And Adjusting, "Fuel System" for a complete explanation of the fuel injection process.

The engine uses the following three types of electronic components:

- Input component
- Control component
- Output component

An input component is one that sends an electrical signal to the ECM. The signal that is sent varies in either of the following ways:

- Voltage
- Frequency
- Pulse width

The variation of the signal is in response to a change in some specific system of the engine. Some specific examples of an input component are the engine speed-timing sensors, and the coolant temperature sensor. The ECM interprets the signal from the input component as information about the condition, environment, or operation of the engine.

An ECM receives the input signals from the input components. Electronic circuits inside the control component evaluate the signals from the input components. These electronic circuits also supply electrical energy to the output components of the system. The electrical energy that is supplied to the output components is based on predetermined combinations of input signal values.

An output component is one that is operated by a control module. The output component receives electrical energy from the control group. The output component uses electrical energy to make an adjustment in one of the engine's systems. An output component may also provide information to the operator.

As an example, a moving solenoid plunger will perform work. By performing work, the component has functioned in order to regulate the engine.

As an example, a control panel light or an alarm will provide information to the operator of the engine.

These electronic components provide the ability to electronically control the engine operation. Engines with electronic controls offer the following advantages:

- Improvement in performance
- Improvement in fuel consumption
- Reduction in emissions levels

Various sensors feed data to the ECM. The following sensors are used by the ECM for data:

- Engine coolant temperature
- Engine oil pressure
- Atmospheric pressure
- Primary speed/timing sensor
- Secondary speed/timing sensor
- Inlet manifold air pressure
- Inlet air temperature

The ECM processes the data. Then, the ECM sends an electronic signal to the fuel injector. The signal will control the amount of fuel that is injected into the cylinder. This will optimize the efficiency and the performance of the engine.

Data Link

A data link is used for the following items:

- Communicate engine information.
- Communicate with Caterpillar Electronic Technician (ET).
- Calibrate the electronic engine control system.
- Troubleshoot the electronic engine control system.
- Program the electronic engine control system.

The data link is used to communicate engine information to other electronic control systems. Also, the data link can interface with Cat ET.

Cat ET can be used to program the customer specified parameters. The tool is plugged into the data link connector. This allows Cat ET to communicate with the ECM. Also, Cat ET can be used to display the real time values of all the information that is available on the data link. This will help diagnose engine problems.

Electronic Control Module (ECM)

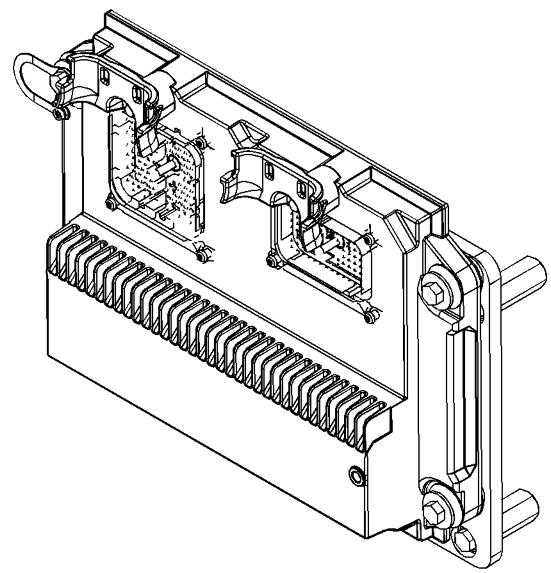

Illustration 5 g01381771

Electronic Control Module (ECM)

The engine uses an ECM. The ECM is a microprocessor based device. The ECM is mounted on the top of the front valve cover on the left side of the engine.

The inputs and the outputs to the ECM are designed to withstand short circuits without damage to the control module. The electronic engine control system has the following features that are designed into the system.

- Resistance to radio frequency
- Resistance to electromagnetic interference

The system has passed tests for interference by two-way radios and by switching noise.

The ECM power supply provides electrical power to all engine mounted sensors and actuators. The following precautions have been designed into the ECM.

- Reverse voltage polarity protection
- Swings or surges of the voltage in the power system due to sudden alternator load

The ECM also monitors all sensor inputs and the ECM provides the correct outputs in addition to acting as a power supply. Also, the ECM ensures the desired engine operation.

The ECM is programmed with a selected factory engine rating. The ECM memory contains a personality module identification code. This code is used to avoid unauthorized tampering or switching of personality modules and other pertinent manufacturing information.

The wiring harness provides communications to the following areas:

- ECM
- Various sensors
- Data link connector
- Engine connectors

The ECM is programmed to perform the following functions:

- Diagnostic tests on all inputs
- Diagnostic tests on all outputs
- Identify a faulty circuit.

Once a fault is detected, the fault can be displayed on a diagnostic lamp. The diagnostic code can be read by using Cat ET. A multimeter can be used to check most problems. Also, a multimeter can be used to troubleshoot most problems. The ECM will record most diagnostic codes that are generated during engine operation. These logged codes or intermittent codes can be read by Cat ET.

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Fuel System

SMCS Code: 1250

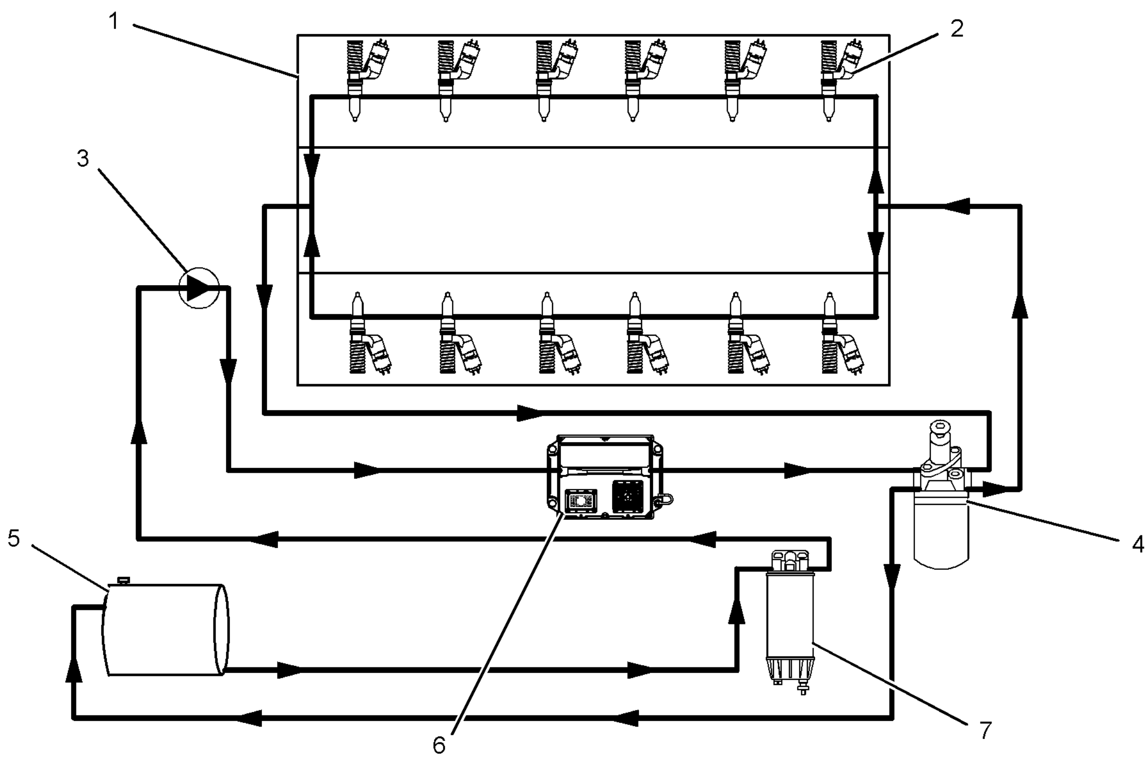

Illustration 6 g01155662

(1) Cylinder head
(2) Unit injector
(3) Fuel transfer pump
(4) Secondary fuel filter and priming pump
(5) Fuel tank
(6) Electronic Control Module (ECM)
(7) Primary fuel filter and water separator

The fuel supply circuit is a conventional design for unit injector diesel engines. The system consists of the following major components that are used to deliver low pressure fuel to the unit injectors:

Fuel tank – The fuel tank is used to store the fuel.

Fuel priming pump – The fuel priming pump is used to evacuate the air from the fuel system. As the air is removed the system fills with fuel.

Fuel filters – The primary fuel filter is used to remove abrasive material and contamination from the fuel system that may be large enough to damage the fuel transfer pump. The secondary fuel filter is used to remove abrasive material and contamination as small as two microns that could damage the injectors.

Supply lines and return lines – Supply lines and return lines are used to deliver the fuel to the different components.

The purpose of the low pressure fuel supply circuit is to supply fuel that has been filtered to the fuel injectors at a rate that is constant and a pressure that is constant. The fuel system is also utilized to cool components such as the fuel injectors and the Electronic Control Module (ECM).

Once the injectors receive the low pressure fuel, the fuel is pressurized again before the fuel is injected into the cylinder. The unit injector uses mechanical energy that is provided by the camshaft to achieve pressures that can be in excess of 200000 kPa (30000 psi).

Control of the fuel delivery is managed by the engine’s ECM. Data from several of the engine systems is collected by the ECM and processed in order to manage these aspects of fuel injection control:

- Injection timing
- Fuel injection timing advance

- Injection duration
- Engine cold mode status

The mechanical electronic fuel system relies on a large amount of data from the other engine systems. The data that is collected by the ECM will be used in order to provide optimum performance of the engine.

Low Pressure Fuel Supply Circuit

The flow of fuel through the system begins at fuel tank (5). Fuel is drawn through the primary fuel filter and water separator (7) from the fuel tank by fuel transfer pump (3). The fuel transfer pump incorporates a check valve that will allow fuel to flow around the gears of the pump during priming of the fuel system. The fuel transfer pump also incorporates a pressure relief valve. The pressure relief valve is used in order to protect the fuel system from extreme pressure.

The fuel transfer pump is designed in order to produce an excess fuel flow throughout the fuel system. The excess fuel flow is used by the system to cool the fuel system components. The excess fuel flow also purges any air from the fuel system during operation. Air that can become trapped in the fuel system can cause cavitation that may damage the components of the unit injector.

After leaving the fuel transfer pump, the fuel flows to the ECM (6) in order to cool the ECM. Next, the fuel flows to the secondary fuel filter and fuel priming pump (4). The fuel priming pump is located on the fuel filter base. The fuel filter base and the secondary fuel filter also incorporate a siphon break that prevents fuel from draining from the fuel system when the engine is not in operation. The priming pump is a hand operated pump that directs the flow of fuel during the priming pump’s operation. The secondary fuel filter is a two micron fuel filter. The fuel is filtered in order to remove small abrasive particles that will cause premature wear to fuel system components. The filtered fuel then flows out of the fuel filter and returns to the passages in the fuel filter base. Prior to exiting the fuel filter base, the fuel pressure and the fuel temperature are sampled by the fuel pressure sensor and by the fuel temperature sensor. The signals that are generated by the sensors are used by the ECM in order to monitor the condition of the engine’s components. This information is also used to adjust the fuel delivery of the engine in order to optimize efficiency.

The fuel is then transfered by the fuel supply lines to the cylinder head (1). Only a portion of the fuel that is supplied to the fuel injectors is used for engine operation. This unused fuel is discharged into the return passages of the fuel gallery. The fuel is returned to the fuel tank by the fuel return lines. A continuous flow of fuel is experienced within the low pressure fuel system.

During engine operation, fuel injectors (2) receive fuel from the low pressure fuel system. The injector pressurizes the fuel to high pressure. The fuel is then injected into the cylinder. The excess fuel is returned to the tank.

A pressure regulating valve is located in the fuel return. The pressure regulating valve allows the low pressure fuel system to maintain a constant pressure. A flow control orifice is also located in the fuel return. The flow control orifice maintains a system back pressure that is constant. The orifice allows the flow of fuel through the system to be constant. This prevents excessive heating of the fuel.

Fuel Heaters

Fuel heaters prevent the waxing of the fuel, and the plugging of the fuel filters in cold weather. The engine does not dissipate enough heat in order to prevent waxing during cold weather conditions. There are two types of fuel heaters that can be used: thermostatically controlled and self-adjusting. Heaters that are not thermostatically controlled can heat the fuel in excess of 65 °C (149 °F). High fuel temperatures can have the following effects:

- Reduced engine efficiency
- Fuel pump damage
- Premature wear

Note: Never use fuel heaters without some type of temperature regulator. Ensure that fuel heaters are turned OFF during warm weather conditions.

Fuel System Electronic Control Circuit

The fuel system is equipped with an electronically controlled, mechanically actuated unit injector in each cylinder. A solenoid on each injector controls the amount of fuel that is delivered by the injector. An ECM sends a signal to each injector solenoid in order to provide complete control of the engine.

There are two major components of the electronic control system that are necessary in order to provide control of the mechanical electronic unit injectors:

- ECM
- Personality module (storage for the ECM flash file)

The ECM is the computer that is used to provide control for all aspects of engine operation. The personality module contains the software that defines the characteristics of the engine control. The personality module contains the operating maps. The operating maps define the following characteristics of the engine:

- Horsepower
- Torque curves
- Engine speed (rpm)
- Other characteristics

The ECM, the personality module, the engine sensors, and the unit injectors work together in order to control the engine. Neither of the four can control the engine alone.

The ECM maintains the desired engine speed by sensing the actual engine speed. The ECM calculates the amount of fuel that needs to be injected in order to achieve the desired engine speed.

Fuel Injection

The ECM controls the amount of fuel that is injected by varying the signals that are sent to the injectors. The ECM sends a high voltage signal to the solenoid in order to energize the solenoid. The injectors will inject fuel only while the injector solenoid is energized. By controlling the timing and the duration of the high voltage signal, the ECM can control injection timing and the amount of fuel that is injected.

The ECM sets certain limits on the amount of fuel that can be injected. The Fuel Ratio Control (FRC) limit is an adjustment that controls the amount of air and the amount of fuel for the purpose of emission control. This limit is based on the boost pressure. When the ECM senses a higher boost pressure, the ECM increases the FRC limit. The rated fuel position is also a limit that is based on the horsepower rating of the engine. This is similar to the rack stops and to the torque spring on a mechanically governed engine. The rated fuel position provides horsepower and torque curves for a specific engine family and for a specific engine rating. All of these limits are programmed into the personality module by the factory. These limits are not programmable by the service technician.

Injection timing depends on three factors: the engine speed (rpm), the engine load, and the operational conditions of the engine. The ECM determines the top center position of No. 1 cylinder from the signal that is provided by the engine speed/timing sensor. The ECM decides when the injection should occur relative to the top center position. The ECM then provides the signal to the electronic unit injector at the desired time.

Electronic Unit Injector Mechanism

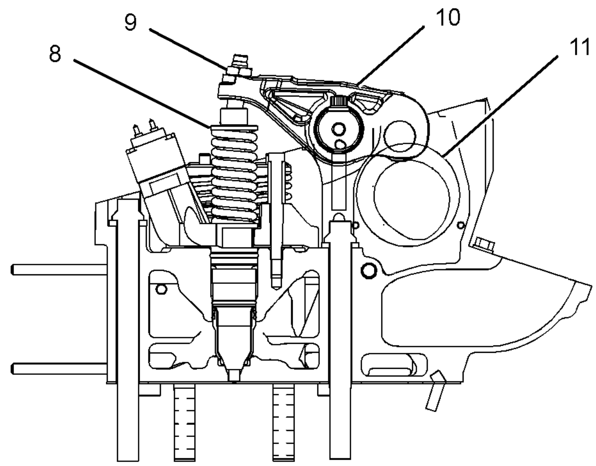

Illustration 7 g01405609

Electronic unit injector mechanism

(8) Electronic unit injector
(9) Adjusting nut
(10) Rocker arm assembly
(11) Camshaft lobe

The electronic unit injector mechanism provides the downward force that is required to pressurize the fuel in the electronic unit injector pump. The electronic unit injector (8) allows fuel to be injected into the combustion chamber with precise timing. Movement is transmitted from the camshaft lobe (11) for the electronic unit injector through the rocker arm assembly (10) to the top of the electronic unit injector. The adjusting nut (9) allows the injector lash to be adjusted. For the proper setting of the injector lash, refer to the topic on adjustment of the electronic unit injector in Testing and Adjusting, “Electronic Unit Injector - Adjust”.

Electronic Unit Injector

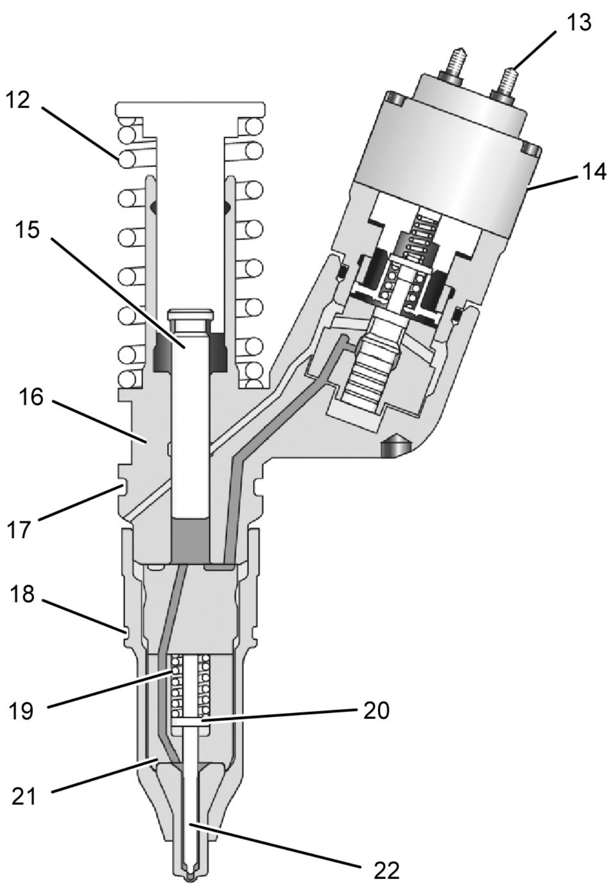

Illustration 8 g01405611

Electronic unit injector

(12) Spring
(13) Solenoid connection to the Electronic Control Module (ECM)
(14) Solenoid valve assembly
(15) Plunger assembly
(16) Barrel
(17) Seal
(18) Seal
(19) Spring
(20) Spacer
(21) Body
(22) Check valve

Fuel at low pressure from the fuel supply manifold enters the electronic unit injector at the fill port through drilled passages in the cylinder head.

As the electronic unit injector mechanism transfers the force to the top of the electronic unit injector, spring (12) is compressed and plunger (15) is driven downward. This action displaces fuel through the valve in solenoid valve assembly (14), and into the return manifold to the fuel tank. As the plunger travels downward, the passage in barrel (16) is closed by the outside diameter of the plunger. The passages within body (21) and along check valve (22) to the injector tip already contain fuel for injection. After the passage in the plunger barrel is closed, the injector is ready for injection at any time. The start of injection relies on the software in the Electronic Control Module (ECM).

When the solenoid valve assembly is energized from a signal across solenoid connection (13), the valve closes and fuel pressure is elevated in the injector tip. Injection begins at 34500 ± 1900 kPa (5000 ± 275 psi) as the force of spring (19) above spacer (20) is overcome. The check valve begins to lift from the valve seat. The pressure continues to rise as the plunger cycles through a full stroke. After the correct amount of fuel has been discharged into the cylinder, the ECM removes the signal to the solenoid connection. The solenoid valve assembly is de-energized and the valve in the solenoid valve assembly is opened. The high pressure fuel is then dumped through the spill port and into the fuel return manifold. The fuel is then returned to the fuel tank. The check valve in the injector tip seats as the pressure in the tip decreases.

