CATERPILLAR®

RENR5078-05
November 2006

Systems Operation Testing and Adjusting

3500B and 3500C Marine Engines

S2A1-Up (Engine)
S2B1-Up (Engine)
S2D1-Up (Engine)
S2E1-Up (Engine)
S2F1-Up (Engine)
B5G1-Up (Engine)
MRG1-Up (Engine)
PAG1-Up (Engine)
S2G1-Up (Engine)
MKH1-Up (Engine)
S2H1-Up (Engine)
S2J1-Up (Engine)
S2K1-Up (Engine)
S2L1-Up (Engine)
S2M1-Up (Engine)
S2N1-Up (Engine)
S2P1-Up (Engine)
S2R1-Up (Engine)
S2S1-Up (Engine)
S2T1-Up (Engine)
S2W1-Up (Engine)
S2X1-Up (Engine)
S2Y1-Up (Engine)
S2Z1-Up (Engine)

Important Safety Information

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

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

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

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

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

⚠ WARNING

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

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

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

Engine Operation

i02217884

Cold Cylinder Cutout

SMCS Code: 1901

The engine uses a strategy for the cold cylinder cutout to reduce white exhaust smoke after start-up and during extended idling in cold weather.

During a cold start and/or extended periods at low idle, the engine's Electronic Control Module (ECM) turns off one unit injector at a time in order to determine if each cylinder is firing by monitoring the change in the fuel rack. If a cylinder is firing, the ECM turns on the injector. If a cylinder is not firing, the injector is turned off. This cold cylinder cutout provides the following benefits: reduction of white smoke, improved engine starting, reduction in the use of ether injection, and reduction of warm-up time.

Note: During operation of the cold cylinder cutout, the engine may seem to misfire. This is normal. No corrective measures are necessary.

The cold cylinder cutout is activated after all of the following conditions are met:

- The cold cylinder cutout is programmed to ENABLE.
- The engine speed is equal to high idle or below high idle.
- The fuel rack is less than 13 mm (0.50 inch).
- The jacket water coolant temperature is below 63 °C (145 °F).

The cold cylinder cutout strategy is activated ten seconds after the engine starts and the engine reaches idle speed or three seconds after ether injection is completed.

The cold cylinder cutout is deactivated if any of the following conditions are met:

- The cold cylinder cutout is disabled with the Caterpillar Electronic Technician (Cat ET).
- The jacket water coolant temperature rises above 70 °C (158 °F).
- The cylinder cutout test is activated.
- The ether injection is used.
- The coolant temperature sensor has failed.

If the fuel rack is greater than 13 mm (0.50 inch), the cold cylinder cutout deactivates for three seconds.

The cold cylinder cutout will deactivate for three seconds when the engine speed varies by more than ± 50 rpm as the cold cylinder cutout begins. A new engine speed is established when the cold cylinder cutout reactivates.

The cold cylinder cutout deactivates for 30 seconds when the engine speed is at low idle for ten seconds and the engine speed falls by more than 50 rpm below low idle.

Electronic Control System

i02388972

Electronic Control System Operation

SMCS Code: 1901

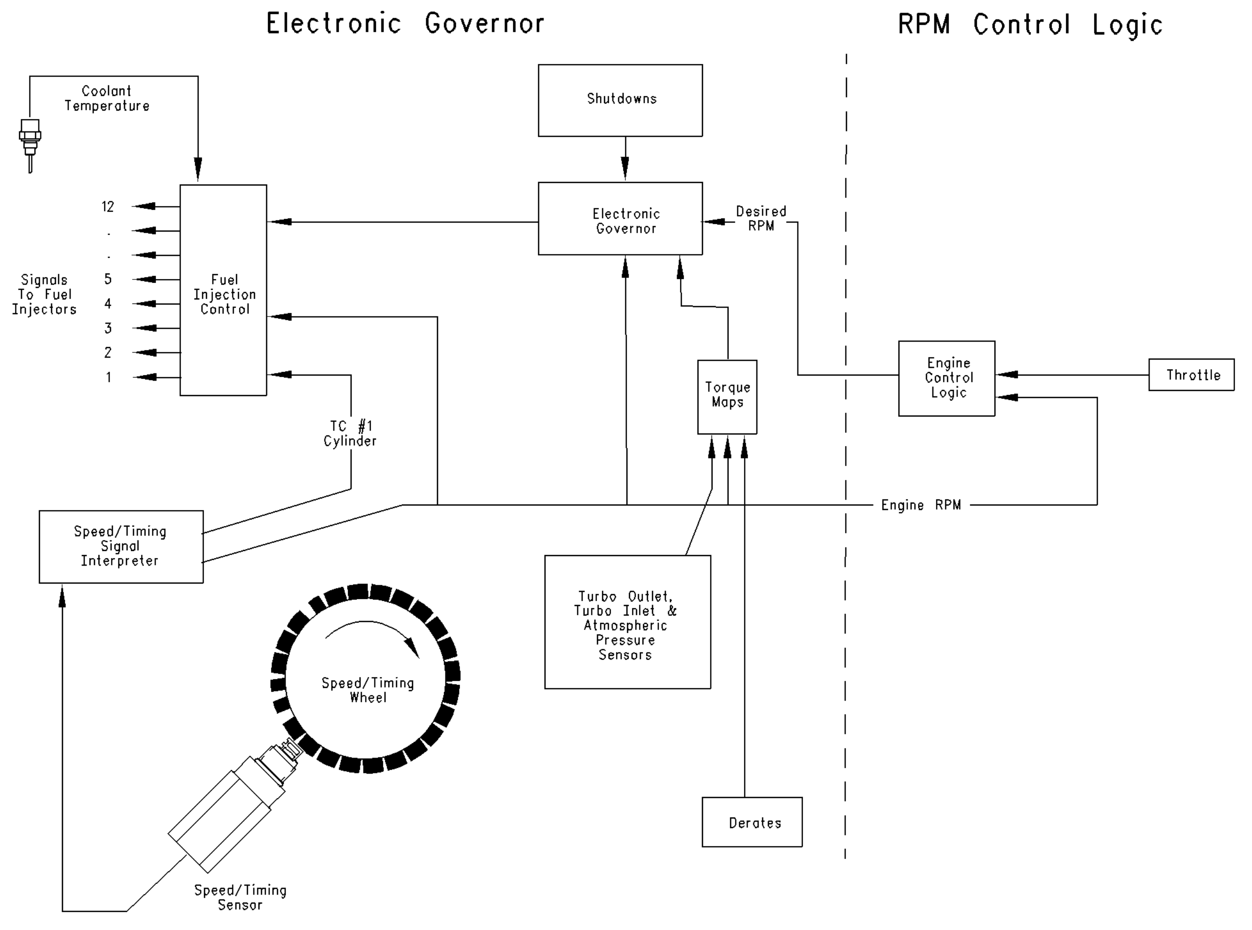


Illustration 1 g00669770

This engine was designed for electronic control. Each cylinder has an electronic unit injector. A solenoid on each injector controls the amount of fuel that is delivered by the injector. The Electronic Control Module (ECM) sends a signal to each injector solenoid in order to provide complete control over the operation of the fuel injection system.

Electronic Controls

The electronic system consists of the following components: the ECM, the mechanically actuated electronically controlled unit injectors (MEUI), the wiring harness, the switches, and the sensors. The ECM is the computer. The flash file is the software for the computer. The flash file contains the operating maps. The operating maps define the following characteristics of the engine:

- Horsepower
- Torque curves

The ECM determines the timing and the amount of fuel that is delivered to the cylinders. These decisions are based on the actual conditions and/or the desired conditions at any given time.

The ECM compares the desired engine speed to the actual engine speed. The actual engine speed is determined through a signal from the engine speed/timing sensor. The desired engine speed is determined through the following items:

- Throttle position sensor
- Other input signals from sensors
- Certain diagnostic codes

If the desired engine speed is greater than the actual engine speed, the ECM injects more fuel in order to increase the actual engine speed.

Fuel Injection

The ECM controls the amount of fuel that is injected by varying the signals to the injectors. The injectors will pump fuel only if the injector solenoid is energized. The ECM sends a high voltage signal to the solenoid. This high voltage signal energizes the solenoid. By controlling the timing and the duration of the high voltage signal, the ECM can control injection timing and the ECM can control the amount of fuel that is injected.

Once the ECM determines the amount of fuel that is required, the ECM must determine the timing of the fuel injection. The ECM determines the top center position of each cylinder from the engine speed/timing sensor's signal. The ECM determines when fuel injection should occur relative to the top center position and the ECM provides the signal to the injector at the desired time. The ECM adjusts timing for optimum engine performance, for optimum fuel economy, and for optimum control of white smoke.

Programmable Parameters

Certain parameters that affect the engine operation may be changed with the Caterpillar Electronic Technician (ET). The parameters are stored in the ECM, and some parameters are protected from unauthorized changes by passwords.

Passwords

Several system configuration parameters and most logged events are protected by factory passwords. Factory passwords are available only to Caterpillar dealers. Refer to Troubleshooting, "Factory Passwords" for additional information.

i02302331

Cat Data Link

SMCS Code: 1901

The engine incorporates a Cat Data Link. The data link is used to communicate with other devices that are based on a microprocessor.