The duration of injection meters the fuel that is consumed during the fuel injection process. Injection duration is controlled by the governor logic that is programmed into the ECM.

As the camshaft lobe rotates past the point of maximum lobe lift, the force on top of the electronic unit injector is removed and the spring for the injector mechanism is allowed to expand. The plunger returns to the original position. This uncovers the fuel supply passage into the plunger barrel in order to refill the injector pump body. The fuel at low pressure is again allowed to circulate through the fuel injector body. After circulating through the fuel injector body, the fuel flows out of the spill port. This continues until the solenoid valve assembly is re-energized for another injection cycle.

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Air Inlet and Exhaust System

SMCS Code: 1050

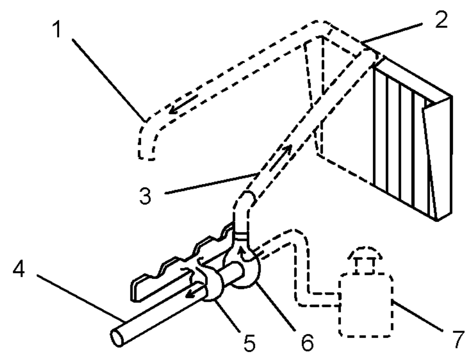


Illustration 9 g01115385

(1) Inlet to the engine
(2) Aftercooler core
(3) Inlet air line
(4) Exhaust outlet from turbocharger
(5) Turbine side of turbocharger
(6) Compressor side of turbocharger
(7) Air cleaner

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

- Air cleaner
- Turbocharger
- Aftercooler
- Cylinder head
- Valves and valve system components
- Piston and cylinder
- Exhaust manifold

The turbocharger compressor wheel pulls inlet air through the air cleaner and into the air inlet. The air is compressed and this causes the air to become hot. The air flows through aftercooler core (2) and the temperature of the compressed air lowers. This helps to provide increased horsepower output. Aftercooler core (2) is a separate cooler core that is mounted along the side of the engine radiator. The engine fan causes ambient air to move across both cores. This cools the turbocharged inlet air and the engine coolant.

Air is forced from the aftercooler into inlet manifold (1). The air flow from the inlet port into the cylinders is controlled by inlet valves.

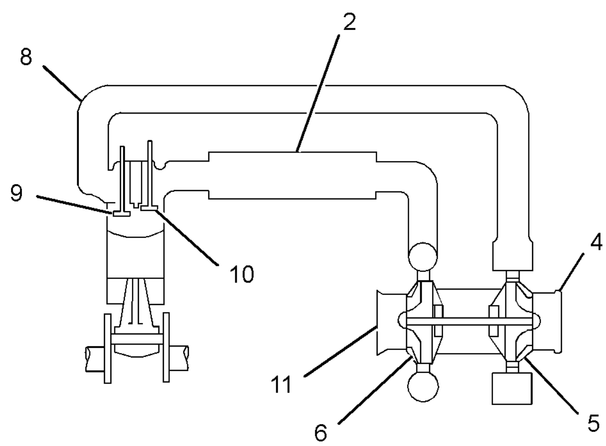


Illustration 10 g01319128

Air inlet and exhaust system

(2) Aftercooler core
(4) Exhaust outlet
(5) Turbine side of turbocharger
(6) Compressor side of turbocharger
(8) Exhaust manifold
(9) Exhaust valve
(10) Inlet valve
(11) Air inlet

Each cylinder has two inlet valves (10) and two exhaust valves (9) in the cylinder head. The inlet valves open on the inlet stroke. When the inlet valves open, compressed air from the inlet port within the inlet manifold is pushed into the cylinder. The inlet valves close when the piston begins the compression stroke. The air in the cylinder is compressed and the fuel is injected into the cylinder when the piston is near the top of the compression stroke. Combustion begins when the fuel mixes with the air. The force of combustion pushes the piston on the power stroke. The exhaust valves open and the exhaust gases are pushed through the exhaust port into exhaust manifold (8). After the piston finishes the exhaust stroke, the exhaust valves close and the cycle begins again.

Exhaust gases from the exhaust manifold flow into the turbine side of turbocharger (5). The high temperature exhaust gases cause the turbocharger turbine wheel to turn. The turbine wheel is connected to the shaft that drives the compressor wheel. Exhaust gases from the turbocharger pass through exhaust outlet (4), through a muffler, and through an exhaust stack.

Turbocharger

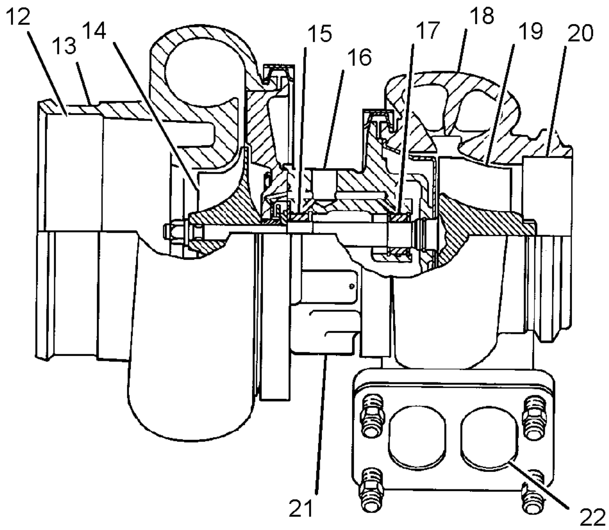


Illustration 11 g01319169

Turbocharger

(12) Air inlet
(13) Compressor housing
(14) Compressor wheel
(15) Bearing
(16) Oil inlet port
(17) Bearing
(18) Turbine housing
(19) Turbine wheel
(20) Exhaust outlet
(21) Oil outlet port
(22) Exhaust inlet

The turbocharger is mounted to the exhaust manifold of the engine. All of the exhaust gases go from the exhaust manifold through the turbocharger.

The exhaust gases enter the turbocharger and the turbine wheel is turned. Because the turbocharger turbine wheel is connected by a shaft to the turbocharger compressor wheel, the turbine wheel and the compressor wheel turn at very high speeds. The rotation of the compressor wheel pulls clean air through the compressor housing air inlet. The action of the compressor wheel blades causes a compression of the inlet air. This compression allows a larger amount of air to enter the engine. With more air in the engine, the engine is able to burn more fuel. The overall effect is an increase in power.

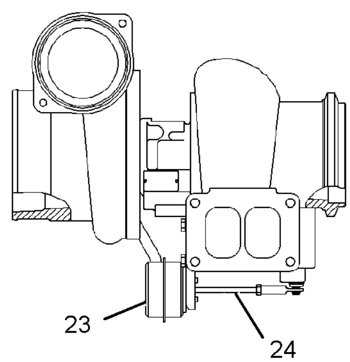


Illustration 12 g01319184

Turbocharger with wastegate

(23) Canister
(24) Actuating lever

The engine can operate under conditions of low boost (lug). Low boost is a condition that occurs when the turbocharger produces less than optimum boost pressure. There is a spring that is inside canister (23). Under low boost, the spring pushes on the diaphragm in canister (23). This moves actuating lever (24). The actuating lever closes the wastegate, which will allow the turbocharger to operate at maximum performance.

Under conditions of high boost, the wastegate opens. The open wastegate allows exhaust gases to bypass the turbine side of the turbocharger. When the boost pressure increases against the diaphragm in canister (23), the wastegate is opened. The rpm of the turbocharger is limited by bypassing a portion of the exhaust gases around the turbine wheel of the turbocharger.

Note: The calibration of the wastegate is preset at the factory. No adjustment can be made to the wastegate.

Bearing (15) and bearing (17) in the turbocharger use engine oil that is under pressure for lubrication. The lubrication for the bearings flows through oil inlet port (8) and into the inlet port in the center section of the turbocharger cartridge. The oil exits the turbocharger through oil outlet port (21). The oil then returns to the engine oil pan through the oil drain line for the turbocharger.

The turbocharger center housing of the turbocharger is cooled by engine coolant. The coolant flows from the thermostat housing to the turbocharger center housing. The coolant flow keeps the components of the turbocharger's center housing cool in order to prevent oil coking in the bearing area.

Valves And Valve Mechanism

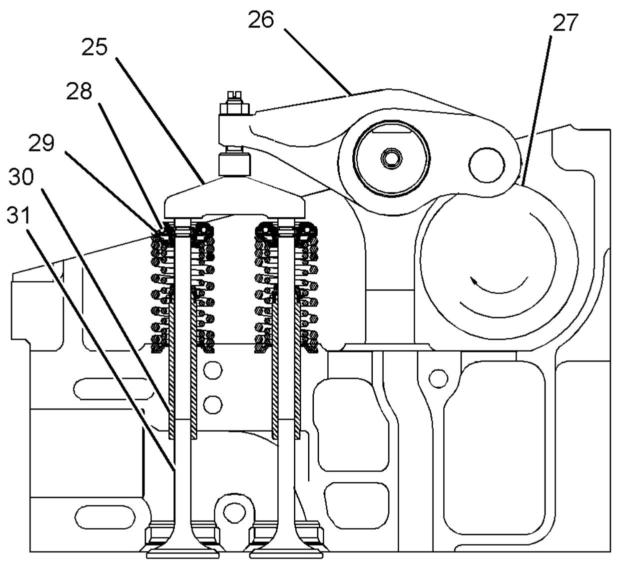


Illustration 13 g01319198

Valve system components

(25) Valve bridge
(26) Rocker arm
(27) Camshaft
(28) Rotocoil
(29) Valve spring
(30) Valve guide
(31) Valve

The valves and the valve mechanism control the flow of inlet air into the cylinders during engine operation. The valves and the valve mechanism control the flow of exhaust gases out of the cylinders during engine operation.

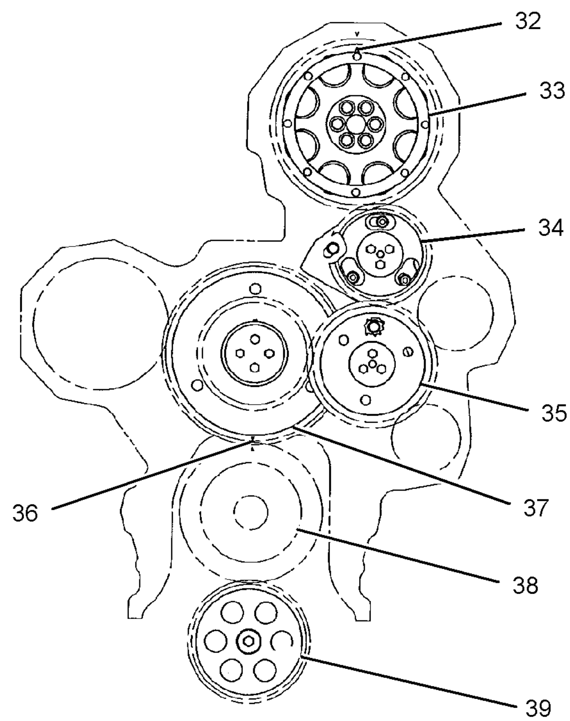


Illustration 14 g01319199

Components of the gear train

(32) Timing mark
(33) Camshaft gear
(34) Adjustable idler gear
(35) Idler gear
(36) Timing mark
(37) Cluster gear
(38) Crankshaft gear
(39) Oil pump gear

The inlet valves and the exhaust valves are opened by the valve mechanism. The inlet valves and the exhaust valves are also closed by the valve mechanism. This occurs as the rotation of the crankshaft causes camshaft (27) to rotate. Camshaft gear (33) is driven by a series of two idler gears (34) and (35). Idler gear (34) is driven by cluster gear (37). Cluster gear (37) is driven by crankshaft gear (38). Timing mark (32) and timing mark (36) are aligned in order to provide the correct relationship between the piston and the valve movement.

The camshaft has three lobes for each cylinder. One lobe operates the inlet valves. A second lobe operates the exhaust valves. The third lobe operates the unit injector mechanism. The camshaft lobes turn and the rocker arms move. Movement of the rocker arms will make the inlet and exhaust valve bridges move. These bridges allow one rocker arm to actuate two valves at the same time. Each cylinder has two inlet valves and two exhaust valves. Each valve has one valve spring (29). The spring closes the valve.

Rotocoils (28) cause the valves to rotate while the engine is running. Valve rotation provides a longer service life. Valve rotation also minimizes carbon deposits on the valves.

Adjustable idler gear (34) is designed to provide the required gear backlash between nonadjustable idler gear (35) and camshaft gear (33). If the cylinder head is removed, tolerances of the components will change. The components that change are the cylinder head and the head gasket. The adjustable idler gear must be relocated. For information on setting the correct backlash, refer to Testing and Adjusting, “Gear Group (Front) - Time”.

The camshaft drive gear has integral pendulums which act as a vibration damper for the front gear group. These pendulums are designed to counteract the torsional forces from the injector pulses. This eliminates vibration and noise. The engine also runs smoother at all operating speeds.

i02270230

Lubrication System

SMCS Code: 1300

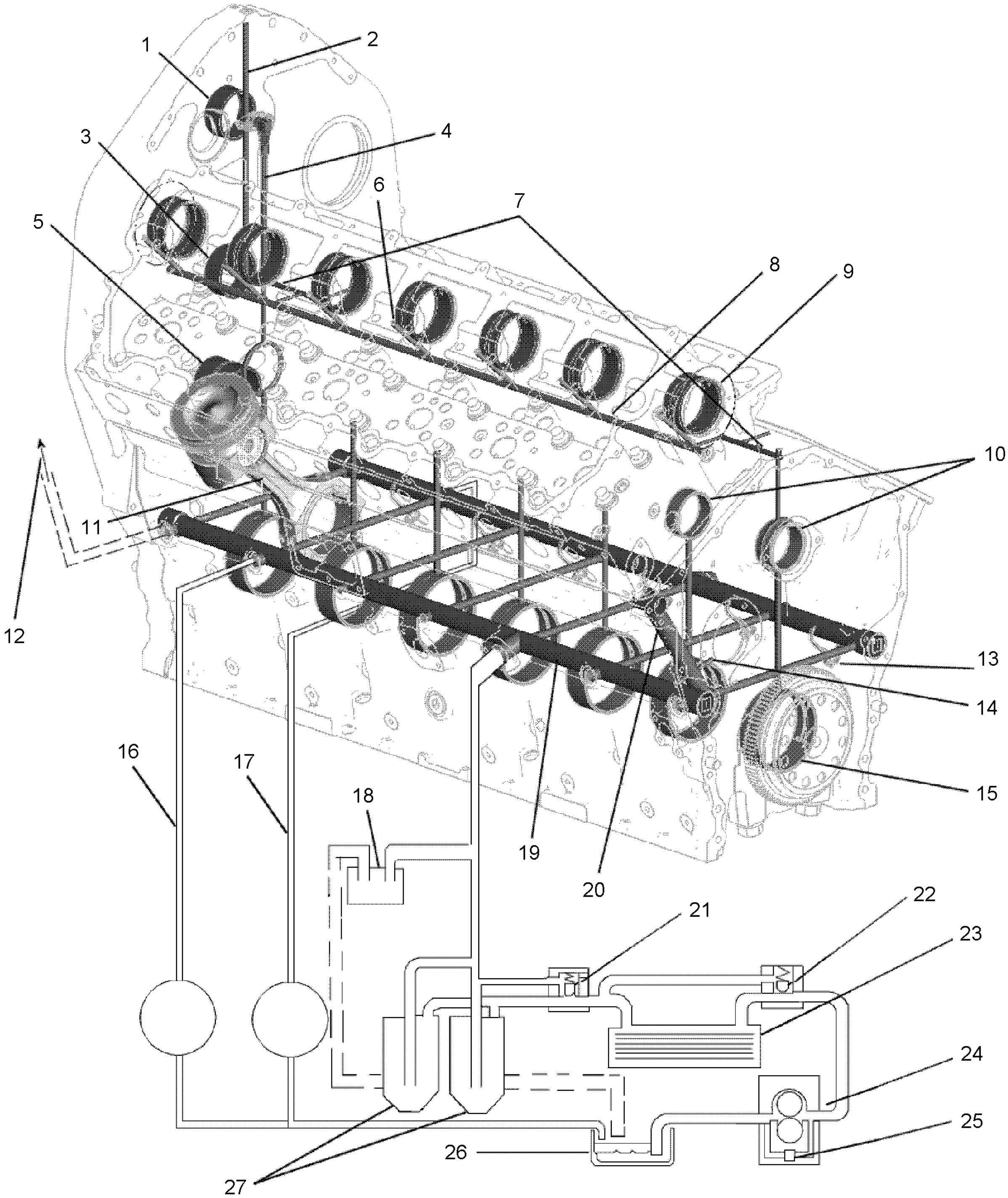


Illustration 15 g01087263

Lubrication system schematic

(1) Upper rear idler bearing
(2) Oil passage for the rear housing
(3) Middle rear idler bearing
(4) Rear oil line
(5) Lower rear idler
(6) Oil passage to rocker arms and camshaft bearings
(7) Oil passage to the heads
(8) Oil gallery in the head
(9) Camshaft bearings
(10) Shaft bearing for the live idler
(11) Connecting rod with drilled oil passage
(12) External oil line to rear gear train
(13) Piston cooling jets
(14) Lower front idler gear bearing
(15) Main bearings
(16) Right side turbocharger oil supply line
(17) Left side turbocharger oil supply line
(18) Auxiliary oil filter (if equipped)
(19) Main oil gallery
(20) Extension for the oil gallery
(21) Oil filter bypass valve
(22) Oil cooler bypass valve
(23) Oil cooler
(24) Oil pump
(25) Oil pump bypass valve
(26) Oil pan
(27) Oil filter

The oil pump (24) is mounted to the bottom of the cylinder block within the oil pan (26). The oil pump (24) pulls oil from the oil pan (26). The oil then flows through a passage to the oil cooler (23). Oil then flows through the oil filters (27). The oil can flow into the main oil gallery (19) from the right side or the left side of the block. The location of the incoming oil supply is dependent on the location of the oil filters which can be located on either side of the block. The oil then flows through a set of cross-drilled holes to the opposite side oil gallery.

The main oil gallery (19) distributes oil to the following components: the crankshaft main bearings (15), the piston cooling jets (13), the extension of the oil gallery (20), the turbocharger oil supply line (16), the turbocharger oil supply line (17), and the live front idler gear bearings (10). The main oil gallery (19) also distributes oil to the rear accessory drives through an external oil line (12).

Oil enters the crankshaft through holes in the bearing surfaces (journals) for the main bearing (15). Passages connect the bearing surface (journal) for the main bearing (15) with the bearing surface (journal) for the connecting rod (11). The oil flows upward through a drilled passage in the connecting rod to the piston pin bearing.

The extension for the oil gallery (20) is located in the front right corner of the engine block. The extension for the oil gallery (20) supplies oil to the lower front idler gear bearing (14).

The oil flows to the live front idler gear bearing (10) and around bearing (10) to the oil passage for the cylinder head (7). The oil then flows to the oil gallery in the cylinder head (8) and the oil flows to the oil passage (6) for the camshaft bearings (9) and the rocker arms.

The oil for the lower rear idler bearing (5) is feed from a passage that is connected to the last rear main crankshaft bearing (15). Oil is also feed from the rear main bearing to the rear oil line (4) and to the oil passage in the rear housing (2) for the middle rear idler gear bearing (3) and the upper rear idler gear bearing (1).

This oil circuit typically operates at a pressure of 214 kPa (31 psi) at low idle and at 400 kPa (58 psi) at rated speed.

The oil pump bypass valve (25) limits the pressure of the oil that comes from the oil pump (24). The oil pump (24) can put more oil into the system than oil that is needed. As the oil pressure increases, the oil pump bypass valve (25) will open. This allows the oil that is not needed to go back to the suction side of the oil pump (24).

Cold oil with high viscosity causes a restriction to the oil flow through the oil cooler (23) and the oil filter (27). The oil cooler bypass valve (22) and the oil filter bypass valve (21) will open if the engine is cold. This will give immediate lubrication to all components. The oil pump (24) sends the cold oil through the bypass valves, around the oil cooler (23), and the oil filter (27), and to the main oil gallery (19) in the cylinder block.

When the oil gets warm, the pressure difference in the bypass valves decreases. This closes the bypass valves. This creates a normal flow of oil through the oil cooler and through the oil filter.

The bypass valves will also open when there is a restriction in the oil cooler (23) or a restriction in the oil filter (27). This action lubricates the engine if the oil cooler (23) or the oil filter (27) are restricted. The bypass valve opening pressures vary with applications.

An oil cooling chamber is formed by the forged lip at the top of the skirt of the piston and the cavity behind the ring grooves in the piston crown. Oil flow from piston cooling jet (13) enters the cooling chamber through a drilled passage in the skirt and returns to the oil pan (26) through the clearance gap between the crown and the skirt. The four holes that have been drilled from the piston oil ring groove to the interior of the piston drain excess oil from the oil ring.

The oil breather allows blowby gases from the cylinders during engine operation to escape from the crankcase. The blowby gases discharge through the flywheel housing to a preformed tube that is routed to the atmosphere. This prevents pressure from building up that could cause seals or gaskets to leak.

Note: Engines that are equipped with an auxiliary oil filter (18) will pick up oil at a port. The filtered oil will be returned to the oil pan (26).

i02414165

Cooling System

SMCS Code: 1350

This engine has a pressure type cooling system that is equipped with a shunt line.

A pressure type cooling system offers two advantages:

- The cooling system can operate safely at a temperature that is higher than the normal boiling point of water.
- The cooling system prevents cavitation in the water pump.

Cavitation is the sudden formation of low pressure bubbles in liquids by mechanical forces. The formation of air or steam pockets is more difficult within a pressure type cooling system.

The shunt line prevents cavitation by the water pump. The shunt line provides a constant head pressure at the water pump inlet.

Note: The coolant mixture must be a minimum of 30 percent ethylene glycol base antifreeze for efficient water pump performance for air to air after cooled engines. The mixture keeps the cavitation temperature range of the coolant high enough for efficient performance.

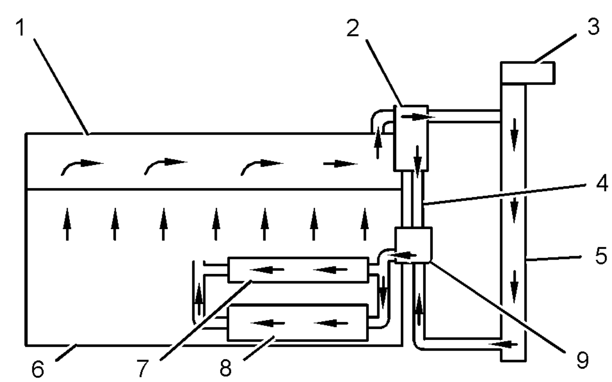


Illustration 16 g01155880

(1) Cylinder head
(2) Water temperature regulator housing
(3) Expansion tank
(4) Bypass hose
(5) Radiator
(6) Cylinder block
(7) Engine oil cooler
(8) Transmission oil cooler (if equipped)
(9) Water pump

Water pump (9) is located on the right side of the cylinder block. The water pump is gear-driven from the front gear group. Coolant can enter the water pump in two places:

- Inlet at the bottom of the water pump
- Bypass hose (4) at the top of the water pump

Coolant from the bottom of the radiator (5) is pulled into the bottom inlet of the water pump (9) by impeller rotation. The coolant exits the back of the pump directly into engine oil cooler (7). Some of the coolant is also diverted to transmission oil cooler (8) (if equipped).

Some of the coolant passes through the core of engine oil cooler (7) and some of the coolant passes through the core of transmission oil cooler (8) (if equipped). The coolant then enters the internal water manifold of the cylinder block. The manifold disperses the coolant to water jackets around the cylinder walls.

From the cylinder block, the coolant flows into passages in the cylinder heads. The passages send the flow around the unit injector sleeves and the inlet and the exhaust passages. The coolant now enters water temperature regulator housing (2) at the front of the cylinder head.

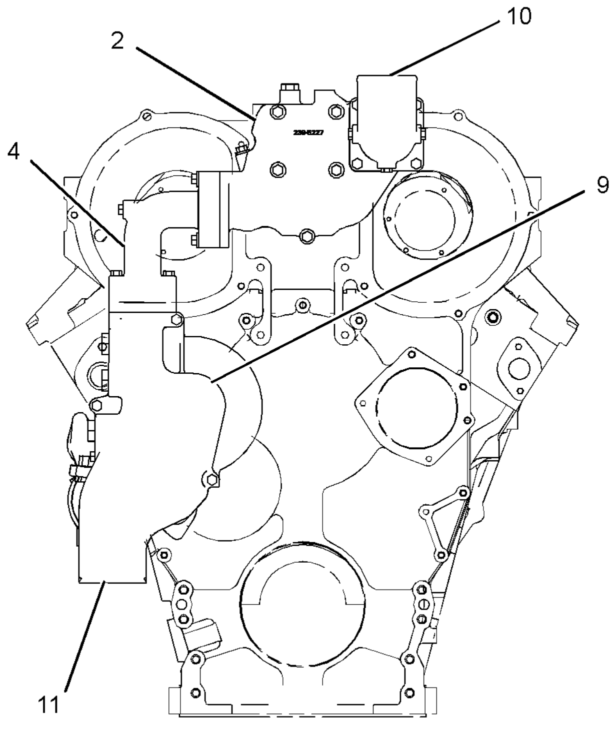


Illustration 17 g01206714

(2) Water temperature regulator housing
(4) Bypass hose
(9) Water pump
(10) Outlet to the radiator
(11) Inlet from the radiator

Two water temperature regulators control the direction of coolant flow. When the coolant temperature is below the normal operating temperature, the water temperature regulators are closed. The coolant is directed through bypass hose (4) and into the top inlet of the water pump. When the coolant temperature reaches the normal operating temperature, the water temperature regulators open. When the water temperature regulators are open, the bypass is closed. Most of the coolant goes through the outlet to the radiator for cooling. The remainder flows through bypass hose (4) and into the water pump.

Note: The water temperature regulators are an important part of the cooling system. The water temperature regulators divide coolant flow between the radiator and the bypass hose in order to maintain the normal operating temperature. If the water temperature regulators are not installed in the system, there is no mechanical control, and most of the coolant will travel the path of least resistance through the bypass hose. This will cause the engine to overheat in hot weather and the engine will not reach normal operating temperature in cold weather.

Coolant Conditioner (If Equipped)

Some conditions of operation can cause pitting. This pitting is caused by corrosion or by cavitation erosion. A corrosion inhibitor is a chemical that provides a reduction in pitting. The addition of a corrosion inhibitor can keep this type of damage to a minimum.

The coolant conditioner element is a spin-on element that is similar to the fuel filter and to the oil filter elements. The coolant conditioner element attaches to the coolant conditioner base that is mounted on the front of the engine. Coolant flows from the water pump to the coolant conditioner base and back to the cylinder block. Coolant constantly flows through the coolant conditioner element when the valves are in the OPEN position.

The element has a specific amount of inhibitor for acceptable cooling system protection. As the coolant flows through the element, the corrosion inhibitor goes into the solution. The corrosion inhibitor is a dry solution, so the inhibitor dissolves. The corrosion inhibitor then mixes to the correct concentration. Two basic types of elements are used for the cooling system. The two elements are the precharge elements and the maintenance elements. Each type of element has a specific use. The elements must be used correctly in order to get the necessary concentration for cooling system protection. The elements also contain a filter. The coolant conditioner elements should remain in the system after the conditioner material has dissolved.

The precharge element contains more than the normal amount of inhibitor. The precharge element is used when a system is first filled with new coolant. This element must add enough inhibitor in order to bring the complete cooling system up to the correct concentration.

The maintenance elements have a normal amount of inhibitor. The maintenance elements are installed at the first change interval. A sufficient amount of inhibitor is provided by the maintenance elements in order to maintain the corrosion protection at an acceptable level. After the first change interval, only maintenance elements are installed. In order to provide the cooling system with protection, maintenance elements are installed at specific intervals.

i02290289

Basic Engine

SMCS Code: 1200

Cylinder Block Assembly

The cylinders in the left side of the block form a 65 degree angle with the cylinders in the right side. The main bearing caps are fastened to the block with four bolts, two bolts through each bearing cap and two bolts through the side of the block.

The cylinder liners can be removed for replacement. The top surface of the block is the seat for the cylinder liner flange. Engine coolant flows around the liners in order to keep the liners cool. Three O-ring seals around the bottom of the liner make a seal between the liner and the cylinder block. A filler band goes under the liner flange. This makes a seal between the top of the liner and the cylinder block. A steel spacer plate is used between the cylinder head and the block. The spacer plate provides improved reusability and durability. A thin gasket is used between the plate and the block. This thin gasket seals water and oil. A thick gasket of metal and graphite is used between the plate and the head. This thick gasket seals the combustion gases, water and oil.

Cylinder Head Assembly

The cylinder heads are a one-piece cast iron head. The cylinder head supports the camshaft. Steel reinforced camshaft bearings are pressed into each bore for the camshaft. The bearings are lubricated under pressure. The cylinder head contains two inlet valves and two exhaust valves for each cylinder, which are controlled by a rotating camshaft for each cylinder. Bridge dowels have been eliminated as the valve train uses floating valve bridges.

The unit injector is mounted in a stainless steel adapter. This adapter has been pressed into the cylinder head injector bore.

Pistons, Rings And Connecting Rods

The piston is a one-piece design that consists of a forged steel crown and a skirt. The piston is retained by the piston pin to the small end of the connecting rod. The pistons have three rings that are located in grooves in the steel crown. These rings seal the combustion gas. The rings provide control of the oil. The top ring has a barrel face. This ring is a Keystone ring with a plasma face coating. The second ring has a tapered face and the ring has a coating of chrome finish for the face. The third ring is the oil ring. The third ring has a coil spring expander. There are four holes that are drilled from the piston oil ring groove to the interior of the piston. These holes return excess oil from the oil ring groove to the crankcase.

The connecting rod is a conventional design. The cap of the connecting rod is attached to the shank by four bolts that are threaded into the shank. Each side of the small end of the connecting rod is machined at an angle of 12 degrees in order to fit within the piston cavity.

Crankshaft

The crankshaft converts the combustion force in the cylinder into rotating torque. A vibration damper is used at the front of the crankshaft in order to reduce the torsional vibrations.

The crankshaft drives a group of gears on the front and the rear of the engine. These gear trains provide power for the following components: camshaft, water pump, oil pump, fuel transfer pump, and accessory items that are specific to the application.

The cylinder block has seven main bearings that support the crankshaft. The cylinder block uses four bolts to hold each of the bearing caps into the block. Pressurized oil is supplied to all bearing surfaces through drilled holes in the webs of the cylinder block. The oil then flows through drilled holes in the crankshaft in order to provide oil to the connecting rod bearings.

Seals and wear sleeves are used at both ends of the crankshaft. The seals and wear sleeves are used for easy replacement and reduction of maintenance cost.

Camshaft

The camshaft has three lobes at each cylinder. These lobes allow the camshaft to operate the unit injector, the exhaust valves, and the inlet valves. The camshaft is supported in the cylinder head by seven journals which are fit with bearings. The camshaft gear contains integral roller dampers that counteract the torsional vibrations that are generated by the high fuel pressure during fuel injector operation. The design reduces gear train noise. The camshaft is driven by an adjustable idler gear which is turned by a fixed idler gear which is turned by a cluster idler gear in the gear train. Each bearing journal is lubricated from the oil manifold in the cylinder head. A thrust plate that is located at the front controls the end play of the camshaft. Timing of the camshaft is accomplished by aligning marks on the crankshaft gear and idler gear, and camshaft gear with a mark on the front timing plate.

Vibration Damper

The twisting of the camshaft is called torsional vibration. The torsional vibration is caused by the regular power impacts along the length of the crankshaft. The vibration damper is installed on the front end of the crankshaft. This vibration damper is used to reduce the torsional vibrations. This eliminates any damage that could occur to the crankshaft.

The rubber damper is made of an outer hub connected to an inner hub by a rubber ring. The rubber makes a flexible coupling between the outer hub and the inner hub.

The viscous damper consists of a casing that is welded to the inner hub. The casing contains a steel weight that is suspended in a viscous silicone lubricant. The silicone lubricant acts as a flexible coupling between the weight and the inner hub.

i02770527

Electrical System

SMCS Code: 1400; 1550; 1900

Reference

Refer to the Schematic and the Troubleshooting, “Electronic Troubleshooting” for additional information on your engine.

Grounding Practices

Proper grounding for the electrical system is necessary for proper engine performance and reliability. Improper grounding will result in unreliable electrical circuit paths and in uncontrolled electrical circuit paths.

Uncontrolled engine electrical circuit paths can result in damage to the main bearings, to the crankshaft bearing journal surfaces, and to the aluminum components.

Uncontrolled electrical circuit paths can cause electrical noise which may degrade performance.

In order to ensure proper functioning of the electrical system, an engine-to-frame ground strap with a direct path to the battery must be used. This may be provided by a ground for the starting motor, by a frame to the ground for the starting motor, or by a direct frame to engine ground. An engine-to-frame ground strap must be run from the grounding stud of the engine to the frame and to the negative battery post.

Connect the battery negative post to the frame rail. From the frame rail, connect the ground wire to one of the following locations:

- Cylinder head ground stud
- Optional engine ground stud connection

The engine must be grounded to the frame rail. Connect the battery negative post to one of the following locations:

- Cylinder head ground stud
- Optional engine ground stud connection

The engine must have a ground wire to the battery.

Ground wires or ground straps should be combined at the studs that are only for ground use.

All of the ground paths must be capable of carrying any potential currents.

The engine alternator should be grounded to the battery with a wire size that is capable of managing the full charging current of the alternator.

NOTICE

When jump starting an engine, the instructions in the Operation and Maintenance Manual, "Starting with Jump Start Cables" should be followed in order to properly start the engine.

This engine may be equipped with a 12 volt starting system or with a 24 volt starting system. Only equal voltage for boost starting should be used. The use of a welder or of a higher voltage will damage the electrical system.

The engine has several input components which are electronic. These components require an operating voltage.

This engine is tolerant to common external sources of electrical noise. Electromechanical buzzers can cause disruptions in the power supply. If electromechanical buzzers are used near the system, the engine electronics should be powered directly from the battery system through a dedicated relay. The engine electronics should not be powered through a common power bus with other devices that are activated by the Engine Control Switch (ECS).

Engine Electrical System

The electrical system can have three separate circuits. The three circuits are the charging circuit, the starting circuit, and the low amperage circuit. Some of the electrical system components are used in more than one circuit.

The charging circuit is in operation when the engine is running. An alternator creates electricity for the charging circuit. A voltage regulator in the circuit controls the electrical output in order to maintain the battery at full charge.

The starting circuit is in operation when the start switch is activated.

The low amperage circuit and the charging circuit are connected through the ammeter. The starting circuit is not connected through the ammeter.

Charging System Components

Alternator

The alternator is driven by the crankshaft pulley through a belt that is a Poly-vee type. This alternator is a three-phase self-rectifying charging unit. The regulator is part of the alternator.

The alternator design has no need for slip rings or for brushes. The only part of this alternator that moves is the rotor assembly. All of the conductors that carry current are stationary. The following components are the conductors: the field winding, the stator windings, six rectifying diodes, and the regulator circuit.

The rotor assembly has many magnetic poles with air space between each of the opposite poles. The poles have residual magnetism that produces a small amount of magnet-like lines of force (magnetic field). This magnetic field is produced between the poles. As the rotor assembly begins to turn between the field winding and the stator windings, a small amount of Alternating Current (AC) is produced in the stator windings. The alternating current is produced from the small magnetic lines of force that are created by the residual magnetism of the poles. The AC is changed into Direct Current (DC) when the current passes through the diodes of the rectifier bridge. Most of this current provides the battery charge and the supply for the low amperage circuit. The remainder of current is sent to the field windings. The DC current flow through the field windings (wires around an iron core) increases the strength of the magnetic lines of force. These stronger magnetic lines of force increase the amount of AC that is produced in the stator windings. The increased speed of the rotor assembly also increases the current output of the alternator and the voltage output of the alternator.

The voltage regulator is a solid-state electronic switch. The voltage regulator senses the voltage of the system. The regulator then uses switches to control the current to the field windings. This controls the voltage output in order to meet the electrical demand of the system.

NOTICE

The alternator should never be operated without the battery in the circuit. The making or the breaking of an alternator connection with a heavy load on the circuit can cause damage to the regulator.

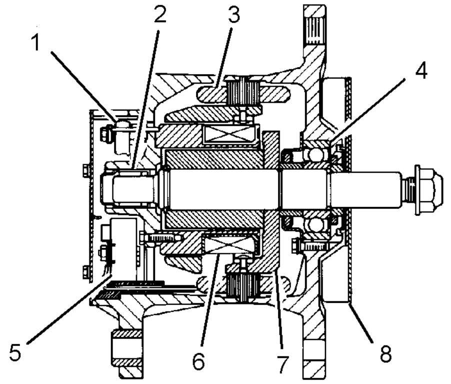


Illustration 18 g01096944

Typical cross section of an alternator

(1) Regulator
(2) Roller bearing
(3) Stator winding
(4) Ball bearing
(5) Rectifier bridge
(6) Field winding
(7) Rotor assembly
(8) Fan

Starting System Components

Solenoid

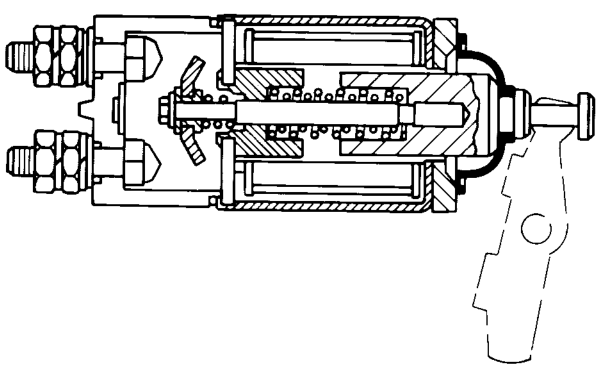


Illustration 19 g00292316

Typical cross section of a solenoid

A solenoid is an electromagnetic switch that performs two basic functions:

- The solenoid closes the high current circuit for the starting motor with a low current start switch circuit.
- The solenoid engages the pinion for the starting motor with the ring gear.

The solenoid has windings (one set or two sets) around a hollow cylinder or a hollow housing. A plunger that is spring loaded is located within the solenoid housing. The plunger can move forward and backward. When the start switch is closed and electricity is sent through the windings, a magnetic field is created. The magnetic field pulls the plunger forward in the solenoid housing. This moves the shift lever in order for the pinion drive gear to engage with the ring gear. The front end of the plunger then makes contact across the battery and across the motor terminals of the solenoid. The starting motor then begins to turn the flywheel of the engine.

When the start switch is opened, current no longer flows through the windings. The spring now returns the plunger to the original position. At the same time, the spring moves the pinion gear away from the flywheel.

When two sets of windings in the solenoid are used, the windings are called the hold-in winding and the pull-in winding. Both of the windings wind around the cylinder for an equal amount of times. The pull-in winding uses a wire with a larger diameter in order to produce a stronger magnetic field. When the start switch is closed, part of the current flows from the battery through the hold-in winding. The remainder of the current flows through the pull-in windings, to the motor terminal, and then to the ground. When the solenoid is activated, the current is shut off through the pull-in windings. Only the smaller hold-in windings are in operation for the extended period of time that is necessary for the engine to be started. The solenoid will now take a smaller amount of current from the battery. Heat that is created by the solenoid will be kept at an acceptable level.