The data link can reduce the duplication of sensors within the system by allowing controls to share information. The data link is used to communicate information about the engine to other electronic control systems. The data link is also used to interface with the electronic service tool.

The information about the engine that is monitored and available on the data link includes the following items (typical example):

- Air filter restriction
- Atmospheric pressure
- Boost pressure
- Cold mode status
- Coolant temperature
- Crankcase pressure
- Diagnostic messages
- Supply voltage for the Electronic Control Module (ECM)
- Engine identification
- Engine speed (actual rpm)
- Engine speed (desired rpm)
- Engine systems status
- Engine warning system
- Exhaust temperature
- Filtered oil pressure
- Fuel pressure
- Maximum air filter restriction
- Oil pressure
- Percent throttle position
- Rated fuel limit
- Timing cal enable/status

- Total fuel consumption
- Turbocharger inlet pressure
- Turbocharger outlet pressure

The electronic service tool plugs into the connector for the data link in order to communicate with the ECM. The communication adapter is installed in series between the electronic service tool and the data link connector. The communication adapter converts data that is in the language from the data link. This language is converted to a language that is used by the electronic service tool. The data link connector is located on the engine harness. The electronic service tool can also be used to display the values of all the information for monitoring of engine operation in real time.

i01941448

CAN Data Link

SMCS Code: 1901

The CAN data link is used to communicate engine information and diagnostic information from the Electronic Control Module (ECM). The CAN data link is used for communication between the following modules: engine's ECM, customer devices, and various display modules.

i02388134

Electronic Control Module (ECM)

SMCS Code: 1901

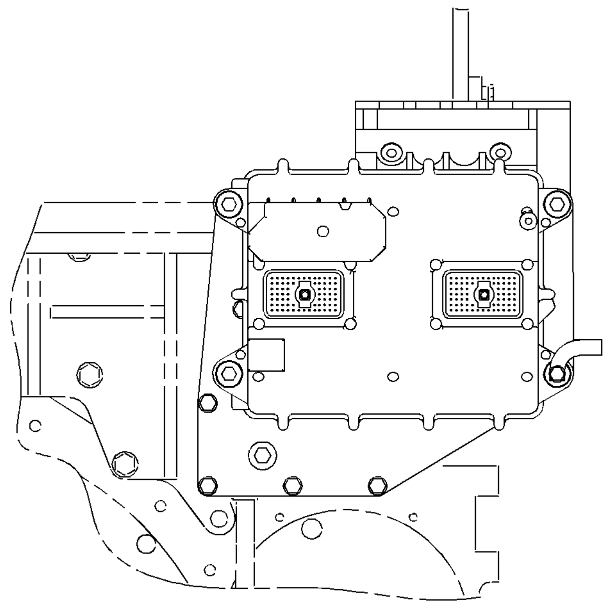


Illustration 2 g01054803

ECM

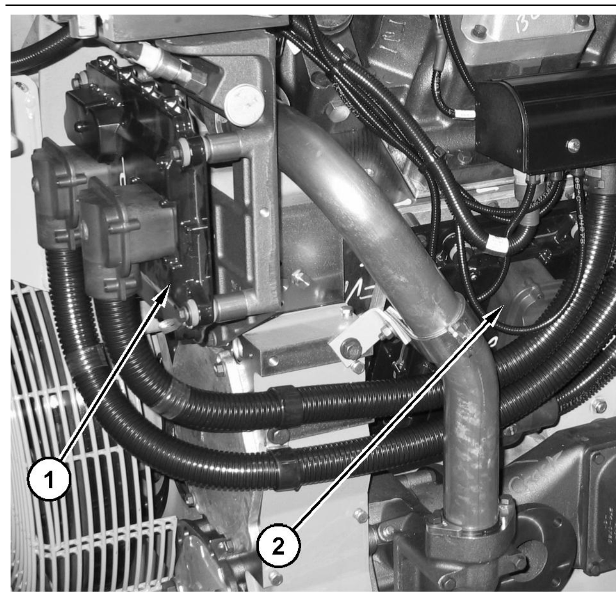


Illustration 3 g01054837

(1) Primary ECM
(2) Secondary ECM

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 and the injection timing. The electronic control system provides increased timing control and fuel air ratio control in comparison to conventional mechanical engines. Injection timing is achieved by precisely controlling the injector firing time. Engine rpm 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.

The ECM has two 70 pin connectors.

The flash file is used by the ECM to store all the rated information for a particular application. The flash file cannot be replaced physically. The flash file must be flash programmed with a PC.

The engine uses the following three types of electronic components:

- Input
- Control
- Output

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

- Voltage
- Frequency
- Pulse width

The variation of the signal is in response to a change in some specific part of the system. A specific example of an input component is the engine speed-timing sensor. The ECM interprets the signal from the input component as information about the condition, environment, or operation of the engine.

A control component 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 operated by a control module. The output component receives electrical energy from the control group. The output component uses that electrical energy in one of two ways. The output component can use that electrical energy in order to perform work. The output component can use that electrical energy in order to provide information.

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, 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

i02296424

Load Feedback Capability (Marine Propulsion Only)

SMCS Code: 1901

S/N: S2D1-Up

S/N: S2E1-Up

S/N: S2F1-Up

S/N: B5G1-Up

S/N: MRG1-Up

S/N: PAG1-Up

S/N: MKH1-Up

S/N: S2J1-Up

S/N: S2K1-Up

S/N: S2L1-Up

S/N: S2M1-Up

S/N: S2N1-Up

S/N: S2S1-Up

S/N: S2T1-Up

S/N: S2W1-Up

S/N: S2X1-Up

S/N: S2Y1-Up

This capability provides a method of outputting the instantaneous percent of load relative to the rack limit at any given engine speed. This information is available on the Cat Data Link. This information allows the user to provide the load feedback to a system controller. A typical application would be in the controllable pitch propeller control systems.

The load feedback function provides an indication of the amount of useful rack or power that is available at any given operating condition. The load feedback is 100 percent when the actual fuel position equals the fuel limit. Zero percent occurs at no load and at low idle.

4 to 20 mA Output

The 4 to 20 mA output provides a method of indicating the load feedback to the user. This output allows the user to provide the load feedback to a system controller. A typical application would be in the controllable pitch propeller control systems in the marine applications.

i01944995

System Configuration Parameters

SMCS Code: 1901

System configuration parameters are parameters that affect the power rating of the engine or various engine features. System configuration parameters are programmed at the factory. The system configuration parameters are not usually changed during the life of the engine.

Refer to Troubleshooting for detailed programming instructions.

i01938729

100 Hour Free Configuration on Engine Start-up

SMCS Code: 1901

The 100 hour free configuration on engine start-up will provide the ability to easily change any configuration or any monitoring system parameter via the Caterpillar Electronic Technician (ET) without a password. This feature is active for the first 100 hours of engine operation.

The 100 hour free configuration on engine start-up provides the ability to easily tailor the programmable set points to the requirements of the installation. The exceptions include the fuel limit, the personality module mismatch, the Electronic Control Module (ECM) hour adjustment, and the total fuel consumption number.

Engine Monitoring System

i02388135

Engine Monitoring System

SMCS Code: 1900; 1901

ECM

A comprehensive, programmable engine monitoring system is provided. The Electronic Control Module (ECM) can monitor parameters. The ECM can initiate an action if a specific operating parameter extends beyond the acceptable range. There are three possible actions by the ECM which are available: “WARNING”, “DERATE”, and “SHUTDOWN”. However, not all of the actions are available for certain parameters.

The Caterpillar Electronic Technician (ET) can be used in order to select the desired action by the ECM. Cat ET can be used to program the level for monitoring and the delay times for each action.

Refer to Troubleshooting for detailed programming instructions.

Engine Instrument Panel

The engine instrument panel is usually mounted on the engine. The engine instrument panel may be mounted up to 15 m (49 ft) away from the engine. The engine instrument panel includes the following controls:

- Emergency stop push button
- Engine Control Switch (ECS)
- Local speed control (if equipped)
- Alarm horn
- ECM ready lamp
- ECM active lamp
- Emergency stop indicator
- Engine overspeed indicator
- Pyrometer (if equipped)
- Marine Power Display (MPD)

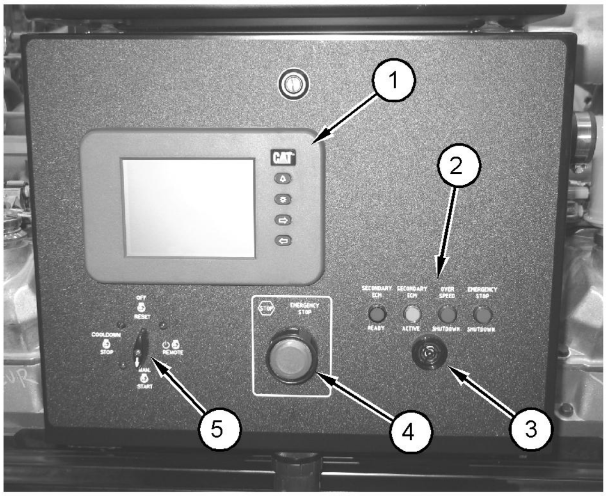


Illustration 4 g01054916

Engine instrument panel (typical example)

(1) Marine Power Display
(2) Indicators
(3) Alarm horn
(4) Emergency stop push button
(5) Engine control switch

The following control panel switches are located inside the engine instrument panel:

- Crank override switch
- Prelube override switch
- Protection override switch
- Torque limit switch
- Throttle control switch
- Low idle switch

The crank override switch allows the operator to crank the engine with the engine starters. This overrides any other control or any engine protection system.

The prelube override switch allows the operator to override the prelube pump sequence at the beginning of the crank cycle during engine start-up.

The protection override switch provides an input for the user in order to override the engine protection devices.

The torque limit switch enables the torque limiting feature.

The throttle control switch allows engine speed to be controlled from a potentiometer on the panel, if equipped.

The low idle switch provides the ability to control engine rpm. When the switch is enabled, the engine will operate at the low idle rpm that is programmed.

Refer to Illustrations 5and 6.

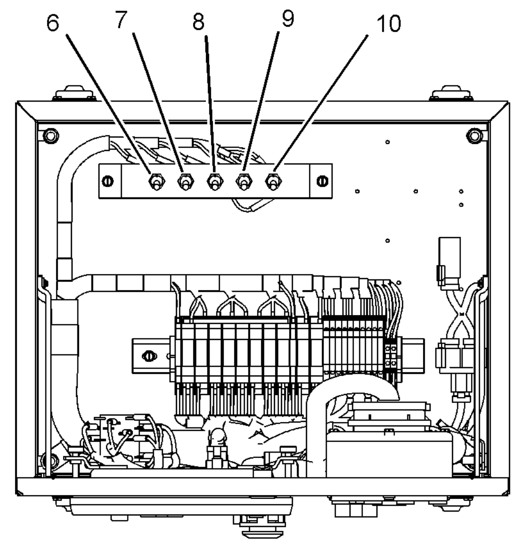


Illustration 5 g01055283

Marine propulsion

(6) Crank override switch
(7) Prelube override switch
(8) Protection override switch
(9) Torque limit switch
(10) Local throttle switch

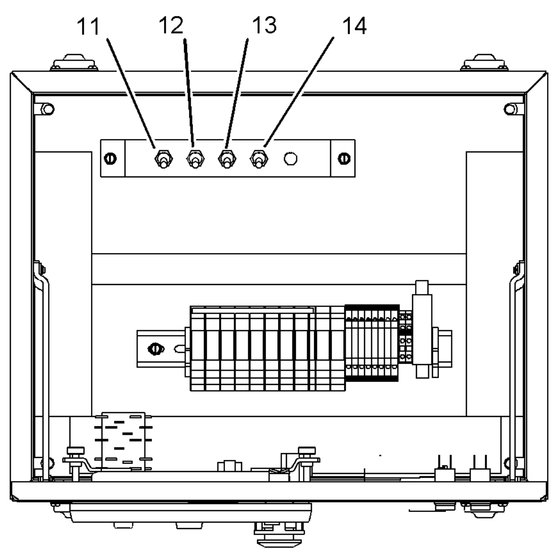


Illustration 6 g01055248

Marine auxiliary

(11) Crank override switch
(12) Prelube override switch
(13) Protection override switch
(14) Low idle switch

i02060752

Protection Override Switch

SMCS Code: 1901

The protection override switch is used in circumstances when it is absolutely necessary to continue to operate the engine. The switch can be used in order to prevent an engine shutdown during critical maneuvers. The protection override switch is a two-position ON/OFF switch. The switch is located inside the engine instrument panel.

If an engine is operating and an alarm occurs, the operator may move the switch from the normal to the override position. In the override position, the engine will not shut off, regardless of alarms. If an engine has shut off because of an event code, the engine may be started again by moving the switch to the override position. However, the engine protection devices will be defeated.

i02388136

Output for the General System Alarm

SMCS Code: 1901

This output provides an indication of a problem with the engine operation via a relay. The relay provides a common ground, a normally open contact, and a normally closed contact. The operation simulates the horn on the electronic monitoring system.

The general alarm relay is contained within the power distribution panel. The general alarm relay will actuate on the presence of active events or active diagnostics.

i02388138

Histogramming

SMCS Code: 1901

Histogram data can be displayed via the Caterpillar Electronic Technician (ET) in order to show the trends of performance for the engine. This is used to improve the overall performance of the engine.

Historical performance data is stored in a format that can be used to construct histograms via the Cat ET. Data is available for speed, load, and exhaust temperature.

i01970428

Fuel Rate Scaling (Fuel Correction Factor)

SMCS Code: 1901

When the engine is shipped from the factory, an estimate of the engine’s fuel consumption is programmed into the Electronic Control Module (ECM). The fuel consumption estimate is based upon the engine’s performance specifications. The actual fuel consumption can be determined with a precision fuel flow meter. Customers are likely to find a slight difference between the programmed fuel consumption and the actual fuel consumption. The customer can use the Caterpillar Electronic Technician (ET) to program the ECM for the actual fuel consumption. No password is required in order to change this configuration parameter.

In order to program the ECM for the actual fuel consumption, change the Fuel Correction Factor (FCF) that is already programmed into the ECM. The FCF can be programmed in increments of 0.5 percent between ± 25 percent.

i02217900

ECM Total Fuel Consumption Adjustment

SMCS Code: 1901

The feature provides a method of adjusting the total fuel consumption by incrementing the total fuel consumption number that is recorded in the Electronic Control Module (ECM). The adjustment is made with the Caterpillar Electronic Technician (ET).

The adjustment for the total fuel consumption will allow a new replacement ECM to be programmed in order to display the correct total fuel consumption number for that particular engine. The adjustment only allows incremental changes to be made. The change requires a factory password.

i01972221

ECM Hour Increment Adjustment

SMCS Code: 1901

The adjustment for the hour increment provides a method of adjusting the hour meter of the Electronic Control Module (ECM). The adjustment is made with the Caterpillar Electronic Technician (ET). The tool increments the number of hours that are recorded in the ECM.

The adjustment for the hour increment will allow a new replacement ECM to be programmed in order to display the correct number of operating hours for that particular engine. The adjustment only allows incremental changes. A password is required in order to make the change.

Fuel System

i02388139

Fuel System Operation

SMCS Code: 1250

General Information

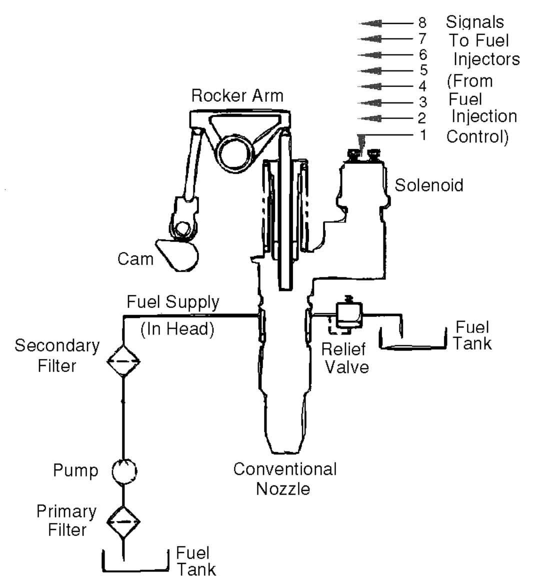


Illustration 7 g01055227

Fuel system schematic (typical example)

The fuel supply circuit is a conventional design for engines that use fuel injectors. The fuel supply circuit uses a fuel transfer pump to deliver fuel from the fuel tank to the electronic fuel injectors. The transfer pump is a fixed displacement gear pump.

The fuel flows through a fuel filter before entering the fuel supply manifold. A fuel priming pump is located on the fuel filter base in order to fill the system. The system must be primed after the filter changes. The system must be primed after draining the fuel supply and the return manifolds, when the fuel injectors are replaced.

The fuel flows continuously from the fuel supply manifold through the fuel injectors. The fuel flows when either the supply or the fill port in the injector is not closed by the injector body assembly plunger. The fuel that is not injected into the cylinder is returned to the tank through the fuel return manifold.

A pressure regulating valve is at the end of the fuel return manifold. The pressure regulating valve controls the entire fuel system pressure. This provides proper filling of the fuel injectors.

The electronically controlled mechanically actuated fuel injector system provides total electronic control of injection timing. The injection timing is varied in order to optimize the engine's performance.

The timing ring is part of the rear gear group. The engine speed/timing sensor monitors the timing ring for detection of crankshaft position and for engine speed. Other information and this data allows the ECM to correctly send a signal to the injector solenoids. The fuel injector's solenoid is energized in order to begin fuel injection. The fuel injector's solenoid is de-energized in order to end fuel injection. Refer to Systems Operation, "Fuel Injector".

Secondary Fuel Filter

Different types of fuel filters are available for the engines.