Starting Motor

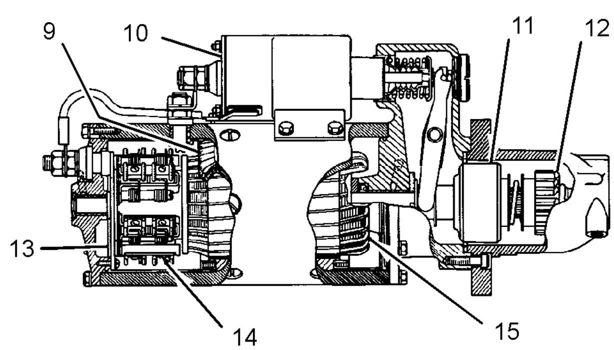


Illustration 20 g01385598

Typical cross section of a starting motor

(9) Field
(10) Solenoid
(11) Clutch
(12) Pinion
(13) Commutator
(14) Brush assembly
(15) Armature

The starting motor rotates the engine flywheel at a rate that is fast enough to start the engine.

The starting motor has a solenoid. When the start switch is activated, the solenoid will move the starter pinion in order to engage the pinion and the ring gear on the engine flywheel. The starting motor pinion and the ring gear will engage before the circuit between the battery and the starting motor is closed by the electric contacts in the solenoid. When the circuit between the battery and the starting motor is complete, the pinion will rotate the engine flywheel. A clutch provides protection for the starting motor so that the engine cannot turn the starting motor too fast. When the switch is released, the starter pinion will move away from the ring gear.

Testing and Adjusting Section

Fuel System

i02486828

Fuel System - Inspect

SMCS Code: 1250-040

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. Install a new fuel filter.

4. Cut the old filter open with the 175-7546 Oil Filter Cutter Gp. Inspect the filter for excess contamination. Determine the source of the contamination. Make the necessary repairs.

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

6. Operate the hand priming pump (if equipped). If excessive resistance is felt, inspect the fuel pressure regulating valve. If uneven resistance is felt, test for air in the fuel. Refer to Testing and Adjusting, “Air in Fuel - Test” for more information.

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

i02486845

Air in Fuel - Test

SMCS Code: 1280-081

This procedure checks for air in the fuel. 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.

2. Install a 2P-8278 Tube As (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

   Observe the fuel flow during engine cranking. Look for air bubbles in the fuel. If there is no fuel 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 of air in the fuel.

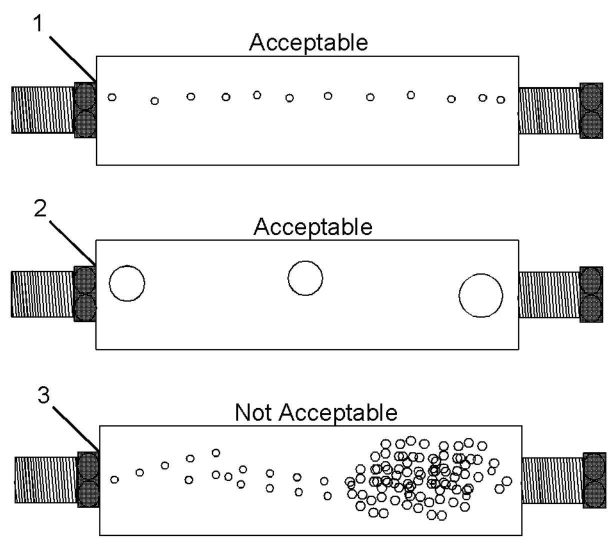


Illustration 21 g01096678

2P-8278 Tube As (SIGHT GAUGE)

(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 not seen at the inlet to the fuel transfer pump, the air is entering the system after the fuel transfer pump. Proceed to Step 6.

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.

6. If the injector sleeve is worn or damaged, combustion gases may be leaking into the fuel system. Also, if the O-rings on the injector sleeves are worn, missing, or damaged, combustion gases may leak into the fuel system.

i02770540

Electronic Unit Injector - Adjust

SMCS Code: 1290-025

Table 1

Required Tools		
Part Number	**Part Name**	**Quantity**
9U-7227	Injector Height Gauge	1

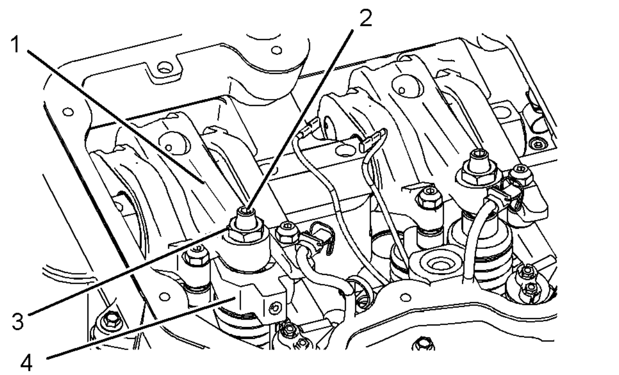


Illustration 22 g01385601

Injector Mechanism

(1) Rocker arm
(2) Adjustment screw
(3) Locknut
(4) 9U-7227 Injector Height Gauge

To make an adjustment to the unit injectors on cylinders 4, 5, 6, 9, 11, and 12 use the following procedure:

1. Put the No. 1 piston at the top center position on the compression stroke. Refer to Testing and Adjusting, "Finding Top Center Position for No. 1 Piston".

2. Injector height gauge (4) is used in order to obtain a dimension of 78.0 ± 0.2 mm (3.07 ± 0.01 inch). The dimension is measured from the top of the unit injector to the machined ledge of the fuel injector body.

3. Turn unit injector adjustment screw (2) clockwise until the correct height is obtained.

4. Hold the adjustment screw in this position and tighten locknut (3) to a torque of 100 ± 10 N·m (75 ± 7 lb ft).

5. To make an adjustment to the unit injectors on cylinders 1, 2, 3, 7, 8, and 10 remove the timing bolt. Turn the flywheel by 360 degrees in the direction of engine rotation. The direction of engine rotation is counterclockwise, as the engine is viewed from the flywheel end. This will put the number 11 piston at the top center position on the compression stroke.

6. Repeat Steps 3 through 4.

7. Remove the timing bolt from the flywheel after all the unit injector adjustments have been made. Reinstall the valve mechanism covers.

i02209818

Electronic Unit Injector - Test

SMCS Code: 1290-081

This procedure assists in identifying the cause for an injector misfiring. Perform this procedure only after performing the Cylinder Cutout Test. Refer to Troubleshooting, “Injector Solenoid Circuit-Test” for more information.

1. Check for air in the fuel, if this procedure has not already been performed. Refer to Testing and Adjusting, “Air in Fuel - Test”.

WARNING

Electrical shock hazard. The electronic unit injector system uses 90-120 volts.

2. Remove the valve cover and look for broken parts. Repair any broken parts or replace any broken parts that are found. Inspect all wiring for the solenoids. Look for loose connections. Also look for frayed wires or broken wires. Ensure that the connector for the unit injector solenoid is properly connected. Perform a pull test on each of the wires. Inspect the posts of the solenoid for arcing. If arcing is found, remove the cap assembly. Clean the connecting posts. Reinstall the cap assembly and tighten the solenoid nuts to a torque of 2.50 ± 0.25 N·m (22 ± 2 lb in). Refer to Disassembly and Assembly Manual, “Electronic Unit Injector - Install”.

3. Look for signs of fuel leakage. Investigate the source of the leaking fuel. Remedy the cause of the fuel leak.

4. Check the valve lash setting for the cylinder of the suspect unit injector. Refer to Testing and Adjusting, “Engine Valve Lash - Inspect/Adjust”.

5. Ensure that the bolt that holds the unit injector is tightened to the proper torque. If necessary, loosen the bolt that holds the unit injector and tighten with the procedure from Specifications, “Electronic Unit Injector Mechanism”.

6. Remove the suspect unit injector and check the unit injector for signs of exposure to coolant. Exposure to coolant will cause rust to form on the injector. If the unit injector shows signs of exposure to coolant, remove the injector sleeve and inspect the injector sleeve. Replace the injector sleeve if the injector sleeve is damaged. Check the unit injector for an excessive brown discoloration that extends beyond the injector tip. If excessive discoloration is found, check the quality of the fuel. Refer to Testing and Adjusting, “Fuel Quality - Test”. Replace the seals on the injector and reinstall the injector. Refer to Disassembly and Assembly Manual, “Electronic Unit Injector - Install”. Also refer to Disassembly and Assembly Manual, “Electronic Unit Injector Sleeve - Install”. Inspect the injector for deposits of soot that are above the surface of the seat of the injector. Deposits of soot indicate combustion gas leakage. The source of the leak should be found, and the source of the leak should be remedied. The injector will not need to be replaced if combustion gas leakage was the problem.

7. If the problem is not resolved, replace the suspect injector with a new injector.

i02226500

Finding Top Center Position for No. 1 Piston

SMCS Code: 1105-531

Table 2

Needed Tools		
9S-9082	Engine Turning Tool	1

The No. 1 piston at Top Center (TC) on the compression stroke is the starting point of all timing procedures.

Note: Some engines have two threaded holes in the flywheel. These holes are in alignment with the holes with plugs in the left and right front of the flywheel housing. The two holes in the flywheel are at a different distance from the center of the flywheel so the timing bolt cannot be put in the wrong hole.

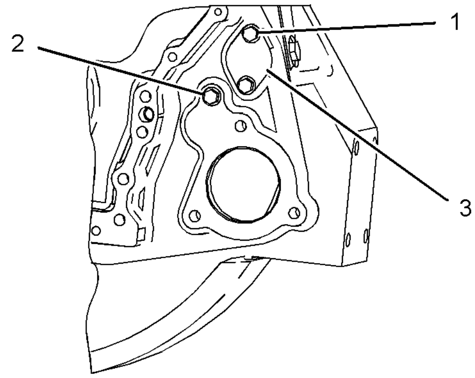


Illustration 23 g01123281

Locating Top Center on the left side of engine

(1) Timing bolt
(2) Timing bolt location
(3) Cover

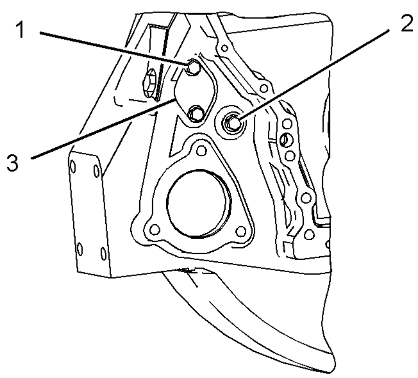


Illustration 24 g01123294

Locating Top Center on the right side of engine

(1) Timing bolt
(2) Timing bolt location
(3) Cover

1. Timing bolt (1) is a cover bolt. The timing bolt can be installed in either the left side of the engine at location (2) or in the right side of the engine at timing bolt location (2). Remove both bolts (1) and cover (3) from the flywheel housing. Remove the plug from the timing hole in the flywheel housing.

2. Put timing bolt (1) (long bolt that holds the cover on the flywheel housing) through the timing hole in the flywheel housing. The 9S-9082 Engine Turning Tool and a 1/2 inch drive ratchet wrench are used in order to turn the engine flywheel in the direction of normal engine rotation. Normal engine rotation is counterclockwise. Normal engine rotation is viewed from the flywheel end of the engine. Turn the engine flywheel until the timing bolt engages with the threaded hole in the flywheel.

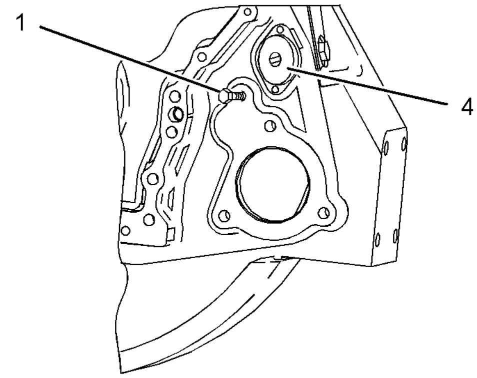


Illustration 25 g01123312

Using 9S-9082 Engine Turning Tool

(1) Timing bolt
(4) 9S-9082 Engine Turning Tool

Note: If the flywheel is turned beyond the point of engagement, the flywheel must be turned in the opposite direction of normal engine rotation approximately 45 degrees. Then turn the flywheel in the direction of normal rotation until the timing bolt engages with the threaded hole. The procedure will eliminate the backlash that will occur when the No. 1 piston is put on the top center.

3. Remove the front valve mechanism cover from the engine.

4. The inlet and exhaust valves for the No. 1 cylinder are fully closed if the No. 1 piston is on the compression stroke and the rocker arms can be moved by hand. If the rocker arms can not be moved and the valves are slightly open the No. 1 piston is on the exhaust stroke.

Note: After the actual stroke position is identified, and the other stroke position is needed, remove the timing bolt from the flywheel. The flywheel is turned 360 degrees in a counterclockwise direction. The timing bolt is reinstalled.

i02486888

Fuel Quality - Test

SMCS Code: 1280-081

This test checks for problems regarding fuel quality. Refer to Diesel Fuels and Your Engine, SEBD0717 for additional details.

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

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

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

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

   - Fuel heaters
   - Blending fuel with additives
   - Utilizing fuel with a low cloud point such as kerosene

   Refer to Operation and Maintenance Manual, SEBU6251, "Caterpillar Commercial Diesel Engine Fluids Recommendations", "Fuel Recommendations" for more information.

3. Check fuel API with a 9U-7840 Fluid and Fuel Calibration Gp for low power complaints. The acceptable range of the fuel API is 30 to 45 when the API is measured at 15 °C (60 °F), but there is a significant difference in energy within this range. Refer to Tool Operating Manual, NEHS0607 for API correction factors when a low power problem is present and API is high.

Note: A correction factor that is greater than 1 may be the cause of low power and/or poor fuel consumption.

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

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

i02285479

Fuel System - Prime

SMCS Code: 1258-548

The Secondary Fuel Filter Has Been Replaced

⚠ WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. To help prevent possible injury, turn the start switch off when changing fuel filters or water separator elements. Clean up fuel spills immediately.

NOTICE

Use a suitable container to catch any fuel that might spill. Clean up any spilled fuel immediately.

NOTICE

Do not allow dirt to enter the fuel system. Thoroughly clean the area around a fuel system component that will be disconnected. Fit a suitable cover over disconnected fuel system component.

Note: Refer to Operation and Maintenance Manual, "Fuel System Secondary Filter - Replace" for information on replacing the filter.

1. Turn the keyswitch to the "OFF" position.

2. Open the air purge screw for the fuel filter by three full turns. Do not remove the air purge screw.

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.

3. Start the engine. The engine should start and the engine should run smoothly. If the engine does not start after 30 seconds, allow the starter motor to cool for two minutes before attempting to start the engine again.

Note: You may use the hand priming pump (if equipped) for the fuel filter instead of starting the engine and running the engine.

4. While the engine is running, observe the air purge screw. When a small drop of fuel appears at the threads of the air purge screw, close and tighten the air purge screw.

Note: There may be a noticeable change in the sound of the running engine when the air purge screw is tightened. The change in the sound of the engine is normal.

Note: Failure to tighten all fittings could result in serious fuel leaks.

5. Clean any residual fuel from the engine components.

The Engine Has Been Run Out of Fuel

NOTICE
Use a suitable container to catch any fuel that might spill. Clean up any spilled fuel immediately.

NOTICE
Do not allow dirt to enter the fuel system. Thoroughly clean the area around a fuel system component that will be disconnected. Fit a suitable cover over disconnected fuel system component.

1. Turn the keyswitch to the “OFF” position.

2. Fill the fuel tank(s) with clean diesel fuel.

3. Bleed the air from the system by opening the fuel pressure regulator valve by two turns and another half turn.

Note: Do not remove the regulating valve completely. Open the valve enough to allow the air that is trapped in the cylinder head to be purged from the fuel system.

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.

4. Crank the engine for 30 seconds. Use a suitable container to catch the fuel while you crank the engine. Allow the starter motor to cool for two minutes.

Note: You may use the hand priming pump (if equipped) for the fuel filter instead of cranking the engine.

5. Crank the engine for 30 seconds. Allow the starter motor to cool for two minutes.

6. Close and tighten the fuel pressure regulating valve.

7. Crank the engine for 30 seconds. Allow the starter motor to cool for two minutes.

8. Repeat Step 7 until the engine starts and the engine runs.

Note: Failure to tighten all fittings could result in serious fuel leaks.

9. Clean any residual fuel from the engine components.

The Engine Has Been Rebuilt

NOTICE
Use a suitable container to catch any fuel that might spill. Clean up any spilled fuel immediately.

NOTICE
Do not allow dirt to enter the fuel system. Thoroughly clean the area around a fuel system component that will be disconnected. Fit a suitable cover over disconnected fuel system component.

1. Turn the keyswitch to the “OFF” position.

2. Fill the fuel tank(s) with clean diesel fuel.

3. Open the air purge screw for the fuel filter by three full turns. Do not remove the air purge screw.

4. Bleed the air from the system by opening the fuel pressure regulator valve by two turns and another half turn.

Note: Do not remove the regulating valve completely. Open the valve enough to allow the air that is trapped in the cylinder head to be purged from the fuel system.

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.

5. Crank the engine for 30 seconds. Use a suitable container to catch the fuel while you crank the engine. Allow the starter motor to cool for two minutes.

Note: You may use the hand priming pump (if equipped) for the fuel filter instead of cranking the engine.

6. Crank the engine for 30 seconds. Allow the starter motor to cool for two minutes.

7. Close and tighten the air purge screw.

8. Crank the engine for 30 seconds. Allow the starter motor to cool for two minutes.

9. Close and tighten the fuel pressure regulating valve.

Note: Failure to tighten all fittings could result in serious fuel leaks.

10. Crank the engine for 30 seconds. Allow the starter motor to cool for two minutes.

11. Repeat Step 10 until the engine starts and runs.

12. Clean any residual fuel from the engine components.

i02229176

Fuel System Pressure - Test

SMCS Code: 1250-081; 1256-081

Low Fuel Pressure

Low fuel pressure can cause low power. Low fuel pressure can also cause cavitation of the fuel which can damage the fuel injectors. The following conditions can cause low fuel pressure:

- Plugged fuel filters
- Debris in the check valves for the fuel priming pump
- Debris in the pressure regulating valve
- Partially open check valve
- Sticking or worn fuel pressure regulating valve in the fuel transfer pump
- Severe wear on return fuel pressure regulating valve in the fuel filter base
- Worn gears in the fuel transfer pump
- Pinched fuel lines or undersized fuel lines
- Old fuel lines that have a reduced interior diameter that was caused by swelling
- Fuel lines with deteriorating interior surfaces
- Pinched fuel line fittings or undersized fuel line fittings
- Debris in the fuel tank, fuel lines, or fuel system components that create restrictions

High Fuel Pressure

Excessive fuel pressure can cause fuel filter gaskets to rupture. The following conditions can cause high fuel pressure:

- Plugged orifices in the fuel pressure regulating valve
- Stuck fuel pressure regulating valve in the fuel transfer pump
- Pinched fuel return line

Fuel Pressure Readings

The typical fuel pressure of the engine at operating temperature can vary. At low idle, the fuel pressure can be 538 kPa (78 psi). At high rpm, the fuel pressure can be 641 kPa (93 psi).

The performance of the unit injector deteriorates when the fuel pressure drops below 241 kPa (35 psi). Low power complaints and erratic operation can occur in this situation. Check for a plugged fuel filter or air in the fuel lines as possible causes for these complaints before replacing fuel system components.