Element Filter

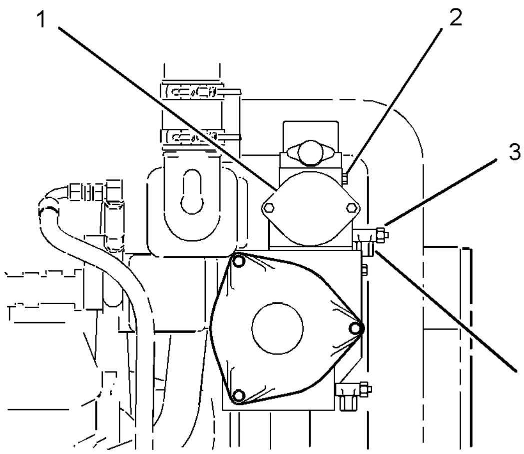


Illustration 8 g01055505

(1) Cover
(2) Plug
(3) Drain valve
(4) Drain

Spin-on Type Filter

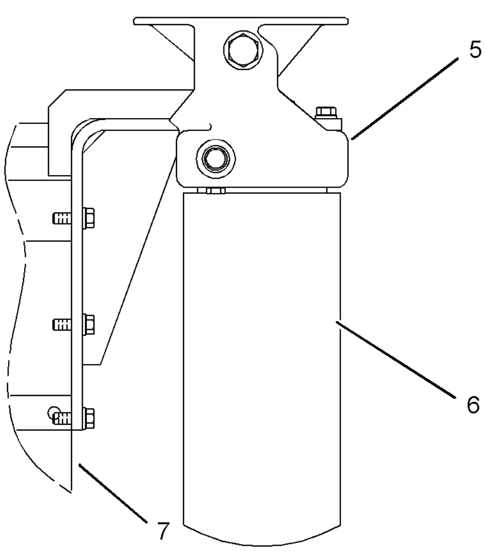


Illustration 9 g01055498

(5) Fuel filter base
(6) Spin-on type filter
(7) Front housing

Duplex Fuel Filter

The duplex fuel filter system enables you to change the filter elements while the engine is running.

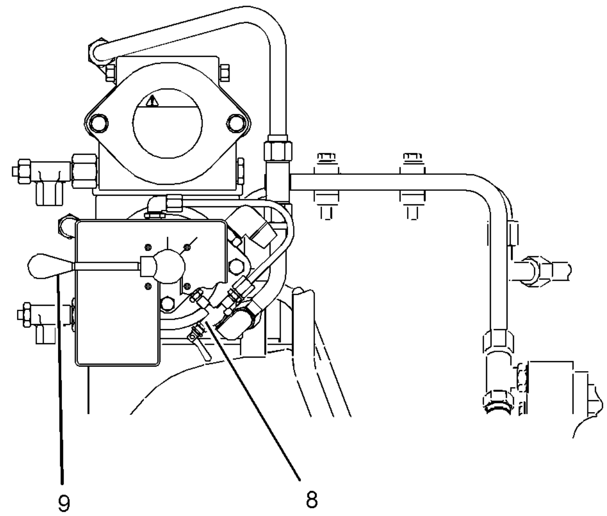


Illustration 10 g01055507

(8) Fill valve
(9) Control valve handle

i02388144

Fuel Injector Mechanism

SMCS Code: 1102; 1290

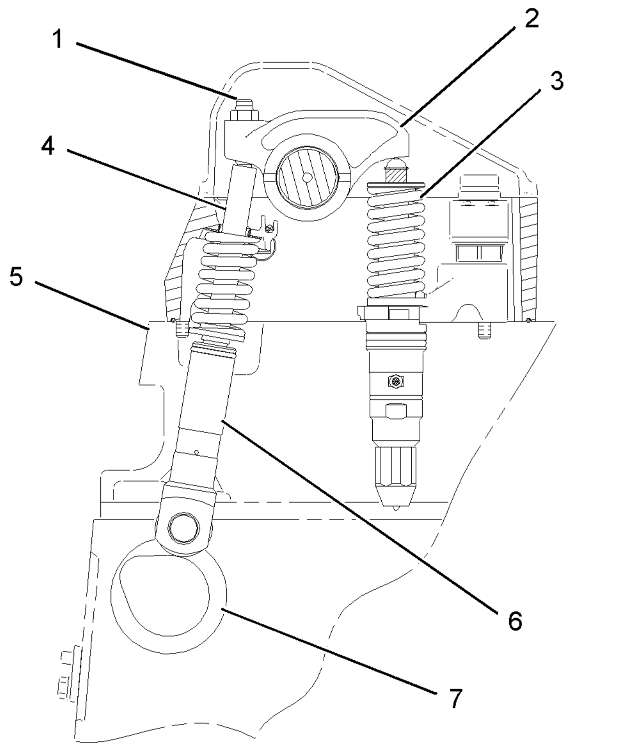


Illustration 11 g01192221

Fuel injector

(1) Adjustment screw
(2) Rocker arm assembly
(3) Spring
(4) Pushrod
(5) Cylinder head
(6) Lifter
(7) Camshaft

Force is transmitted from the lobe for the fuel injector on camshaft (7). The force is sent through lifter (6) and to pushrod (4). From pushrod (4), force is transmitted through rocker assembly (2) and to the top of the fuel injector pump. Adjustment screw (1) allows setting of the injector lash. Refer to Testing and Adjusting, "Fuel Injector Adjustment" for the proper setting.

i02383581

Fuel Injector

SMCS Code: 1290

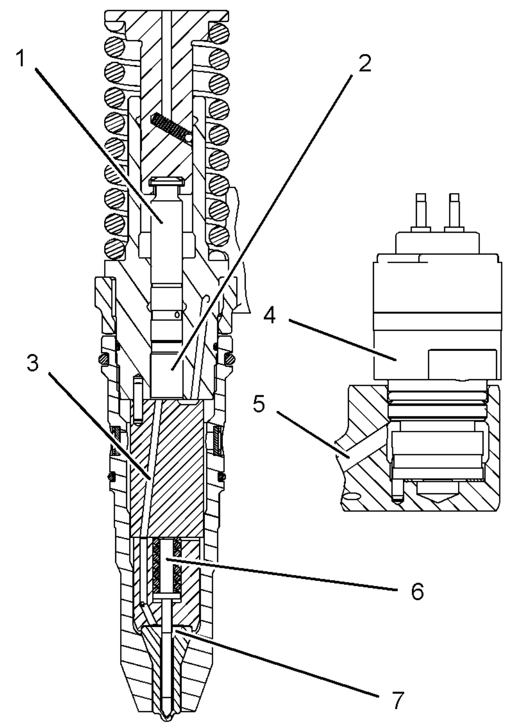


Illustration 12 g01009248

Fuel injector

(1) Plunger
(2) Pumping chamber
(3) High pressure fuel passage
(4) Cartridge valve
(5) Low pressure fuel passage
(6) Needle valve
(7) Valve chamber

When the stroke of plunger (1) is at the top, fuel flows through the low pressure fuel passages in the body. The fuel then flows to the center passage in the plunger and into pumping chamber (2) below the plunger. When the stroke of the plunger is at the bottom, fuel flows through high pressure fuel passages (3). The fuel flows through open cartridge valve (4) and into low pressure fuel passages (5). When the cartridge valve is closed or energized, the fuel flow through the cartridge valve is blocked. This blockage causes a buildup in fuel pressure and injection to begin. Injection continues until the cartridge valve is de-energized or open. Fuel is allowed to flow through the cartridge valve. This causes the drop in pressure and the stopping of the injection. The plunger continues to force fuel through the open cartridge valve until the stroke of the plunger reaches the bottom. The fuel injector spring returns the plunger to the starting position and the cycle repeats.

The start of fuel injection is determined when the cartridge valve is opened or closed by the Electronic Control Module (ECM) via the injector solenoid. The quantity of fuel that is injected is determined when the cartridge valve is opened or closed.

During the fuel injection stroke, the fuel passes from the pumping chamber into the fuel injector nozzle. The nozzle has a needle valve (6) that is spring loaded. Fuel flows through the fuel passage around the needle valve to valve chamber (7). In the valve chamber, the fuel pressure lifts the needle valve away from the seat. The fuel can now flow through the orifices in the tip into the combustion chamber.

The bottom of the fuel injector protrudes for a short distance below the cylinder head into the combustion chamber. The fuel injector tip has several small orifices that are equally spaced around the outside diameter. These orifices spray fuel into the combustion chamber.

Air Inlet and Exhaust System

i02388162

Air Inlet and Exhaust System Operation

SMCS Code: 1050

The components of the air inlet and exhaust system control the quality and the amount of air that is available for combustion. There are separate turbochargers and exhaust manifolds on each side of the engine. A common aftercooler is located between the cylinder heads in the center of the engine. The inlet manifold is a series of elbows that connect the aftercooler chamber to the inlet ports (passages) of the cylinder heads. There is one camshaft in each side of the block. The two camshafts control the movement of the valve system components.

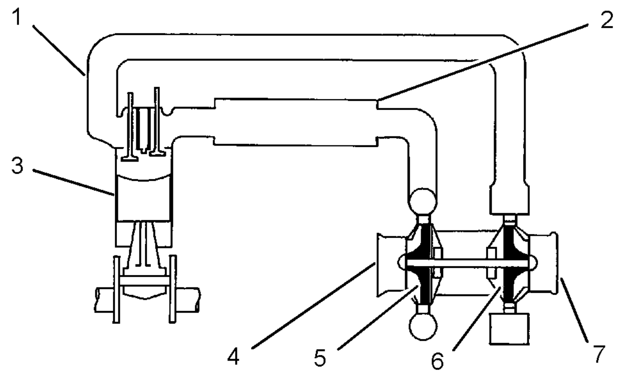


Illustration 13 g01188937

Air Inlet And Exhaust System

(1) Exhaust manifold
(2) Aftercooler
(3) Engine cylinder
(4) Air inlet
(5) Turbocharger compressor wheel
(6) Turbocharger turbine wheel
(7) Exhaust outlet

Clean inlet air from the air cleaners is pulled through air inlet (4) into the turbocharger compressor by compressor wheel (5). The rotation of the compressor wheel compress the air. The rotation of the turbocharger compressor wheel then forces the air through a tube to aftercooler (2). The aftercooler lowers the temperature of the compressed air before the air enters the inlet chamber in each cylinder head. Air flow from the inlet chamber into the cylinder heads is controlled by the inlet valves.

There are two inlet valves and two exhaust valves for each cylinder. Refer to Systems Operation, "Valve Mechanism". The inlet valves open when the piston moves down on the inlet stroke. The cooled, compressed air is pulled into the cylinder from the inlet chamber.

The inlet valves close and the piston starts to move up on the compression stroke. When the piston is near the top of the compression stroke, fuel is injected into the cylinder. The fuel mixes with the air and combustion starts. The force of the combustion pushes the piston downward on the power stroke. When the piston moves upward again, the piston is on the exhaust stroke. The exhaust valves open and the exhaust gases are pushed through the exhaust port into exhaust manifold (1). After the piston makes the exhaust stroke, the exhaust valves close and the cycle starts again.

Exhaust gases from exhaust manifold (1) go into the turbine side of the turbocharger. The exhaust gases cause turbine wheel (6) to turn. The turbine wheel is connected to the shaft that drives the turbocharger compressor wheel (5). The exhaust gases exit through exhaust outlet (7).

i01938828

Aftercooler

SMCS Code: 1063

The aftercooler is located at the center of the vee. The aftercooler has a core assembly that is charged by the coolant. Coolant from the water pump flows through a pipe into the aftercooler. Coolant then flows through the core assembly. Coolant flows back out the aftercooler through a different pipe.

Inlet air from the compressor side of the turbochargers flows into the aftercooler through pipes. The air then passes through the fins of the core assembly which lowers the temperature. The cooler air flows out of the bottom of the aftercooler and into the air chamber. The air flows through the elbows to the inlet ports in the cylinder heads.

i02390307

Valve Mechanism

SMCS Code: 1102

Type 1

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

The crankshaft gear drives the camshaft gears through idlers. Both camshafts must be timed to the crankshaft in order to get the correct relation between the piston and the valve movement.

The camshafts have three lobes for each cylinder. Two lobes operate the valves and one operates the fuel injector.

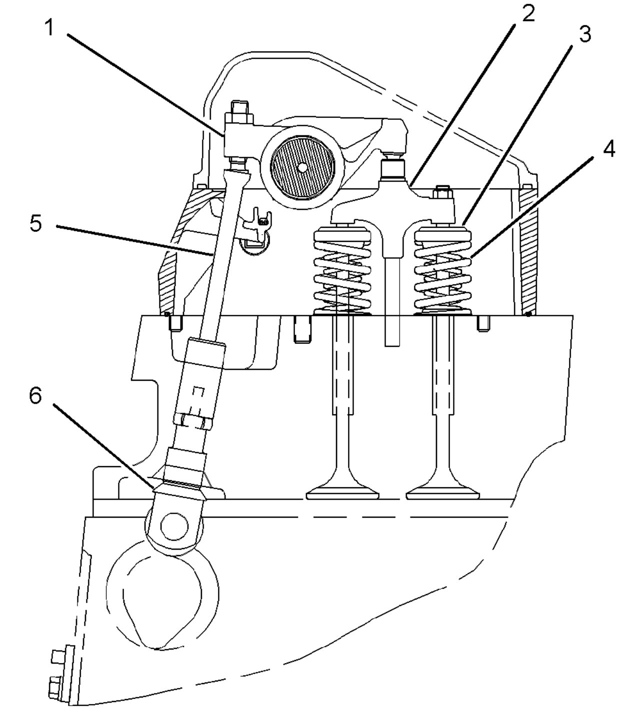


Illustration 14 g01193826

Valve system components

(1) Rocker arm
(2) Bridge
(3) Rotocoil
(4) Valve spring
(5) Pushrod
(6) Lifter

As each camshaft turns, the lobes on the camshaft cause lifters (6) to move up and down. This movement causes pushrods (5) to move rocker arms (1). The movement of the rocker arms cause bridges (2) to move downward on the dowels in the cylinder head. The bridges open two valves simultaneously. The valves can be either inlet valves or exhaust valves. There are two inlet valves and two exhaust valves for each cylinder.

Valve springs (4) cause the valves to close when the lifters move downward.

Rotocoils (3) cause the valves to turn while the engine is running. The rotation of the valves keeps the carbon deposits on the valves to a minimum which gives the valves a longer service life.

Type 2

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

The crankshaft gear drives the camshaft gears through idlers. Both camshafts must be timed to the crankshaft in order to get the correct relation between the piston and the valve movement.

The camshafts have three lobes for each cylinder. Two lobes operate the valves and one operates the fuel injector.

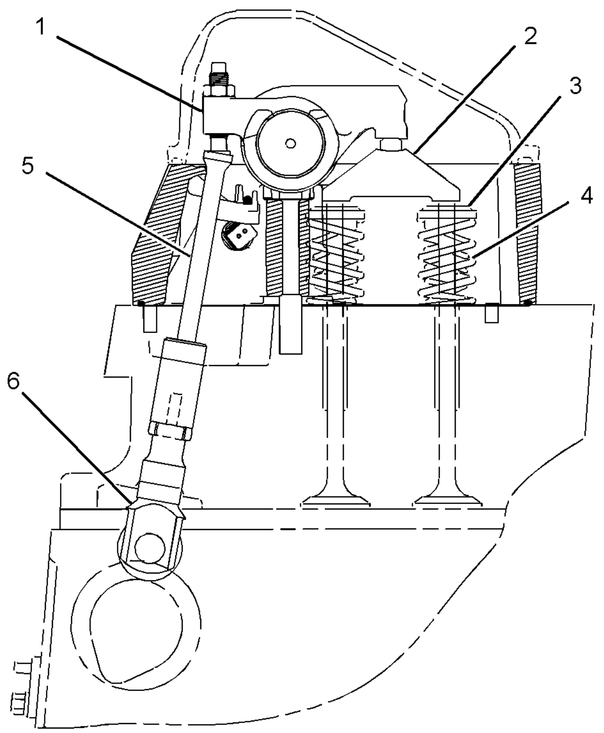


Illustration 15 g01042301

Valve system components

(1) Rocker arm
(2) Bridge
(3) Rotocoil
(4) Valve spring
(5) Pushrod
(6) Lifter

As each camshaft turns, the lobes on the camshaft cause lifters (6) to move up and down. This movement causes pushrods (5) to move rocker arms (1). The movement of the rocker arms cause bridges (2) to move downward. The bridges open two valves simultaneously. The valves can be either inlet valves or exhaust valves. There are two inlet valves and two exhaust valves for each cylinder.

Valve springs (4) cause the valves to close when the lifters move downward.

Rotocoils (3) cause the valves to turn while the engine is running. The rotation of the valves keeps the carbon deposits on the valves to a minimum which gives the valves a longer service life.

i02388169

Turbocharger

SMCS Code: 1052

Rear Mounted

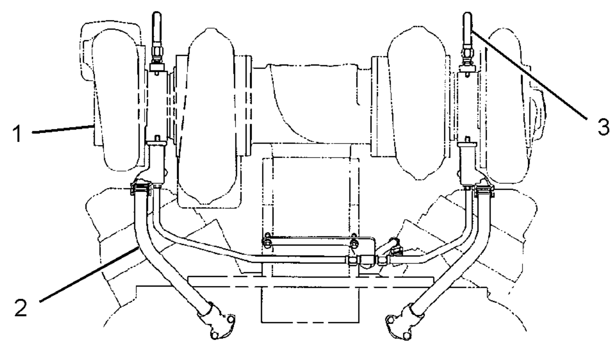


Illustration 16 g01192255

Turbocharger (typical example)

(1) Turbocharger
(2) Oil drain line
(3) Oil supply line

Two turbochargers (1) are used on the rear of the engine. The turbine side of each turbocharger is connected to the turbocharger’s respective exhaust manifold. The compressor side of each turbocharger is connected by pipes to the aftercooler housing.

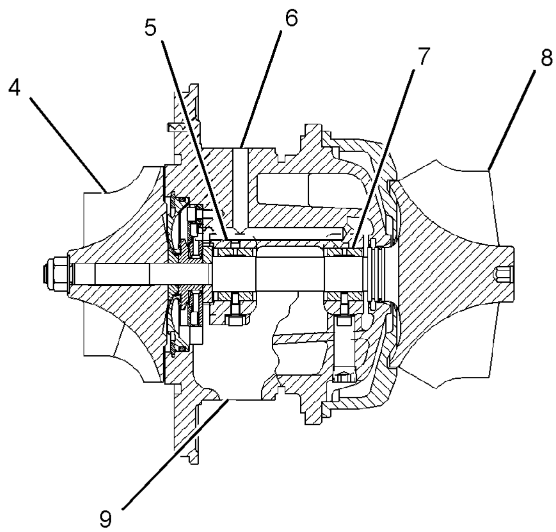


Illustration 17 g01192286

Turbocharger (typical example)

(4) Compressor wheel
(5) Bearing
(6) Oil inlet port
(7) Bearing
(8) Turbine wheel
(9) Oil outlet port

The exhaust gases go into the exhaust inlet of the turbine housing. The exhaust gases push the blades of turbine wheel (8).