Checking Fuel Pressure

Table 3

Required Tools		
Part Number	Part Name	Quantity
1U-5470 or 198-4240	Engine Pressure Group or Digital Pressure Indicator	1

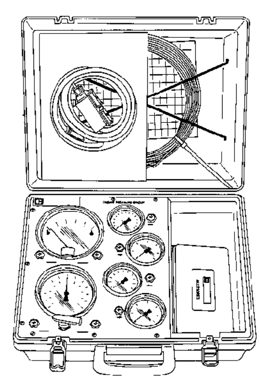


Illustration 26 g00294866

1U-5470 Engine Pressure Group

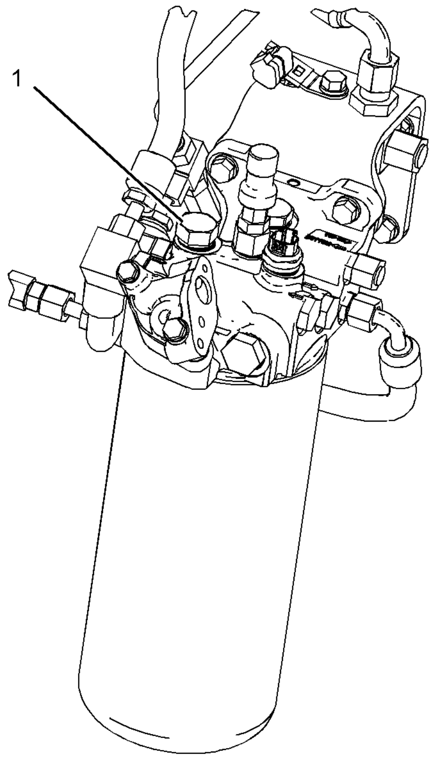


Illustration 27 g01124671

Location of fuel pressure tap

To check the fuel transfer pump pressure, remove the plug (1) from the fuel filter base. Install the pressure gauge and appropriate fittings from the 1U-5470 Engine Pressure Group and start the engine.

Check the fuel pressure of the engine with the 1U-5470 Engine Pressure Group. The engine pressure group includes Special Instruction, SEHS8907, “Using the 1U-5470 Engine Pressure Group”. This instruction provides information about the usage of the group.

i02227448

Rear Gear Group - Time

SMCS Code: 1206-531

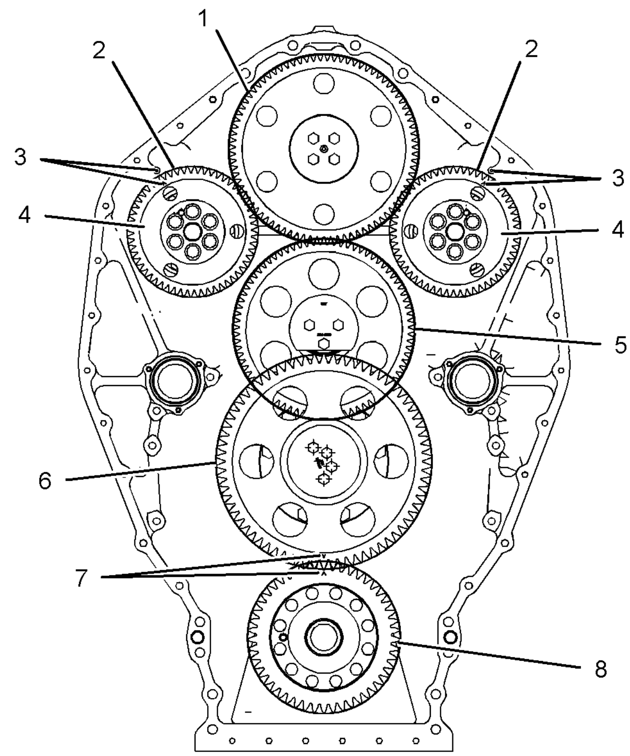


Illustration 28 g01114567

Rear gear group

(1) Idler gear
(2) Gear assembly for the camshaft
(3) Alignment marks
(4) Camshaft gear
(5) Idler gear assembly
(6) Idler gear assembly
(7) Alignment marks
(8) Crankshaft gear

Position the number one piston in the top center position (TC). Align the “V” mark (3) on the camshaft gear (4) with the mark in the flywheel housing.

Align the “V” marks (7) on idler gear (6) and the crankshaft gear (8).

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

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

Air Inlet and Exhaust System

i02310859

Air Inlet and Exhaust System - Inspect

SMCS Code: 1050-040

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

Table 4

Required Tools		
Part Number	**Part Name**	**Quantity**
1U-5470 or 198-4240	Engine Pressure Group or Digital Pressure Indicator	1

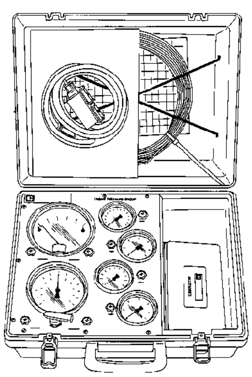


Illustration 29 g00295554

1U-5470 Engine Pressure Group

Air Inlet Restriction

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

1. Inspect the engine air cleaner inlet and ducting in order to ensure that the passageway is not blocked or collapsed.
2. Inspect the engine air cleaner element. Replace a dirty engine air cleaner element with a clean engine air cleaner element.
3. Check for dirt contamination on the clean side of the engine air cleaner element. If any dirt contamination is observed, contaminants are flowing past the engine air cleaner element and/or the seal for the engine air cleaner element.

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.

4. Use the differential pressure gauge of the 1U-5470 Engine Pressure Group.
    a. Connect the vacuum port of the differential pressure gauge to the test location. The test location may be located anywhere along the air inlet piping after the air cleaner but before the turbocharger.
    b. Leave the pressure port of the differential pressure gauge open to the atmosphere.
    c. Start the engine. Run the engine in the no-load condition at high idle.
    d. Record the value.
    e. Multiply the value from Step 4.d by 1.8.
    f. Compare the result from Step 4.e to the appropriate values that follow.

The air flow through a used engine air cleaner may have a restriction. The air flow through a plugged engine air cleaner will be restricted to some magnitude. In either case, the restriction must not be more than the following amount:

Maximum restriction .... 7.6 kPa (30.54 inch of H_2O)

The air flow through a new engine air cleaner element must not have a restriction of more than the following amount:

Maximum restriction .... 3.7 kPa (14.87 inch of H_2O)

Exhaust Restriction

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

Back pressure is the difference in the pressure between the exhaust at the outlet elbow and the atmospheric air.

⚠ 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. Connect the pressure port of the differential pressure gauge to the test location. The test location can be located anywhere along the exhaust piping after the turbocharger but before the muffler.
2. Leave the vacuum port of the differential pressure gauge open to the atmosphere.
3. Start the engine. Run the engine in the no-load condition at high idle.
4. Record the value.
5. Multiply the value from Step 4 by 1.8.
6. Compare the result from Step 5 to the value that follows.

Back pressure from the exhaust must not be more than the following amount:

Maximum back pressure .... 6.8 kPa (27.33 inch of H_2O)

i02030344

Turbocharger - Inspect

SMCS Code: 1052-040

⚠ WARNING

Disconnect batteries before performance of any service work.

⚠ 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.

Refer to Special Publication, NENG2500, “Caterpillar Tools and Shop Products Guide” for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to local regulations and mandates.

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

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

- Inspection of the Compressor and the Compressor Housing
- Inspection of the Turbine Wheel and the Turbine Housing

Inspection of the Compressor and the Compressor Housing

Remove air piping from the compressor inlet.

1. Inspect the 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 inlet system. Replace the turbocharger. If there is no damage, go to Step 3.

2. Clean the compressor wheel and clean the compressor housing if you find buildup of foreign material. If there is no buildup of foreign material, go to Step 3.

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

4. Inspect the compressor and the compressor wheel housing for oil leakage. An oil leak from the compressor may deposit oil in the aftercooler. 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 engine crankcase breather or replace the engine crankcase breather if the engine crankcase breather is plugged.

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

   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

Remove the air piping from the turbine outlet casing.

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

2. Inspect the turbine wheel for buildup of carbon and other foreign material. Inspect the turbine housing for buildup of carbon and foreign material. Clean the turbine wheel and clean the turbine housing if you find buildup of carbon or foreign material. If there is no buildup of carbon or foreign material, go to Step 3.

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

4. Inspect the turbine and the turbine wheel housing for oil leakage. Inspect the turbine and the turbine wheel housing for oil coking. Some oil coking may be cleaned. Heavy oil coking may require replacement of the turbocharger. If the oil is coming from the turbocharger center housing go to Step 4.a.

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

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

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

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

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

i02227890

Inlet Manifold Pressure - Test

SMCS Code: 1058-081

Table 5

Required Tools		
Part Number	Part Name	Quantity
1U-5470 or 198-4240	Engine Pressure Group or Digital Pressure Indicator	1

The efficiency of an engine can be checked by making a comparison of the pressure in the inlet manifold with the information given in the Technical Marketing Information (TMI). This test is used when there is a decrease of horsepower from the engine, yet there is no real sign of a problem with the engine.

The correct pressure for the inlet manifold is listed in the TMI. Development of this information is performed under the following conditions:

- 99 kPa (29.7 in Hg) dry barometric pressure
- 29 °C (85 °F) outside air temperature
- 35 API rated fuel

On a turbocharged, aftercooled engine, a change in the fuel rating will change the horsepower. A change in the fuel rating will change the inlet manifold pressure. If the fuel is rated above 35 API, the inlet manifold pressure can be less than the pressure given in the TMI. If the fuel is rated below 35 API, the inlet manifold pressure can be more than the pressure listed in the TMI.

Note: Ensure that the air inlet and the exhaust are not restricted when you check the inlet manifold pressure. Refer to Testing and Adjusting, "Air Inlet and Exhaust System - Inspect" for more information.

Use the following procedure in order to use an electronic service tool to measure the inlet manifold pressure:

1. Connect the Caterpillar Electronic Technician (ET).
2. Operate the engine under the suspect conditions.
3. Record the value.
4. Compare the value that was recorded in Step 3 to the pressure that is given in the TMI.

Use the following procedure in order to use the 1U-5470 Engine Pressure Group to measure the inlet manifold pressure:

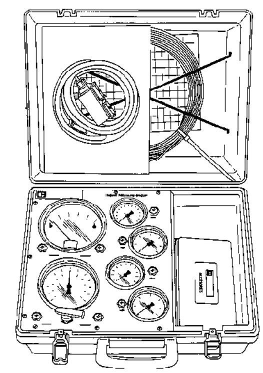


Illustration 30 g00293196

1U-5470 Engine Pressure Group

1. Remove the pipe plug from the inlet manifold. It is not necessary to remove the air temperature sensor from the inlet manifold.
2. Connect the 1U-5470 Engine Pressure Group to the inlet manifold at the pressure test location.

   Refer to Special Instruction, SEHS8907, "Using the 1U-5470 Engine Pressure Group" for more information on using the tool.
3. Operate the engine under the suspect conditions.
4. Record the value.
5. Compare the value that was recorded in Step 4 to the pressure that is given in the TMI.

i02387243

Exhaust Temperature - Test

SMCS Code: 1088-081

Table 6

Required Tools		
Part Number	Part Name	Qty
164-3310	Infrared Thermometer	1

When the engine runs at low idle, the temperature of an exhaust manifold port can indicate the condition of a fuel injection nozzle.

A low temperature indicates that no fuel is flowing to the cylinder. An inoperative fuel injection nozzle or a problem with the fuel injection pump could cause this low temperature.

A very high temperature can indicate that too much fuel is flowing to the cylinder. A malfunctioning fuel injection nozzle could cause this very high temperature.

Use the 164-3310 Infrared Thermometer to check exhaust temperature.

i02227927

Engine Crankcase Pressure (Blowby) - Test

SMCS Code: 1215; 1317

Table 7

Tools Needed		
Part Number	Part Name	Quantity
8T-2700	Blowby/Air Flow Indicator	1

Excessive blowby can cause a fouling or plugged condition in the following components:

- The filter for the Closed Crankcase Ventilation (CCV) system
- Turbocharger
- Aftercooler

Damaged pistons or rings can cause too much pressure in the crankcase. This condition will cause the engine to run rough. The CCV can then become restricted in a very short time, causing oil leakage at gaskets and seals that would not normally have leakage. Blowby can also be caused by worn valve guides or by a failed turbocharger seal.

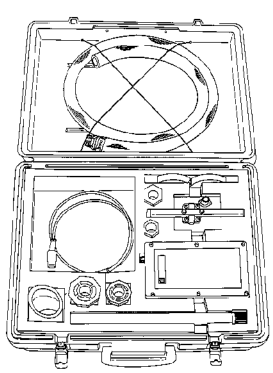


Illustration 31 g00286269

8T-2700 Blowby/Air Flow Indicator

The 8T-2700 Blowby/Air Flow Indicator is used to check the amount of blowby. Refer to Special Instruction, SEHS8712, "Using the 8T-2700 Blowby/Air Flow Indicator" for the test procedure for checking the blowby.

i02774006

Engine Valve Lash - Inspect/Adjust

SMCS Code: 1102-025

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.

WARNING

This engine uses high voltage to control the fuel injectors.

Disconnect electronic fuel injector enable circuit connector to prevent personal injury.

Do not come in contact with the fuel injector terminals while the engine is running.

Note: Valve lash is measured between the rocker arm and the valve bridge. All measurements and adjustments must be made with the engine stopped and the valves fully closed.

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 range is specified in Table 8.

Table 8

Quick Reference for Engine Valve Lash Setting		
	Inlet Valves	Exhaust Valves
Valve Lash Setting	0.38 ± 0.08 mm (0.015 ± 0.003 inch)	0.76 ± 0.08 mm (0.030 ± 0.003 inch)
TC Compression Stroke of No. 1 Piston	1-2-3-7-8-10	1-2-5-6-9-10
TC Compression Stroke of No. 11 Piston(1)	4-5-6-9-11-12	3-4-7-8-11-12
Firing Order	1-10-9-6-5-12-11-4-3-8-7-2(2)	

(1) 360° from TC compression stroke
(2) Refer to Illustration 32 in order to locate the No. 1 cylinder.

If the measurement is not within this range adjustment is necessary. Refer to “Valve Lash Adjustment”.

Valve Lash Adjustment

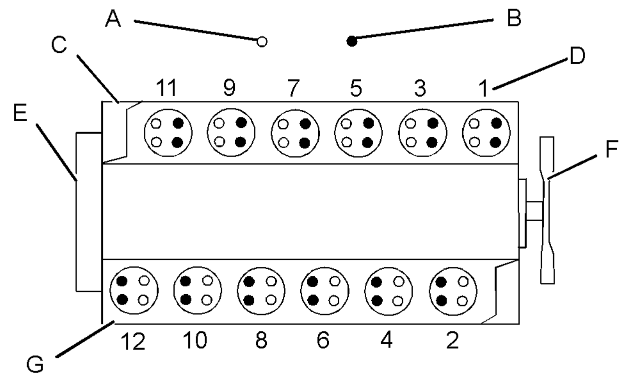


Illustration 32 g01386737

(A) Inlet valves
(B) Exhaust valves
(C) Left side of the engine
(D) Cylinder number
(E) Flywheel end of the engine
(F) Front of the engine
(G) Right side of the engine

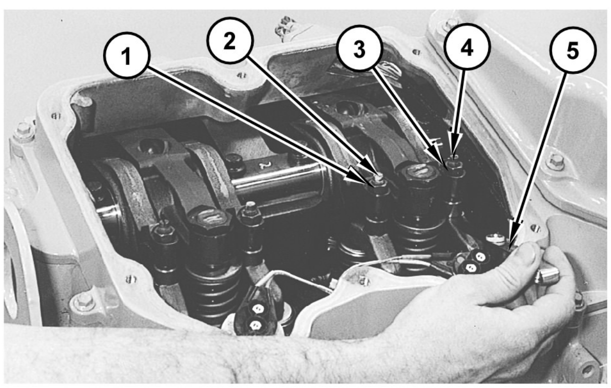


Illustration 33 g01386742

Typical example

(1) Valve adjustment locknut
(2) Exhaust adjustment screw
(3) Valve adjustment locknut
(4) Inlet adjustment screw
(5) Feeler gauge

Table 9

Valve Lash	
Valves	**Thickness of Gauge**
Inlet	0.38 mm (0.015 inch)
Exhaust	0.76 mm (0.030 inch)

Adjust the valve lash while the engine is stopped. Use the following procedure in order to adjust the valves:

1. Put the No. 1 piston at the top center position.

Note: See Testing and Adjusting, “Finding Top Center Position for the No. 1 Piston” for further details.

2. With No. 1 piston at the top center position of the compression stroke, an adjustment can be made to the valves.

Before any adjustments are made, lightly tap each rocker arm at the top of the adjustment screw. Use a soft mallet to ensure that the lifter roller seats against the camshaft’s base circle.

3. Make an adjustment to the valve lash on the inlet valves for cylinders 1, 2, 3, 7, 8, and 10.

a. Loosen valve adjustment locknut (3).

b. Place the appropriate feeler gauge (5) between the inlet rocker arm and the inlet valve bridge. Turn inlet adjustment screw (4) while valve adjustment locknut (3) is being held from turning. Adjust the valve lash until the correct specification is achieved. Refer to Table 9.

c. After each adjustment, tighten valve adjustment locknut (3) while valve adjustment screw (4) is being held from turning. Tighten to a torque of 30 ± 7 N·m (22 ± 5 lb ft). Recheck each adjustment.

4. Make an adjustment to the valve lash on the exhaust valves for cylinders 1, 2, 5, 6, 9, and 10.

a. Loosen valve adjustment locknut (1).

b. Place the appropriate feeler gauge (5) between the exhaust rocker arm and the exhaust valve bridge. Turn exhaust adjustment screw (2) while valve adjustment locknut (1) is being held from turning. Adjust the valve lash until the correct specification is achieved. Refer to Table 9.

c. After each adjustment, tighten valve adjustment locknut (1) while valve adjustment screw (2) is being held from turning. Tighten to a torque of 30 ± 7 N·m (22 ± 5 lb ft). Recheck each adjustment.

5. Remove the timing bolt, and turn the flywheel by 360 degrees in the direction of engine rotation. This will position the No. 11 piston at the top center at the beginning of the compression stroke. Install the timing bolt in the flywheel.

6. Make an adjustment to the valve lash on the inlet valves for the following cylinders 4, 5, 6, 9, 11, and 12.

a. Loosen valve adjustment locknut (3).

b. Place the appropriate feeler gauge (5) between the inlet rocker arm and the inlet valve bridge. Turn inlet adjustment screw (4) while valve adjustment locknut (3) is being held from turning. Adjust the valve lash until the correct specification is achieved. Refer to Table 9.

c. After each adjustment, tighten valve adjustment locknut (3) while valve adjustment screw (4) is being held from turning. Tighten to a torque of 30 ± 7 N·m (22 ± 5 lb ft). Recheck each adjustment.

7. Make an adjustment to the valve lash on the exhaust valves for cylinders 3, 4, 7, 8, 11, and 12.

a. Loosen valve adjustment locknut (1).

b. Place the appropriate feeler gauge (5) between the exhaust rocker arm and the exhaust valve bridge. Turn exhaust adjustment screw (2) while valve adjustment locknut (1) is being held from turning. Adjust the valve lash until the correct specification is achieved. Refer to Table 9.

c. After each adjustment, tighten valve adjustment locknut (1) while valve adjustment screw (2) is being held from turning. Tighten to a torque of 30 ± 7 N·m (22 ± 5 lb ft). Recheck each adjustment.

8. Remove the timing bolt from the flywheel after all valve lash adjustments have been made.

Lubrication System

i02414081

Engine Oil Pressure - Test

SMCS Code: 1304-081

Measuring Engine Oil Pressure

WARNING

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

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.