Clean air from the air cleaners is pulled through the compressor housing air inlet by the rotation of compressor wheel (4). The compressor wheel blades compress the inlet air. This compression gives the engine more power because the compression allows the engine to burn additional fuel with greater efficiency.

The maximum speed of the turbocharger is controlled by the engine's electronic control of fuel delivery. When the engine is operating, the height above sea level also controls the maximum speed of the turbocharger.

Bearing (5) and bearing (7) in the turbocharger use engine oil under pressure for lubrication. The oil is sent through the oil inlet line to oil inlet port (6) at the top. The oil then goes through passages in the center section for lubrication of the bearings. The oil goes out of oil outlet port (9) at the bottom. The oil then goes back to the flywheel housing through oil drain line (2).

Center Mounted

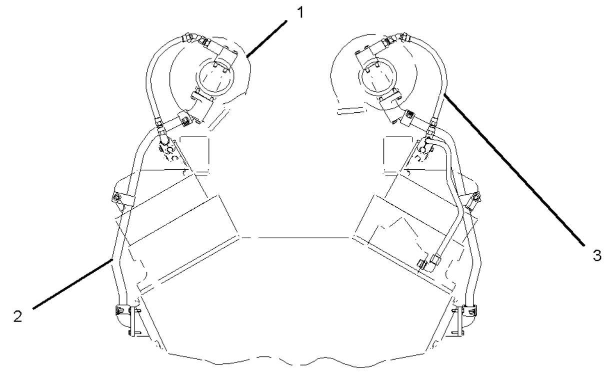


Illustration 18 g01192313

Turbocharger (typical example)

(1) Turbocharger
(2) Oil drain line
(3) Oil supply line

Four turbochargers (1) are used on the top of the engine. The turbochargers are located on each side of the vee. The turbine side of each turbocharger is mounted to the respective exhaust manifold. The compressor side of each turbocharger is connected by pipes to the top of the aftercooler housing.

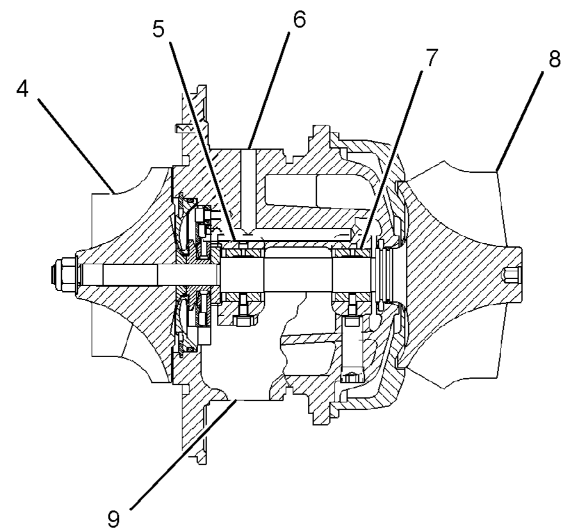


Illustration 19 g01192286

Turbocharger (typical example)

(4) Compressor wheel
(5) Bearing
(6) Oil inlet port
(7) Turbine wheel
(8) Bearing
(9) Oil outlet port

The exhaust gases go into the exhaust inlet of the turbine housing. The exhaust gases push the blades of turbine wheel (8).

Clean air from the air cleaners is pulled through the compressor housing air inlet by the rotation of compressor wheel (4). The compressor wheel blades compress the inlet air. This compression gives the engine more power because the compression allows the engine to burn additional fuel with greater efficiency.

The maximum speed of the turbocharger is controlled by the engine's electronic control of fuel delivery. When the engine is operating, the height above sea level also controls the maximum speed of the turbocharger.

Bearing (5) and bearing (7) in the turbocharger use engine oil under pressure for lubrication. The oil is sent through the oil inlet line to oil inlet port (6) at the top. The oil then goes through passages in the center section for lubrication of the bearings. The oil goes out of oil outlet port (9) at the bottom. The oil then goes back to the engine block through oil drain line (2).

Lubrication System

i02389290

Lubrication System Operation

SMCS Code: 1300

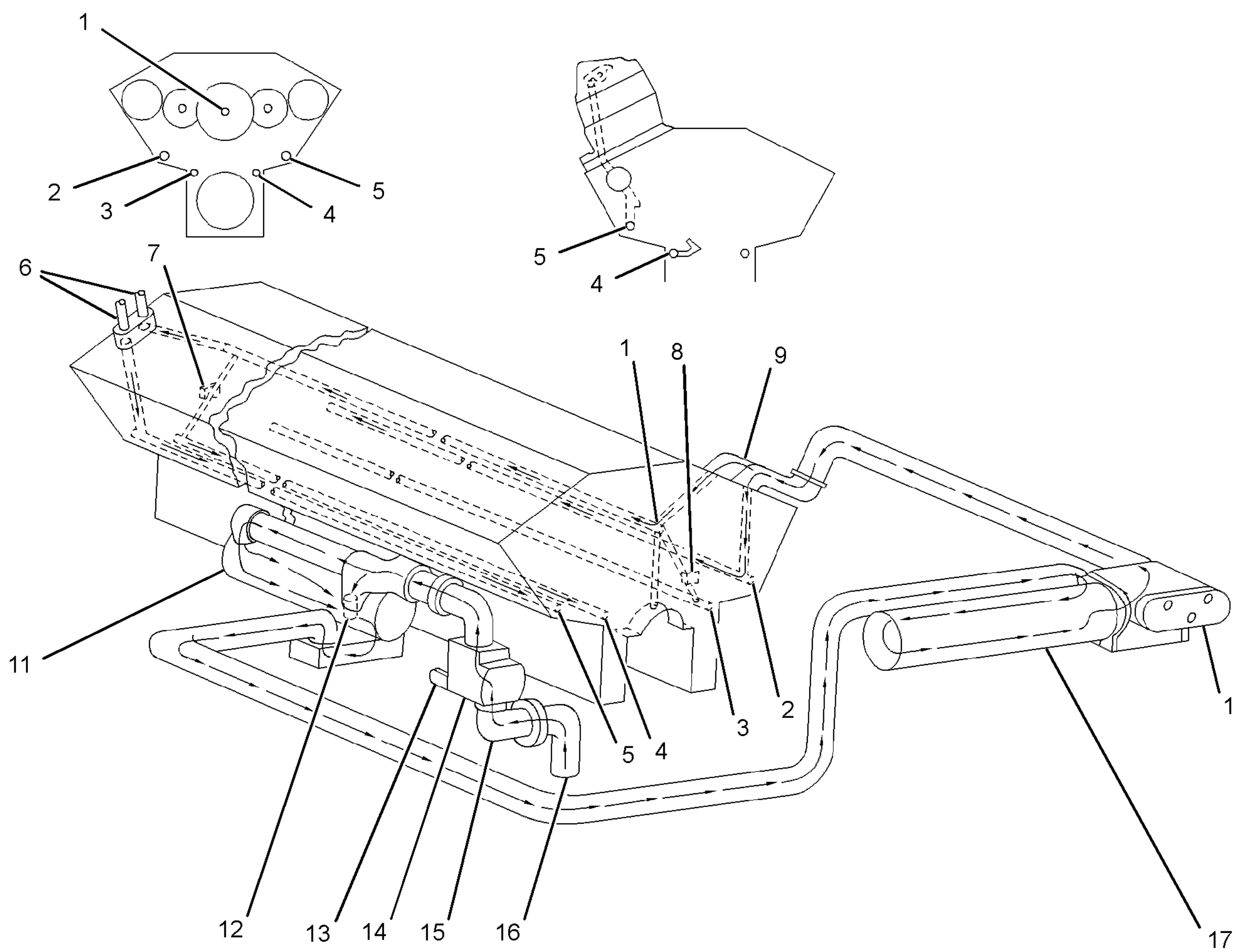


Illustration 20 g01192996

Main oil pump and lubrication system schematic (typical example)

(1) Main oil gallery
(2) Camshaft oil gallery
(3) Piston cooling jet gallery
(4) Piston cooling jet gallery
(5) Camshaft oil gallery
(6) Turbocharger oil supply
(7) Sequence valve
(8) Sequence valve
(9) Elbow
(10) Engine oil filter bypass valve
(11) Engine oil cooler
(12) Engine oil cooler bypass valve
(13) Engine oil relief valve
(14) Engine oil pump
(15) Elbow
(16) Suction bell
(17) Engine oil filter housing

This system uses an engine oil pump (14) with three pump gears. The pump gears are driven by the front gear train. Oil is pulled from the pan through suction bell (16) and through elbow (15) by the engine oil pump. The suction bell has a screen in order to clean the engine oil.

There is an engine oil relief valve (13) in the engine oil pump. The engine oil relief valve controls the pressure of the engine oil from the engine oil pump. The engine oil pump can put too much engine oil into the system. When there is too much engine oil, the engine oil pressure goes up and the relief valve opens. This allows the engine oil that is not needed to go back to the inlet oil passage of the engine oil pump.