Refer to Special Publication, NENG2500, “Caterpillar Dealer Service Tool Catalog” for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to local regulations and mandates.

Table 10

Tools Needed		
Part Number	**Part Name**	**Quantity**
1U-5470	Engine Pressure Group	1

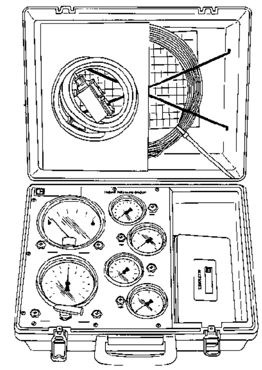


Illustration 34 g00296486

1U-5470 Engine Pressure Group

The 1U-5470 Engine Pressure Group measures the oil pressure in the system. This engine tool group can read the oil pressure inside the oil manifold.

Note: Refer to Special Instruction, SEHS8907, “Using the 1U-5470 Engine Pressure Group” for more information on using the 1U-5470 Engine Pressure Group.

Note: The engine oil pressure can also be measured by using Caterpillar Electronic Technician (ET). Refer to Troubleshooting for information on the use of Cat ET.

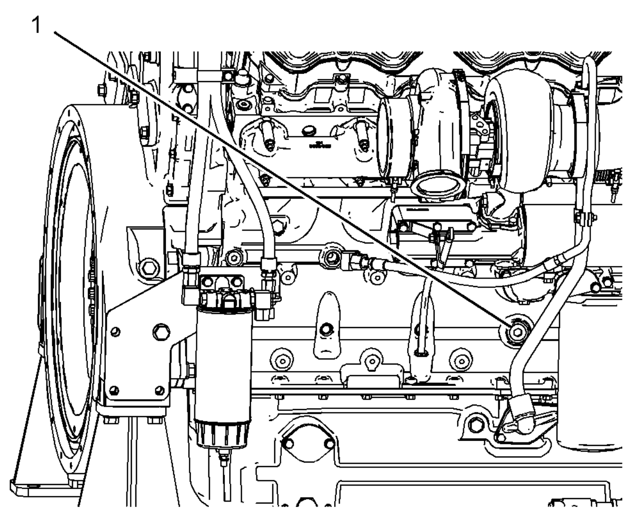


Illustration 35 g01206665

Oil gallery plug

1. Install the 1U-5470 Engine Pressure Group into oil gallery plug (1).

2. Start the engine. Run the engine with SAE 10W30 or SAE 15W40 oil. The information in the engine oil pressure graph is invalid for other oil viscosities. Refer to Operation and Maintenance Manual for the recommendations of engine oil.

Note: Allow the engine to reach operating temperature before you perform the pressure test.

Note: The engine oil temperature should not exceed 115 °C (239 °F).

3. Record the value of the engine oil pressure when the engine has reached operating temperature.

4. Locate the point that intersects the lines for the engine rpm and for the oil pressure on the engine oil pressure graph.

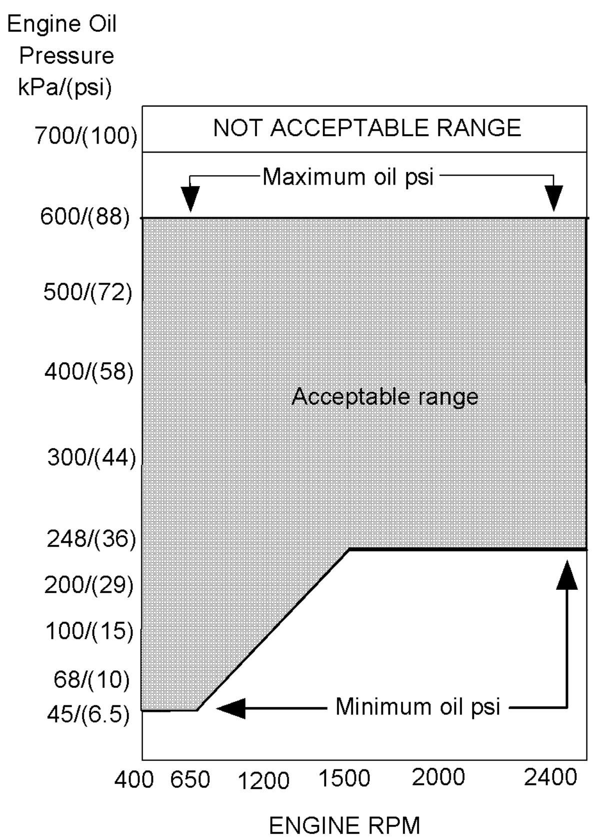


Illustration 36 g01046794

5. The results must fall within the “ACCEPTABLE” range on the chart. A problem exists when the results fall within the “NOT ACCEPTABLE” range on the chart. The problem needs to be corrected. Engine failure or a reduction in engine life can be the result if engine operation is continued with oil manifold pressure outside this range.

Note: A record of engine oil pressure can be used as an indication of possible engine problems or damage. A possible problem could exist if the oil pressure suddenly increases or decreases 70 kPa (10 psi) and the oil pressure is in the “ACCEPTABLE” range. The engine should be inspected and the problem should be corrected.

6. Compare the recorded engine oil pressure with the oil pressure indicators on the instrument panel and the engine oil pressure that is displayed on Cat ET.

7. An engine oil pressure indicator that has a defect or an engine oil pressure sensor that has a defect can give a false indication of a low oil pressure or a high oil pressure. If there is a notable difference between the engine oil pressure readings make necessary repairs.

8. Refer to “Reasons for Low Engine Oil Pressure” if you determine that the engine oil pressure is low.

9. Refer to “Reasons for High Engine Oil Pressure” if you determine that the engine oil pressure is high.

Reasons for Low Engine Oil Pressure

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.

Refer to Special Publication, NENG2500, “Caterpillar Dealer Service Tool Catalog” for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to local regulations and mandates.

- Engine oil level is low. Refer to Step 1.
- Engine oil is contaminated. Refer to Step 2.
- The engine oil bypass valves are open. Refer to Step 3.
- The engine lubrication system is open. Refer to Step 4.

- The oil suction tube has a leak or a restricted inlet screen. Refer to Step 5.
- The engine oil pump is faulty. Refer to Step 6.
- Engine Bearings have excessive clearance. Refer to Step 7.

1. Check the engine oil level in the crankcase. The oil level can possibly be too far below the oil pump supply tube. This will cause the oil pump not to have the ability to supply enough lubrication to the engine components. If the engine oil level is low add engine oil in order to obtain the correct engine oil level. Refer to Operation and Maintenance Manual for the recommendations of engine oil.

2. Engine oil that is contaminated with fuel or coolant will cause low engine oil pressure. High engine oil level in the crankcase can be an indication of contamination. Determine the reason for contamination of the engine oil and make the necessary repairs. Replace the engine oil with the approved grade of engine oil. Also replace the engine oil filter. Refer to Operation and Maintenance Manual for the recommendations of engine oil.

NOTICE

Caterpillar oil filters are built to Caterpillar specifications. Use of an oil filter not recommended by Caterpillar could result in severe engine damage to the engine bearings, crankshaft, etc., as a result of the larger waste particles from unfiltered oil entering the engine lubricating system. Only use oil filters recommended by Caterpillar.

3. If the engine oil bypass valves are held in the open position, a reduction in the oil pressure can be the result. This may be due to debris in the engine oil. If the engine oil bypass valves are stuck in the open position, remove each engine oil bypass valve and clean each bypass valve in order to correct this problem. You must also clean each bypass valve bore. Install new engine oil filters. Refer to the Disassembly and Assembly manual for more information on servicing the bypass valves.

4. An oil line or an oil passage that is open, broken, or disconnected will cause low engine oil pressure. An open lubrication system could be caused by a piston cooling jet that is missing or damaged.

Note: The piston cooling jets direct engine oil toward the bottom of the piston in order to cool the piston. This also provides lubrication for the piston pin. Breakage, a restriction, or incorrect installation of the piston cooling jets will cause seizure of the piston.

5. The inlet screen of the oil suction tube for the engine oil pump can have a restriction. This restriction will cause cavitation and a loss of engine oil pressure. Check the inlet screen on the oil pickup tube and remove any material that may be restricting engine oil flow. Low engine oil pressure may also be the result of the oil pickup tube that is drawing in air. Check the joints of the oil pickup tube for cracks or a damaged O-ring seal. Remove the engine oil pan in order to gain access to the oil pickup tube and the oil screen. Refer to Disassembly and Assembly, “Engine Oil Pan - Remove and Install” for more information.

6. Check the following problems that may occur to the engine oil pump.

   a. Air leakage in the supply side of the oil pump will also cause cavitation and loss of oil pressure. Check the supply side of the oil pump and make necessary repairs. For information on the repair of the engine oil pump, refer to Disassembly and Assembly, “Engine Oil Pump - Remove”.

   b. Oil pump gears that have too much wear will cause a reduction in oil pressure. Repair the engine oil pump. For information on the repair of the engine oil pump, refer to Disassembly and Assembly, “Engine Oil Pump - Remove”.

7. Excessive clearance at engine bearings will cause low engine oil pressure. Check the engine components that have excessive bearing clearance and make the necessary repairs.

Reasons for High Engine Oil Pressure

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.

Refer to Special Publication, NENG2500, "Caterpillar Dealer Service Tool Catalog" for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to local regulations and mandates.

Engine oil pressure will be high if the engine oil bypass valves become stuck in the closed position and the engine oil flow is restricted. Foreign matter in the engine oil system could be the cause for the restriction of the oil flow and the movement of the engine oil bypass valves. If the engine oil bypass valves are stuck in the closed position, remove each bypass valve and clean each bypass valve in order to correct this problem. You must also clean each bypass valve bore. Install new engine oil filters. New engine oil filters will prevent more debris from causing this problem. Refer to the Disassembly and Assembly manual for more information on servicing the bypass valves and the oil filters.

NOTICE

Caterpillar oil filters are built to Caterpillar specifications. Use of an oil filter not recommended by Caterpillar could result in severe engine damage to the engine bearings, crankshaft, etc., as a result of the larger waste particles from unfiltered oil entering the engine lubricating system. Only use oil filters recommended by Caterpillar.

i01432243

Engine Oil Pump - Inspect

SMCS Code: 1304-040

The inlet screen of the supply tube for the engine oil pump can have a restriction. This will cause cavitation and a loss of oil pressure. Air leakage in the supply side of the engine oil pump will also cause cavitation and loss of oil pressure. If the bypass valve for the engine oil pump is held in the open position, the lubrication system cannot achieve maximum pressure. Oil pump gears that have too much wear will cause a reduction in the oil pressure.

If any part of the engine oil pump is worn enough in order to affect the performance of the engine oil pump, the engine oil pump must be replaced. Refer to Specifications, "Engine Oil Pump" for clearances.

i01126690

Excessive Bearing Wear - Inspect

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

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

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

i02487769

Excessive Engine Oil Consumption - Inspect

SMCS Code: 1348-040

Engine Oil Leaks on the Outside of the Engine

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

Engine Oil Leaks into the Combustion Area of the Cylinders

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

- 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.

i02286625

Increased Engine Oil Temperature - Inspect

SMCS Code: 1348-040

When the engine is at operating temperature and the engine is using SAE 10W30 or SAE 15W40 oil, the maximum oil temperature should be 110 °C (230 °F). This is the temperature of the oil after passing through the oil cooler.

If the oil temperature is high, then check for a restriction in the oil passages of the oil cooler. A restriction in the oil cooler will not cause low oil pressure in the engine.

Determine if the oil cooler bypass valve is held in the open position. This condition will allow the oil to pass through the valve instead of the oil cooler. The oil temperature will increase.

Cooling System

i02630833

Cooling System - Check (Overheating)

SMCS Code: 1350-535

Above normal coolant temperatures can be caused by many conditions. Use the following procedure to determine the cause of above normal coolant temperatures:

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. Check the coolant level in the cooling system. Refer to Operation and Maintenance Manual, "Cooling System Coolant Level - Check". If the coolant level is too low, air will get into the cooling system. Air in the cooling system will cause a reduction in coolant flow and bubbles in the coolant. Air bubbles will keep coolant away from the engine parts, which will prevent the transfer of heat to the coolant. Low coolant level is caused by leaks or incorrectly filling the radiator.

2. Check the mixture of antifreeze and water. The mixture should be approximately 50 percent water and 50 percent antifreeze with 3 to 6 percent coolant conditioner. Refer to Operation and Maintenance Manual, "Refill Capacities and Recommendations". If the coolant mixture is incorrect, drain the system. Put the correct mixture of water, antifreeze and coolant conditioner in the cooling system.

3. Check for air in the cooling system. Air can enter the cooling system in different ways. The most common causes of air in the cooling system are not filling the cooling system correctly and combustion gas leakage into the cooling system. Combustion gas can get into the system through inside cracks, a damaged cylinder head, or a damaged cylinder head gasket. Air in the cooling system causes a reduction in coolant flow and bubbles in the coolant. Air bubbles keep coolant away from the engine parts, which prevents the transfer of heat to the coolant.

4. Check the fan clutch. A fan clutch that is not turning at the correct speed can cause improper air speed across the radiator core. The lack of proper air flow across the radiator core can cause the coolant not to cool to the proper temperature differential.

5. Check the water temperature gauge. A water temperature gauge which does not work correctly will not show the correct temperature. Refer to Testing and Adjusting, "Cooling System - Inspect".

6. Check the sending unit. In some conditions, the temperature sensor in the engine sends signals to a sending unit. The sending unit converts these signals to an electrical impulse which is used by a mounted gauge. If the sending unit malfunctions, the gauge can show an incorrect reading. Also if the electric wire breaks or if the electric wire shorts out, the gauge can show an incorrect reading.

7. Check the radiator.

   a. Check the radiator for a restriction to coolant flow. Check the radiator for debris, dirt, or deposits on the inside of the radiator core. Debris, dirt, or deposits will restrict the flow of coolant through the radiator.

   b. Check for debris or damage between the fins of the radiator core. Debris between the fins of the radiator core restricts air flow through the radiator core. Refer to Testing and Adjusting, "Cooling System - Inspect".

   c. Ensure that the radiator size is according to the specifications of the Original Equipment Manufacturer (OEM). An undersized radiator does not have enough area for the effective release of heat. This may cause the engine to run at a temperature that is higher than normal. The normal temperature is dependent on the ambient temperature.

8. Check the filler cap. A pressure drop in the radiator can cause the boiling point to be lower. This can cause the cooling system to boil. Refer to Testing and Adjusting, "Cooling System - Test".

9. Check the fan and/or the fan shroud.

   a. The fan must be large enough to send air through most of the area of the radiator core. Ensure that the size of the fan and the position of the fan are according to the OEM specifications.

   b. The fan shroud must be the proper size and the fan shroud must be positioned correctly. Ensure that the size of the fan shroud and the position of the fan shroud are according to the OEM specifications.

10. Check for loose drive belts.

a. A loose fan drive belt will cause a reduction in the air flow across the radiator. Check the fan drive belt for proper belt tension. Adjust the tension of the fan drive belt, if necessary. Refer to Operation and Maintenance Manual, “Belt - Inspect/Adjust/Replace”.

b. Worn gears within the water pump will cause a reduction in coolant flow through the radiator. Check the gears within the water pump for any worn edges.

11. Check the cooling system hoses and clamps. Damaged hoses with leaks can normally be seen. Hoses that have no visual leaks can soften during operation. The soft areas of the hose can become kinked or crushed during operation. These areas of the hose can cause a restriction in the coolant flow. Hoses become soft and/or get cracks after a period of time. The inside of a hose can deteriorate, and the loose particles of the hose can cause a restriction of the coolant flow. Refer to Operation and Maintenance Manual, “Hoses and Clamps - Inspect/Replace”.

12. Check for a restriction in the air inlet system. A restriction of the air that is coming into the engine can cause high cylinder temperatures. High cylinder temperatures require higher than normal temperatures in the cooling system. Refer to Testing and Adjusting, “Air Inlet and Exhaust System - Inspect”.

a. If the measured restriction is higher than the maximum permissible restriction, remove the foreign material from the engine air cleaner element or install a new engine air cleaner element. Refer to Operation and Maintenance Manual, “Engine Air Cleaner Element (Dual Element) - Clean/Replace”.

b. Check for a restriction in the air inlet system again.

c. If the measured restriction is still higher than the maximum permissible restriction, check the air inlet piping for a restriction.

13. Check for a restriction in the exhaust system. A restriction of the air that is coming out of the engine can cause high cylinder temperatures.

a. Make a visual inspection of the exhaust system. Check for damage to exhaust piping or for a damaged muffler. If no damage is found, check the exhaust system for a restriction. Refer to Testing and Adjusting, “Air Inlet and Exhaust System - Inspect”.

b. If the measured restriction is higher than the maximum permissible restriction, there is a restriction in the exhaust system. Repair the exhaust system, as required.

14. Check the water temperature regulator. A water temperature regulator that does not open, or a water temperature regulator that only opens part of the way can cause overheating. Refer to Testing and Adjusting, “Water Temperature Regulator - Test”.

15. Check the water pump. A water pump with a damaged impeller does not pump enough coolant for correct engine cooling. Remove the water pump and check for damage to the impeller. Refer to Testing and Adjusting, “Water Pump - Test”.

16. Check the air flow through the engine compartment. The air flow through the radiator comes out of the engine compartment. Ensure that the filters, air conditioner, and similar items are not installed in a way that prevents the free flow of air through the engine compartment.

17. Consider high outside temperatures. When outside temperatures are too high for the rating of the cooling system, there is not enough of a temperature difference between the outside air and coolant temperatures.

18. Consider high altitude operation. The cooling capacity of the cooling system goes down as the engine is operated at higher altitudes. A pressurized cooling system that is large enough to keep the coolant from boiling must be used.

19. The engine may be running in the lug condition. When the load that is applied to the engine is too large, the engine will run in the lug condition. When the engine is running in the lug condition, engine rpm does not increase with an increase of fuel. This lower engine rpm causes a reduction in air flow through the radiator. This lower engine rpm also causes a reduction in coolant flow through the system. This combination of less air and less coolant flow during high input of fuel will cause above normal heating.

i02228221

Cooling System - Inspect

SMCS Code: 1350-040

Cooling systems that are not regularly inspected are the cause for increased engine temperatures. Make a visual inspection of the cooling system before any tests are performed.

⚠ 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. Check the coolant level in the cooling system. Refer to Operation and Maintenance Manual, "Cooling System Coolant Level - Check".

2. Check the quality of the coolant. The coolant should have the following properties:

   - Color that is similar to new coolant
   - Odor that is similar to new coolant
   - Free from dirt and debris

   If the coolant does not have these properties, drain the system and flush the system. Refill the cooling system with the correct mixture of water, antifreeze, and coolant conditioner. Refer to Operation and Maintenance Manual, "Refill Capacities and Recommendations".

3. 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.

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

5. Inspect the filler cap, and check the surface that seals the filler cap. This surface must be clean.

i02779025

Cooling System - Test

SMCS Code: 1350-040; 1350-081

This engine has a pressure type cooling system. A pressure type cooling system has two advantages. The cooling system can be operated in a safe manner at a temperature higher than the normal boiling point (steam) of water.

This type of system prevents cavitation in the water pump. Cavitation is the forming of low pressure bubbles in liquids that are caused by mechanical forces. A pressure type cooling system helps to prevent pockets of air from forming.

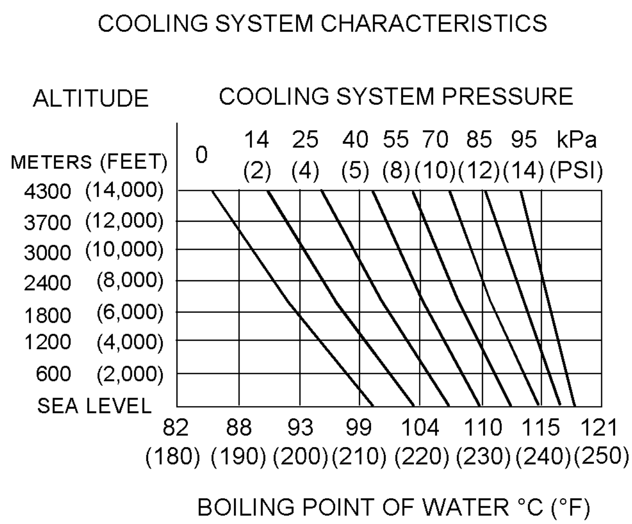


Illustration 37 g01106438

Effects of pressure on boiling point of a cooling system

Temperature and pressure work together. When a diagnosis is made of a cooling system problem, both temperature and pressure must be checked. Cooling system pressure will have an effect on the cooling system temperature. For an example, refer to Illustration 37. 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.

⚠ 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.

Cooling System Conditioner contains alkali. Avoid contact with skin and eyes.

The coolant 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.

Slowly 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 proper level in the sight glass.

Tools for Testing the Cooling System

Table 11

Tools Needed		
Part Number	Part Name	Quantity
4C-6500	Digital Thermometer	1
8T-2700	Blowby/Air Flow Indicator	1
9S-8140	Pressurizing Pump	1
9U-7400	Multitach Tool Group	1
245-5829	Coolant/Battery Tester Gp	1

⚠ 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.

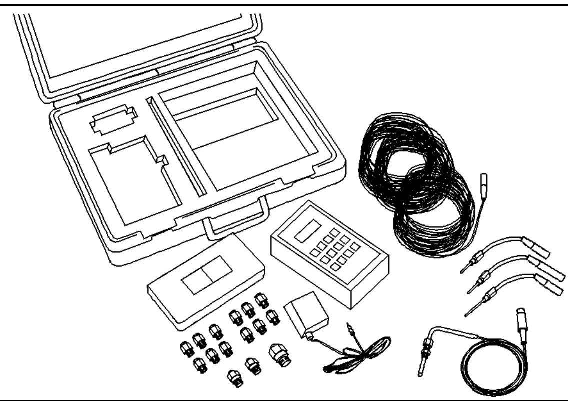


Illustration 38 g00876179

4C-6500 Digital Thermometer

The 4C-6500 Digital Thermometer is used for the diagnosis of overheating conditions and for the diagnosis of overcooling conditions. This group can be used to check temperatures in several different parts of the cooling system. Refer to the tool's Operating Manual for the testing procedures.

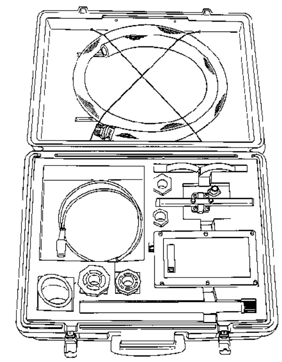


Illustration 39 g00286269

8T-2700 Blowby/Air Flow Indicator

The 8T-2700 Blowby/Air Flow Indicator is used to check the air flow through the radiator core. Refer to Special Instruction, SEHS8712, "Using the 8T-2700 Blowby/Air Flow Indicator" for the test procedure for checking the blowby of a cooling system's radiator.

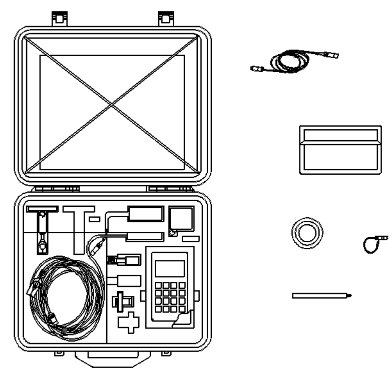


Illustration 40 g00286276

9U-7400 Multitach

The 9U-7400 Multitach Tool Group is used to check the fan speed for an engine. Refer to the tool's Operating Manual for the testing procedure.

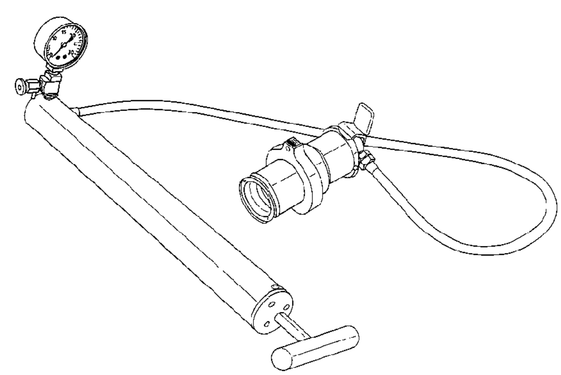


Illustration 41 g00286369

9S-8140 Pressurizing Pump

The 9S-8140 Pressurizing Pump is used to pressure test the radiator's filler cap. This pressurizing pump is also used to pressure test the cooling system for leaks.

Check the coolant frequently in cold weather for the proper glycol concentration. Use the 245-5829 Coolant/Battery Tester Gp in order to ensure adequate freeze protection. The tester can be used for antifreeze and coolants that contain ethylene or propylene glycol.

Test and Inspect the Filler Cap

Table 12

Tools Needed		
Part Number	Part Name	Quantity
9S-8140	Pressurizing Pump	1

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

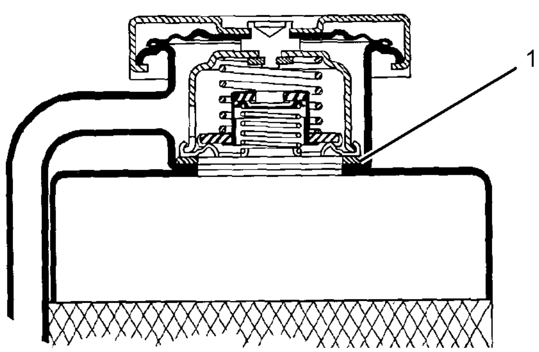


Illustration 42 g01096114

Cutaway view of a filler cap and radiator

(1) Sealing surface of both filler cap and 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.

Cooling System Conditioner contains alkali. Avoid contact with skin and eyes.

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.

   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.

2. Install the filler cap on the 9S-8140 Pressurizing Pump.

3. Look at the gauge for the exact pressure that opens the filler cap.

4. Compare the gauge reading with the opening pressure that is listed on the filler cap.

5. If the filler cap is damaged, replace the filler cap.

Test the Radiator and the Cooling System for Leaks

Table 13

Tools Needed		
Part Number	Part Name	Quantity
9S-8140	Pressurizing Pump	1

Use the following procedure in order to check 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.

Cooling System Conditioner contains alkali. Avoid contact with skin and eyes.

1. Ensure that the engine is cool. Loosen the filler cap slowly and allow pressure out of the cooling system. Then remove the filler cap from the radiator.

2. Ensure that the coolant level is above the top of the radiator core.

3. Install the 9S-8140 Pressurizing Pump onto the radiator.

4. Take the pressure reading on the gauge to 20 kPa (3 psi) more than the pressure on the filler cap.

5. Check the radiator for leakage on the outside.

6. Check all connection points for leakage, and check the hoses for leakage.

The following conditions exist if the cooling system does not have external leakage:

- You do not observe any outside leakage.

- The pressure reading on the cooling system remains steady after five minutes.

The following conditions exist if the cooling system has internal leakage:

- The pressure reading on the cooling system decreases in a five minute period.

- You do not observe any outside leakage.

Repair the cooling system, as required.

Test for the Water Temperature Gauge

Table 14

Tools Needed		
Part Number	Part Name	Quantity
4C-6500	Digital Thermometer	1

Note: Caterpillar Electronic Technician (ET) can also be used in order to display the engine's coolant temperature.

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.

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.

Check the accuracy of the water temperature indicator or water temperature sensor if you find either of the following conditions:

- The engine runs at a temperature that is too hot, but a normal temperature is indicated. A loss of coolant is found.

- The engine runs at a normal temperature, but a hot temperature is indicated. No loss of coolant is found.

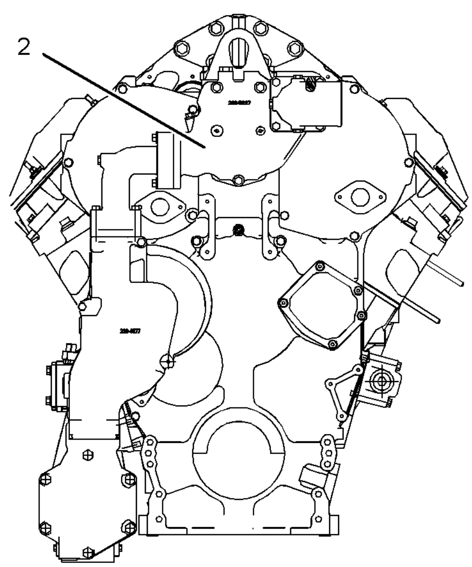


Illustration 43 g01388322

Remove a plug from water manifold assembly (2). Install the thermometer into the open port:

- The 4C-6500 Digital Thermometer

Any temperature indicator of known accuracy can also be used to make this check.

Start the engine. Run the engine until the temperature reaches the desired range according to the test thermometer. If necessary, place a cover over part of the radiator in order to cause a restriction of the air flow. The reading on the temperature indicator should agree with the test thermometer within the tolerance range of the water temperature indicator.

i01666401

Water Temperature Regulator - Test

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

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.

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.

i02228472

Water Pump - Test

SMCS Code: 1361-081

Table 15

Tools Needed		
Part Number	Part Name	Quantity
6V-7775	Air Pressure Gauge	1

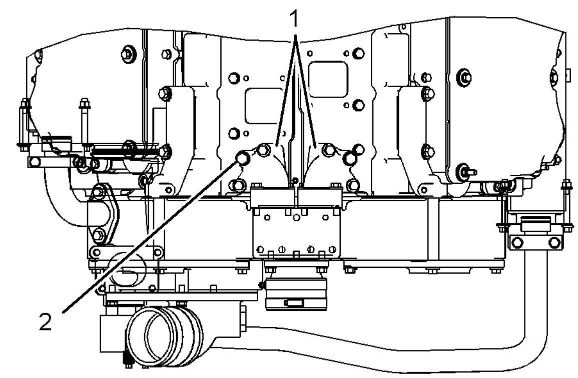


Illustration 44 g01124406

(1) Water manifold
(2) Plug

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.

Perform the following procedure in order to determine if the water pump is operating correctly:

1. Remove plug (2) from water manifold (1).

2. Install the 6V-7775 Air Pressure Gauge in the port.

3. Start the engine. Run the engine until the coolant is at operating temperature.

4. Note the water pump pressure. The water pump pressure should be at least 100 kPa (15 psi) at rated speed.

Basic Engine

i02287898

Piston Ring Groove - Inspect

SMCS Code: 1214-040

The piston rings may have a Keystone design, which is tapered or the piston rings may have a square cut design. The 1U-6431 Piston Ring Groove Gauge Gp is used for checking pistons with the Keystone design. A 5P-3519 Piston Ring Groove Gauge Gp is available for checking ring grooves with straight sides. For instructions on the use of the gauge, refer to Guideline For Reusable Parts and Salvage Operations, SEBF8049, "Piston Visual Inspection".

i01406562

Connecting Rod - Inspect

SMCS Code: 1218-040

The bores in the connecting rod must be within specifications or the bearings will not fit properly. If the bores in the connecting rod have worn too much, the bearings will fit loosely. This will cause further wear and damage to the connecting rod, the bearing for the piston pin, the bearing for the crankshaft, the piston pin, and the crankshaft.

Measure the bores in the connecting rod and ensure that the bores meet the diameters according to the engine's specifications. When you install the connecting rod, follow the instructions of the engine's specifications for tightening the bolts. Refer to Specifications, "Connecting Rod".

i02142592

Main Bearings - Inspect

SMCS Code: 1203-040

Main bearings are available with smaller inside diameters than the original size bearings. These bearings are for crankshafts that have been ground.

Main bearings are available with larger outside diameters than the original size bearings. These bearings are used for the cylinder blocks with the main bearing bore that is made larger than the bore's original size.

Refer to the Guideline For Reusable Parts, SEBF8009, "Main and Connecting Rod Bearings" for reuse information.

Refer to Special Instruction, SMHS7606, "Use of 1P-4000 Line Boring Tool Group" for the instructions that are needed to use the tool group. This tool is used in order to check the alignment of the main bearing bores. The 1P-3537 Dial Bore Gauge Group can be used to check the size of the bore.

i02487145

Cylinder Block - Inspect

SMCS Code: 1201-040

Table 16

Required Tools		
Part Number	Part Name	Quantity
1P-3537	Dial Bore Gauge Group	1

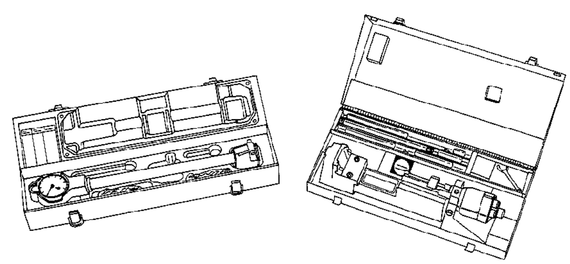


Illustration 45 g00285686

1P-3537 Dial Bore Gauge Group

If the main bearing caps are installed without bearings, the bore in the block for the main bearings can be checked. Tighten the nuts on the bearing caps to the torque that is given in Specifications, "Cylinder Block". Alignment error in the bores must not be more than 0.08 mm (0.003 inch).

The 1P-3537 Dial Bore Gauge Group can be used to check the size of the bore.

i02779075

Cylinder Liner Projection - Inspect

SMCS Code: 1216-040

Note: The following procedure does not require the use of an "H" bar to hold the liners while the liner projection measurements are taken.

The 8T-0455 Liner Projection Tool Group can be used to check the liner projection. Refer to Special Instruction, "Use of the 8T-0455 Liner Projection Tool Group" for more information on the use of the tool.

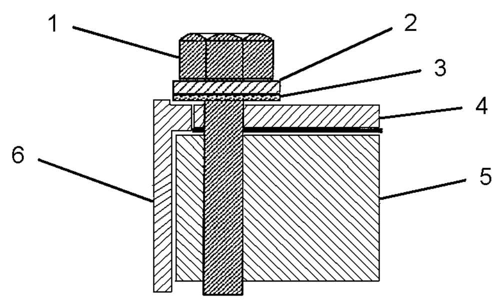


Illustration 46 g01388332

Liner Projection Components

(1) Bolt
(2) Washer
(3) Washer
(4) Spacer plate
(5) Block
(6) Cylinder liner

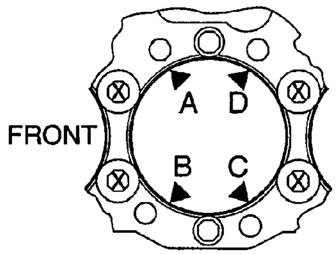
Table 17

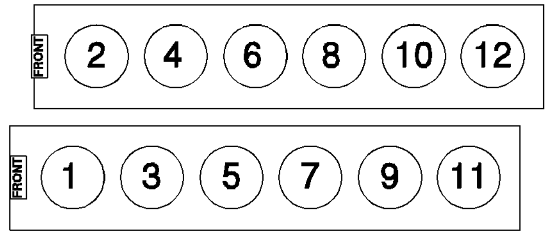
Needed Components			
Item	**Part Number**	**Description**	**Quantity For One Cylinder**
1	7H-3598	Track Bolt	6
2	8F-1484 or 7X-0564	Washer or Hard Washer	6
3	7K-1977 or 126-1454	Washer or Liner Projection Washer	6

Note: The 7K-1977 Washer and the 126-1454 Liner Projection Washer are fabric washers. These washers are a disposable item. You may wish to order more washers than the amount that is indicated.

Liner Projection Measurements

Date ______________ Miles, Km Hours ______________ Engine Serial Number ______________ Vehicle Serial Number ______________





Liner Projection
Max 0.15 mm (.006 in)
Min 0.03 mm (.001 in)

1A		2A	
1B		2B	
1C		2C	
1D		2D	
SUM 1		SUM 2	
AVG 1		AVG 2	
3A		4A	
3B		4B	
3C		4C	
3D		4D	
SUM 3		SUM 4	
AVG 3		AVG 4	
5A		6A	
5B		6B	
5C		6C	
5D		6D	
SUM 5		SUM 6	
AVG 5		AVG 6	
7A		8A	
7B		8B	
7C		8C	
7D		8D	
SUM 7		SUM 8	
AVG 7		AVG 8	
9A		10A	
9B		10B	
9C		10C	
9D		10D	
SUM 9		SUM 10	
AVG 9		AVG 10	
11A		12A	
11B		12B	
11C		12C	
11D		12D	
SUM 11		SUM 12	
AVG 11		AVG 12	

Max Variation Each Cylinder Max 0.051 mm (.002 in)

Max 1A-1D		Max 2A-2D	
Min 1A-1D		Min 2A-2D	
Variation		Variation	
Max 3A-3D		Max 4A-4D	
Min 3A-3D		Min 4A-4D	
Variation		Variation	
Max 5A-5D		Max 6A-6D	
Min 5A-5D		Min 6A-6D	
Variation		Variation	
Max 7A-7D		Max 8A-8D	
Min 7A-7D		Min 8A-8D	
Variation		Variation	
Max 9A-9D		Max 10A-10D	
Min 9A-9D		Min 10A-10D	
Variation		Variation	
Max 11A-11D		Max 12A-12D	
Min 11A-11D		Min 12A-12D	
Variation		Variation	

Max Variation of AVG Under One Cylinder Head Max 0.051 mm (.002 in)

AVG 1		AVG 2	
AVG 3		AVG 4	
Variation		Variation	
AVG 3		AVG 4	
AVG 5		AVG 6	
Variation		Variation	
AVG 5		AVG 6	
AVG 7		AVG 8	
Variation		Variation	
AVG 7		AVG 8	
AVG 9		AVG 10	
Variation		Variation	
AVG 9		AVG 10	
AVG 11		AVG 12	
Variation		Variation	

Max Variation of AVG Under One Cylinder Head Max 0.102 mm (.004 in)

Max AVG 1-11		Max AVG 2-12	
Min AVG 1-11		Min AVG 2-12	
Variation		Variation	

Illustration 47 g01086418

1. Install a new spacer plate gasket and a clean spacer plate.

2. Install the cylinder liners in the cylinder block without seals or bands.

3. Install the washers.

4. Install all bolts or the six bolts around the liner.

   Torque for bolts .... 95 N·m (70 lb ft)

5. Use the 8T-0455 Liner Projection Tool Group to measure the liner projection at “A”, “B”, “C” and “D”.

6. Record measurements for each cylinder.

7. Add the four readings for each cylinder. Divide the sum by four in order to find the average.

Table 18

Specifications	
Liner Projection	0.025 to 0.152 mm (0.0010 to 0.0060 inch)
Maximum Variation In Each Liner	0.051 mm (0.0020 inch)
Maximum Average Variation Between Adjacent Liners	0.051 mm (0.0020 inch)
Maximum Variation Between All Liners	0.102 mm (0.0040 inch)

Note: If the liner projection changes around the liner, turn the liner to a new position within the bore. If the liner projection is not within specifications, move the liner to a different bore. Inspect the top face of the cylinder block.

A thinner spacer plate should be installed if the liner projection measurements are below the specifications. The spacer plate should also be installed if the liner projection measurements are low within a range. These plates are 0.076 mm (0.0030 inch) thinner than the regular plate. The plates will increase the liner projection. This will increase the crush of the fire ring. Use these spacer plates to compensate for low liner projections that are less than the 0.076 mm (0.0030 inch). Use these spacer plates if the inspection of the top deck reveals no measurable damage directly under the liner flanges but the average liner projection is less than 0.076 mm (0.0030 inch).