The engine oil pump pushes engine oil through engine oil cooler (11) and through the engine oil filters to main oil gallery (1) and through camshaft oil gallery (2). Engine oil cooler (11) lowers the temperature of the engine oil before the engine oil is sent to the filters.

Engine oil cooler bypass valve (12) allows engine oil to flow directly to the filters if the engine oil cooler becomes plugged. The engine oil cooler bypass valve also allows engine oil to flow directly to the filters if the engine oil becomes thick. The engine oil cooler bypass valve will bypass the engine oil to the filters above 180 ± 20 kPa (26 ± 3 psi) of oil pressure differential.

Cartridge type filters are used. The filters are located in an engine oil filter housing. Cartridge type filters use a single bypass valve that is located in the engine oil filter housing.

Clean engine oil from the filters flows through the engine oil line and into the block through elbow (9). Part of the engine oil flows to left camshaft oil gallery (2). The remainder of the engine oil flows to main oil gallery (1).

Camshaft oil gallery (2) and camshaft oil gallery (5) are connected to each camshaft bearing by a drilled hole. The engine oil flows around each camshaft journal. The engine oil then travels through the cylinder head and through the rocker arm housing to the rocker arm shaft. A drilled hole connects the bores for the valve lifters to the oil hole for the rocker arm shaft. The valve lifters are lubricated at the top of each stroke.

Main oil gallery (1) is connected to the main bearings by drilled holes. Drilled holes in the crankshaft connect the main bearing oil supply to the rod bearings. Engine oil from the rear of the main oil gallery goes to the rear of right camshaft oil gallery (5).

Sequence valve (7) and sequence valve (8) allow engine oil from main oil gallery (1) to flow to piston cooling jet gallery (3) and to piston cooling jet gallery (4). The sequence valves begin to open at approximately 130 kPa (19 psi). The sequence valves will not allow engine oil into the piston cooling jet galleries until there is pressure in the main oil gallery. This decreases the amount of time that is necessary for pressure buildup when the engine is started. This also helps hold pressure at idle speed.

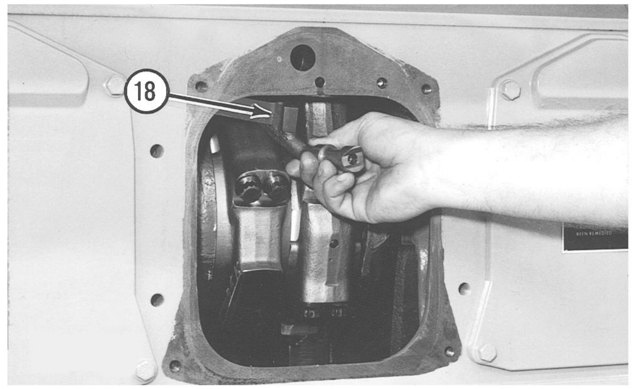


Illustration 21 g00281794

Piston cooling and lubrication (typical example)

(18) Piston cooling jet

There is a piston cooling jet (18) below each piston. Each piston cooling jet has two openings. One opening is in the direction of a passage in the bottom of the piston. This passage takes engine oil to a manifold behind the ring band of the piston. A slot (groove) is in the side of both piston pin bores in order to connect with the manifold behind the ring band. The other opening is in the direction of the center of the piston. This helps cool the piston and this lubricates the piston pin.

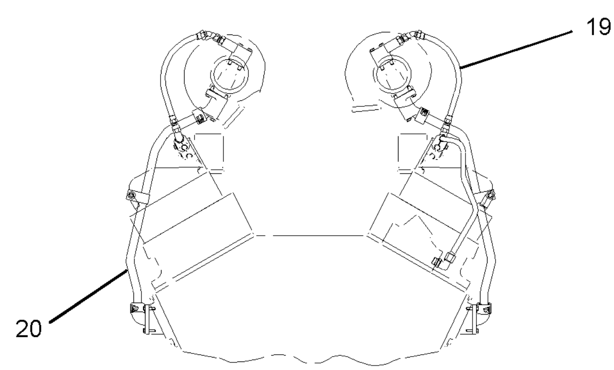


Illustration 22 g01193001

Center mounted turbochargers (typical example)

(19) Oil supply line
(20) Oil drain line

On center mounted turbochargers, oil supply lines (19) send engine oil from the front and the rear adapters to the turbochargers. Oil drain lines (20) are connected to a camshaft inspection cover.

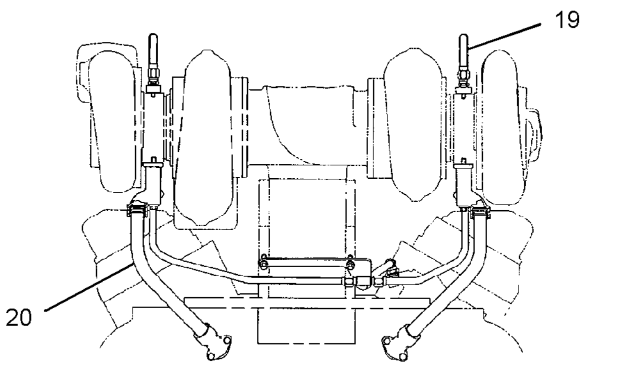


Illustration 23 g01193018

Rear mounted turbochargers (typical example)

(19) Oil supply line
(20) Oil drain line

On rear mounted turbochargers, oil supply lines (19) send engine oil from the rear adapter to the turbochargers. Oil drain lines (20) are connected to the flywheel housing on each side of the engine.

Engine oil is sent to the front gear group and the rear gear group through drilled passages. The drilled passages are in the front housing, the rear housing and cylinder block faces. These passages are connected to camshaft oil galleries (2) and (5).

After the engine oil has finished lubricating, the engine oil goes back to the engine oil pan.

Cooling System

i02389385

Cooling System Operation (Jacket Water Aftercooled)

SMCS Code: 1350

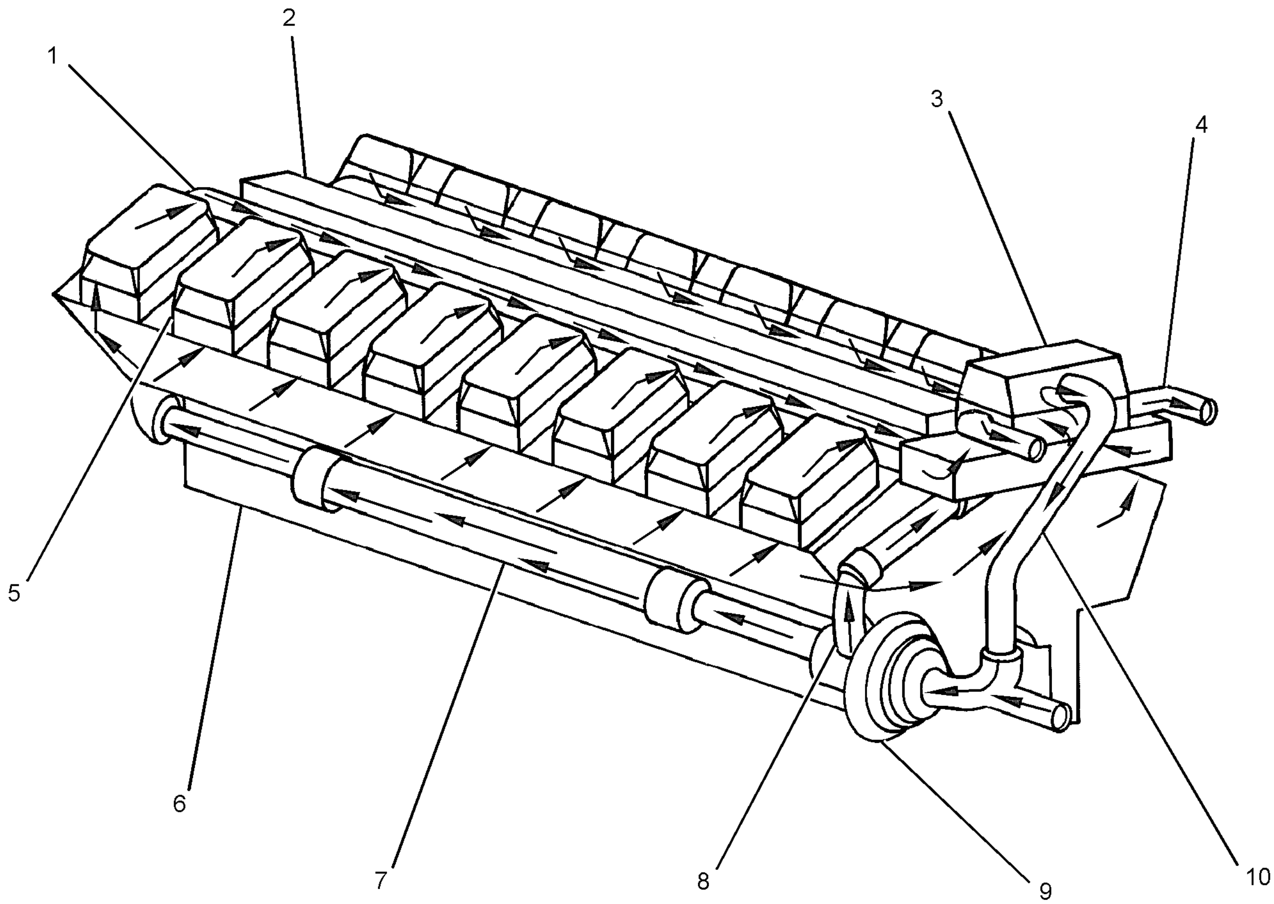


Illustration 24 g01193035

Schematic of cooling system (typical example)

(1) Water manifold
(2) Aftercooler
(3) Water temperature regulator housing
(4) Tube
(5) Cylinder head
(6) Cylinder block
(7) Engine oil cooler
(8) Tube
(9) Water pump
(10) Bypass tube

Coolant goes into water pump (9) through an elbow. The elbow connects to the radiator or to the heat exchanger. The coolant flow is divided at the outlet of the water pump. Part of the coolant flow is sent to aftercooler (2) through tube (8). The remainder of the coolant goes through engine oil cooler (7).