Do not exceed the maximum liner projection of 0.152 mm (0.0060 inch). The excessive liner projection will contribute to cracking of the liner flange.

When the liner projection is correct, put a temporary mark on the liner and the spacer plate. Set the liners aside.

Note: Refer to Disassembly and Assembly, “Cylinder Liner - Install” for the correct final installation procedure for the cylinder liners.

When the engine is ready for final assembly, the following items must be lubricated before installation.

- O-ring seals
- Cylinder block
- Upper filler band

Note: Apply liquid soap and/or clean engine oil immediately before assembly. Avoid applying the liquid soap and/or clean engine oil to the seals too early. The seals may swell. This will cause the seals to be pinched underneath the liners during the liner installation.

i02630856

Flywheel - Inspect

SMCS Code: 1156-040

Face Runout (Axial Eccentricity) of the Flywheel

Table 19

Tools Needed		Quantity
8T-5096	Dial Indicator Gp	1

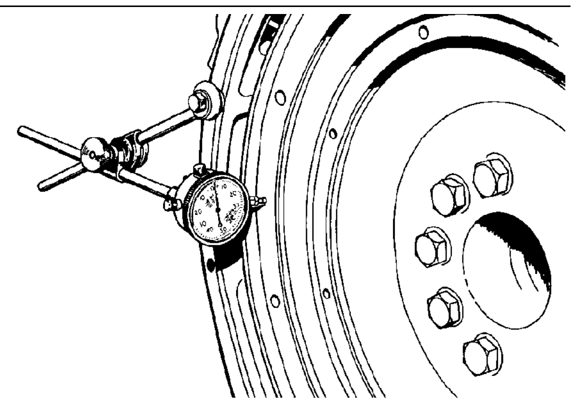


Illustration 48 g00812156

Checking face runout of the flywheel

1. Refer to Illustration 48 and install the dial indicator. Always put a force on the crankshaft in the same direction before the dial indicator is read. This will remove any crankshaft end clearance.

2. Set the dial indicator to read 0.0 mm (0.00 inch).

3. Turn the flywheel at intervals of 90 degrees and read the dial indicator.

4. Take the measurements at all four points. The difference between the lower measurements and the higher measurements that are performed at all four points must not be more than 0.15 mm (0.006 inch), which is the maximum permissible face runout (axial eccentricity) of the flywheel.

Bore Runout (Radial Eccentricity) of the Flywheel

Table 20

Tools Needed		Quantity
8T-5096	Dial Indicator Gp	1

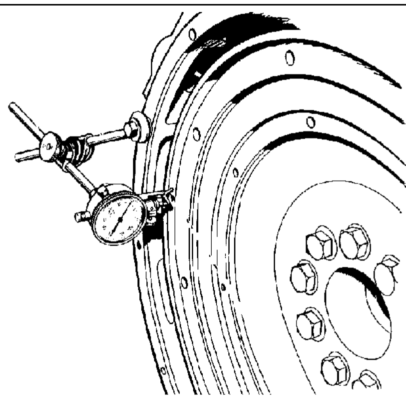


Illustration 49 g00812155

Checking bore runout of the flywheel

1. Install 7H-1942 Dial Indicator. Make an adjustment of 7H-1940 Universal Attachment so the dial indicator makes contact on the flywheel.

2. Set the dial indicator to read 0.0 mm (0.00 inch).

3. Turn the flywheel at intervals of 90 degrees and read the dial indicator.

4. Take the measurements at all four points. The difference between the lower measurements and the higher measurements that are performed at all four points must not be more than the following values for the maximum permissible bore runout (radial eccentricity) of the flywheel.

   Maximum flywheel bore runout .... 0.15 mm (0.006 inch)

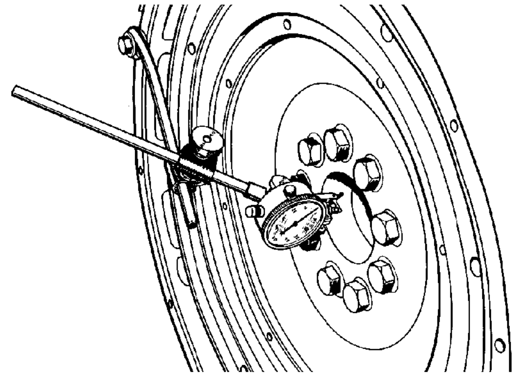


Illustration 50 g00286058

Checking the flywheel clutch pilot bearing bore

5. To find the runout (eccentricity) of the pilot bearing bore, use the preceding procedure.

6. The runout (eccentricity) of the bore for the pilot bearing in the flywheel must not exceed the following value:

   Maximum runout of the bore for the pilot bearing in the flywheel .... 0.13 mm (0.005 inch)

i02487225

Flywheel Housing - Inspect

SMCS Code: 1157-040

Table 21

Tools Needed		
Part Number	Part Name	Quantity
8T-5096	Dial Indicator Gp	1

Face Runout (Axial Eccentricity) of the Flywheel Housing

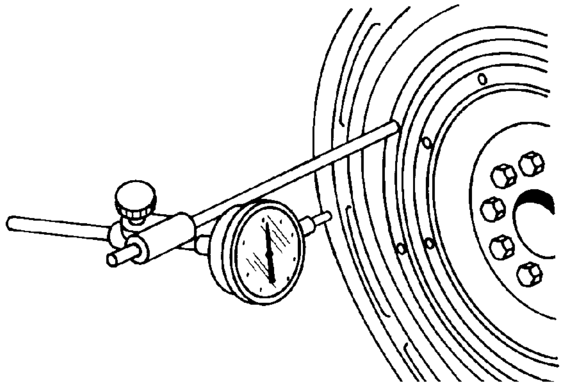


Illustration 51 g00285931

8T-5096 Dial Indicator Gp

If you use any other method except the method that is given here, always remember that the bearing clearance must be removed in order to receive the correct measurements.

1. Fasten a dial indicator to the flywheel so the anvil of the dial indicator will contact the face of the flywheel housing.

2. Use a rubber mallet and tap the crankshaft toward the rear before the dial indicator is read at each point.

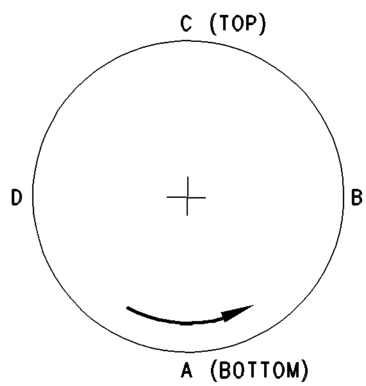


Illustration 52 g00285932

Checking face runout of the flywheel housing

3. Turn the flywheel while the dial indicator is set at 0.0 mm (0.00 inch) at location (A). Read the dial indicator at locations (B), (C) and (D).

4. The difference between the lower measurements and the higher measurements that are performed at all four points must not be more than 0.38 mm (0.015 inch), which is the maximum permissible face runout (axial eccentricity) of the flywheel housing.

Bore Runout (Radial Eccentricity) of the Flywheel Housing

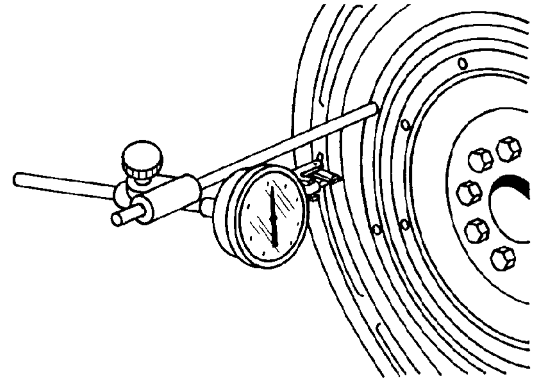


Illustration 53 g00285934

8T-5096 Dial Indicator Gp

1. Fasten a dial indicator to the flywheel so the anvil of the dial indicator will contact the bore of the flywheel housing.

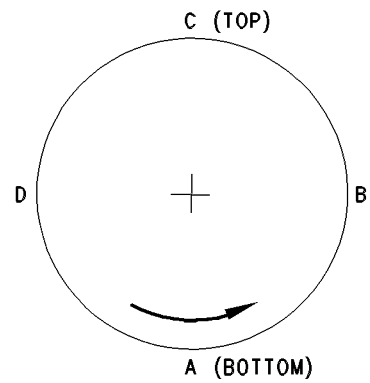


Illustration 54 g00285932

Checking bore runout of the flywheel housing

CHART FOR DIAL INDICATOR MEASUREMENTS					
	Position of dial indicator				
	Line No.	A	B	C	D
Correction for bearing clearance	1	0			
Dial Indicator Reading	2	0			
Total of Line 1 & 2	3	0			
the total horizontal eccentricity.					

Illustration 55 g00763974

2. While the dial indicator is in the position at location (C) adjust the dial indicator to 0.0 mm (0.00 inch). Push the crankshaft upward against the top of the bearing. Refer to Illustration 55. Write the measurement for bearing clearance on line 1 in column (C).

Note: Write the measurements for the dial indicator with the correct notations. This notation is necessary for making the calculations in the chart correctly.

3. Divide the measurement from Step 2 by two. Write this number on line 1 in columns (B) and (D).

4. Turn the flywheel in order to put the dial indicator at position (A). Adjust the dial indicator to 0.0 mm (0.00 inch).

5. Turn the flywheel counterclockwise in order to put the dial indicator at position (B). Write the measurements in the chart.

6. Turn the flywheel counterclockwise in order to put the dial indicator at position (C). Write the measurement in the chart.

7. Turn the flywheel counterclockwise in order to put the dial indicator at position (D). Write the measurement in the chart.

8. Add the lines together in each column.

9. Subtract the smaller number from the larger number in column B and column D. Place this number on line III. The result is the horizontal eccentricity (out of round). Line III in column C is the vertical eccentricity.

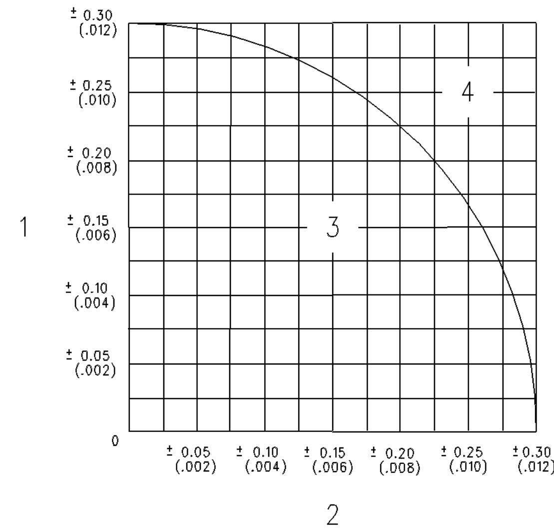


Illustration 56 g00286046

Graph for total eccentricity

(1) Total vertical eccentricity
(2) Total horizontal eccentricity
(3) Acceptable value
(4) Unacceptable value

10. Find the intersection of the eccentricity lines (vertical and horizontal) in Illustration 56.

11. If the point of the intersection is in the “Acceptable” range, the bore is in alignment. If the point of intersection is in the “Not acceptable” range, the flywheel housing must be changed.

i02031090

Vibration Damper - Check

SMCS Code: 1205-535

Viscous Vibration Damper

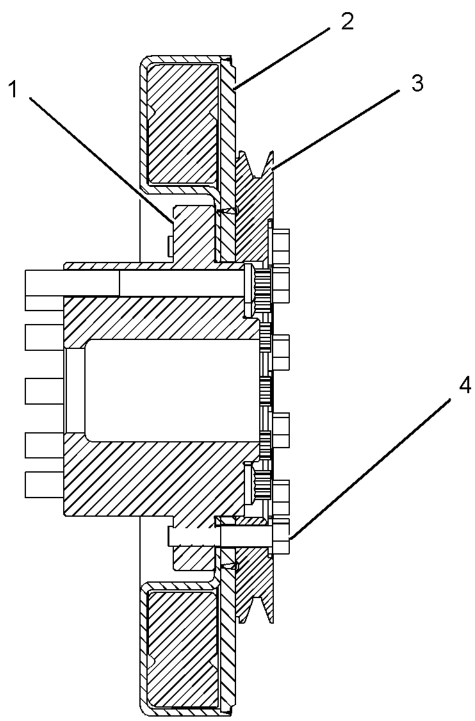


Illustration 57 g01034223

Typical example

(1) Adapter
(2) Damper assembly
(3) Pulley
(4) Bolts

The vibration damper is installed on the front of crankshaft. Damage to the vibration damper or failure of the vibration damper will increase vibrations. This will result in damage to the crankshaft.

Replace the damper if any of the following conditions exist:

- The damper is dented, cracked, or fluid is leaking from the damper.
- The paint on the damper is discolored from excessive heat.
- The damper is bent.
- The bolt holes are worn or there is a loose fit for the bolts.
- The engine has had a crankshaft failure due to torsional forces.

NOTICE

Inspect the viscous vibration damper for signs of leaking and for signs of damage to the case. Either of these conditions can cause the weight to contact the case. This contact can affect damper operation.

Electrical System

i02482495

Battery - Test

SMCS Code: 1401-081

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

WARNING

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

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

NOTICE

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

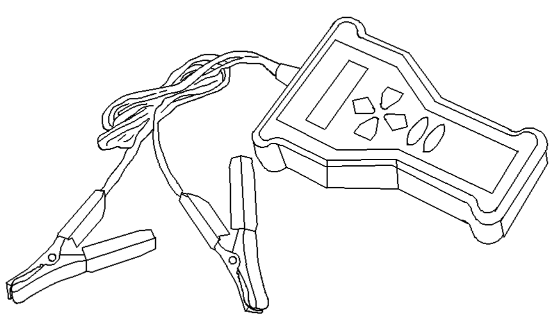


Illustration 58 g00859857

177-2330 Battery Analyzer

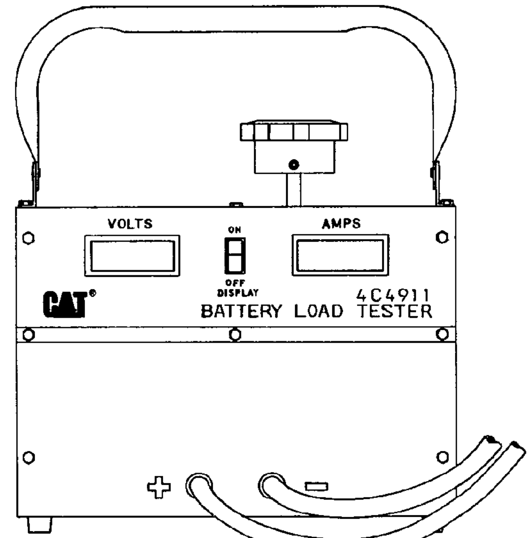


Illustration 59 g00283565

4C-4911 Battery Load Tester

Use the 4C-4911 Battery Load Tester or the 177-2330 Battery Analyzer in order to test a battery that does not maintain a charge when the battery is active. The 4C-4911 Battery Load Tester and the 177-2330 Battery Analyzer are portable units. The 4C-4911 Battery Load Tester or the 177-2330 Battery Analyzer can be used under field conditions and under high temperatures. The tester can be used to load test all 6, 8, and 12 Volt batteries. This tester has two heavy-duty load cables that can easily be fastened to the battery terminals. A load adjustment knob is located on the top of the tester. The load adjustment knob permits the current that is being drawn from the battery to be adjusted to a maximum of 1000 amperes. The tester is cooled by an internal fan that is automatically activated when a load is applied.

The tester has a built-in LCD. The LCD is a digital voltmeter. The LCD is a digital meter that will also display the amperage. The digital voltmeter accurately measures the battery voltage at the battery through wires for tracing. These wires are buried inside the load cables. The digital meter, that displays the amperage, accurately displays the current that is being drawn from the battery which is being tested.

Note: Refer to Operating Manual, SEHS9249, “Use of 4C-4911 Battery Load Tester for 6, 8, and 12 Volt Lead Acid Batteries” for detailed instruction on the use of the 4C-4911 Battery Load Tester. Refer to Operating Manual, NEHS0764, “Using the 177-2330 Battery Analyzer” for detailed instruction on the use of the 177-2330 Battery Analyzer. See Special Instruction, SEHS7633, “Battery Test Procedure” for the correct procedures to use when you test the battery. This publication also contains the specifications to use when you test the battery.

i02482986

Charging System - Test

SMCS Code: 1406-081

The condition of charge in the battery at each regular inspection will show if the charging system is operating correctly. An adjustment is necessary when the battery is constantly in a low condition of charge or a large amount of water is needed. A large amount of water would be more than one ounce of water per a cell per a week or per every 100 service hours.

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

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

Test Tools For The Charging System

Table 22

Tools Needed		
Part Number	Part Name	Quantity
225-8266	Ammeter Tool Gp	1
237-5130 or 146-4080	Digital Multimeter Gp or Digital Multimeter Gp	1

225-8266 Ammeter Tool Gp

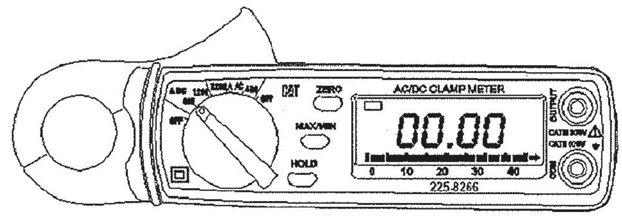


Illustration 60 g01012117

225-8266 Ammeter Tool Gp

The 225-8266 Ammeter Tool Gp is completely portable. This ammeter is a self-contained instrument that measures electrical currents without breaking the circuit and without disturbing the conductor’s insulation.

The ammeter contains a digital display that is used to monitor current directly within a range between 1 ampere and 1200 amperes. If an optional 6V-6014 Cable is connected between this ammeter and a digital multimeter, current readings can be viewed directly from the display of the multimeter. The multimeter should be used under only one condition:

- the readings are less than 1 ampere.

A lever opens the ammeter’s jaws over a conductor. The conductor’s diameter can not be larger than 19 mm (0.75 inch).

The spring loaded jaws close around the conductor for measuring the current. A trigger switch controls the ammeter. The trigger switch can be locked into the ON position or into the OFF position.

After the trigger has been working and the trigger is turned to the OFF position, the reading appears in the digital display for five seconds. This accurately measures currents in areas with a limited access. For example, these areas include areas that are beyond the operator’s sight. For DC operation, an ammeter contains a zero control, and batteries inside the handle supply the power.

237-5130 Digital Multimeter Gp or 146-4080 Digital Multimeter Gp

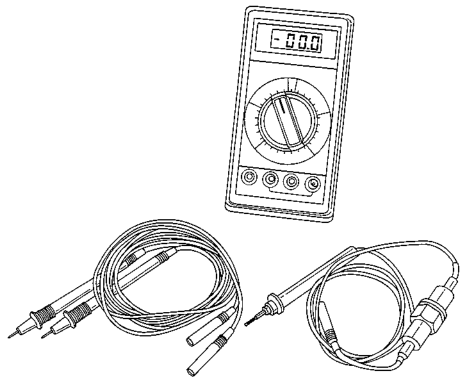


Illustration 61 g00283566

237-5130 Digital Multimeter Gp or 146-4080 Digital Multimeter Gp

The 237-5130 Digital Multimeter Gp and the 146-4080 Digital Multimeter Gp are portable hand-held service tools with a digital display. These multimeters are built with extra protection against damage in field applications. Both multimeters are equipped with 7 functions and 29 ranges. The 237-5130 Digital Multimeter Gp and the 146-4080 Digital Multimeter Gp have an instant ohms indicator. This indicator permits checking continuity for a fast inspection of the circuits. These multimeters can also be used for troubleshooting capacitors that have small values.

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