Coolant that is sent to the aftercooler goes through the aftercooler core. The coolant is sent by an elbow into a passage in cylinder block (6). The passage is near the center of the vee at the rear of the cylinder block.

The coolant flows through the engine oil cooler into the water jacket of the cylinder block at the right rear cylinder. The cooler coolant and the hotter coolant are then mixed. The coolant goes to both sides of the cylinder block through distribution manifolds. The distribution manifolds are connected to the water jacket of all the cylinders. The main distribution manifold is located just above the main bearing oil gallery.

The coolant flows upward through the water jackets. The coolant flows around the cylinder liners from the bottom to the top. The hottest temperature is near the top of the cylinder liners. The water jacket is smaller near the top of the cylinder liners. This shelf causes the coolant to flow faster for better liner cooling.

Coolant from the top of the liners goes into cylinder head (5). The cylinder head sends the coolant around the hottest parts. Coolant then goes to the top of the cylinder head. The coolant goes out through an elbow at each cylinder head and into water manifold (1) at each bank of cylinders. Coolant goes through the water manifold to temperature regulator housing (3).

The water temperature regulator housing has an upper flow section and a lower flow section. The housing uses four temperature regulators. The sensing bulbs of the four temperature regulators are in the lower section of the housing. Before the regulators open, cold coolant is sent through bypass tube (10) back to the inlet of water pump (9). As the temperature of the coolant increases and the regulators start to open, the coolant flow in the bypass tube is restricted. Some coolant is sent through the outlets to the radiator or to the heat exchanger.

The total system capacity will depend on the amount of coolant in the following components: cylinder block, radiator or the heat exchanger, and the coolant lines.

i01939295

Separate Circuit Cooling System

SMCS Code: 1350

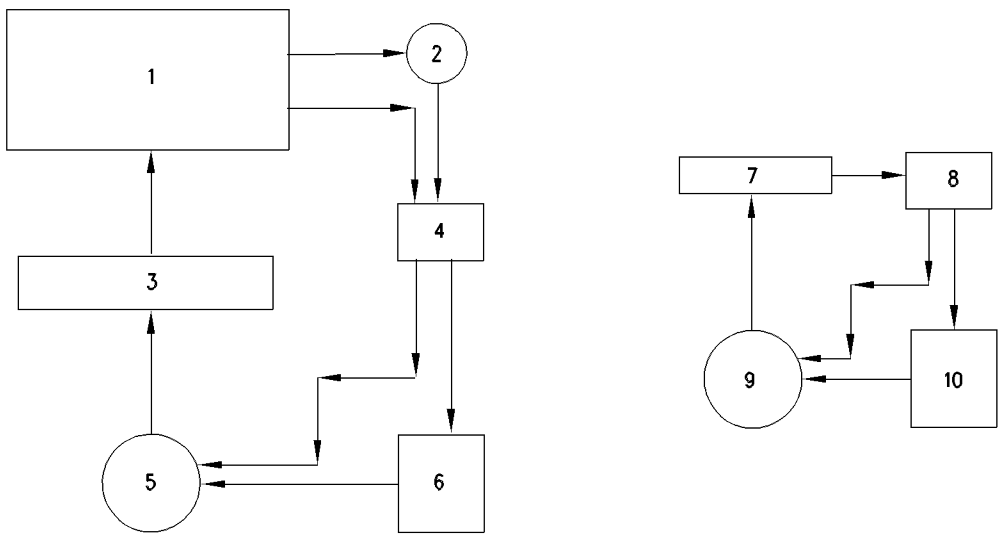


Illustration 25 g00309803

(1) Cylinder block
(2) Water cooled turbocharger (if equipped)
(3) Engine oil cooler
(4) Water temperature regulator housing
(5) Jacket water pump
(6) Jacket water coolant
(7) Aftercooler
(8) Thermostatic valve
(9) Separate circuit water pump
(10) Separate circuit coolant

Coolant flows to jacket water pump (5) through an elbow. The elbow connects to jacket water coolant (6). The coolant flow is sent through engine oil cooler (3).

The coolant flows through engine oil cooler (3). The coolant then flows into the water jacket of cylinder block (1) at the right rear cylinder. The coolant flows to both sides of the block through the distribution manifolds. The distribution manifolds are connected to the water jacket of all the cylinders. The main distribution manifold is located just above the main bearing oil gallery.

The coolant flows upward through the cylinder water jacket. The coolant flows around the cylinder liners from the bottom to the top. Near the top of the cylinder liners, the water jacket is made smaller. This is the area that has the hottest temperature. This shelf (smaller area) causes the coolant to flow faster for better liner cooling. Coolant from the top of the liners flows into the cylinder head which sends the coolant around the parts that have the hottest temperature. Coolant flows to the top of the cylinder head (one at each cylinder). The coolant flows out of the cylinder head through an elbow into a water manifold. Coolant then flows through the manifold to regulator housing (4).

Regulator housing (4) has an upper flow section and a lower flow section. The regulator housing uses four temperature regulators. The sensing bulbs of the four temperature regulators are in the coolant in the lower section of the housing. Before the regulators open, cold coolant is sent through the bypass line back to the inlet of water pump (5). The coolant flow in the bypass line is restricted when the temperature of the coolant increases enough to make the regulators open. Some of the coolant is sent through the outlets to jacket water coolant (6).

Coolant flows to separate circuit water pump (9) through an elbow that connects to separate circuit coolant (10). The coolant flow is sent through aftercooler (7).

Coolant flows through aftercooler (7) and back to thermostatic valve (8). Before thermostatic valve (8) opens, cold coolant is sent back to separate circuit water pump (9). The coolant flow in the bypass line is restricted when the temperature of the coolant increases enough to make the thermostatic valve open. Some of the coolant is sent through the outlet to the separate circuit coolant (10).

Coolant for water cooled turbochargers (2) is picked up from the rear of the water manifolds. The coolant flows through water cooled turbochargers (2) and the coolant returns to regulator housing (4).

Basic Engine

i02388283

Cylinder Block, Liners and Heads

SMCS Code: 1100; 1200

The cylinders in the left side of the block form a 60 degree angle with the cylinders in the right side. The main bearing caps are fastened to the cylinder block with four bolts per cap.

The cylinder liners can be removed for replacement. The top surface of the cylinder block is the seat for the cylinder liner flange. Engine coolant flows around the cylinder liners in order to keep the cylinder liners cool. Three O-ring seals around the bottom of the cylinder liner make a seal between the cylinder liner and the cylinder block. A filler band goes under the cylinder liner flange. This makes a seal between the top of the cylinder liner and the cylinder block.

The engine has a separate cylinder head for each cylinder. Two inlet valves and two exhaust valves, which are controlled by a pushrod valve system, are used for each cylinder. Valve guides without shoulders are pressed into the cylinder heads. The opening for the unit injector is located between the four valves. A lobe on the camshaft moves the pushrod that operates the unit injector. Fuel is injected directly into the cylinder.

There is an aluminum spacer plate between each cylinder head and the cylinder block. Coolant goes out of the cylinder block through the spacer plate and into the cylinder head through eight openings in each cylinder head face. Water seals are used in each opening to prevent coolant leakage. Gaskets seal the engine oil drain line between the cylinder head, the spacer plate, and the cylinder block.

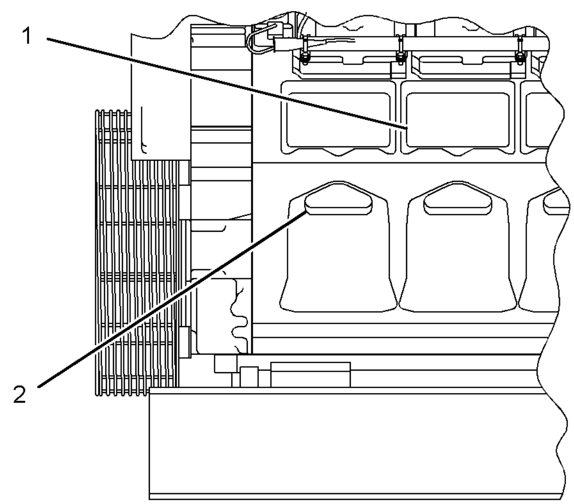


Illustration 26 g01192345

Left side of engine (typical example)

(1) Camshaft covers
(2) Crankcase covers

Camshaft covers (1) allow access to the camshaft and to the valve lifters. Crankcase covers (2) allow access to the crankshaft connecting rods, to the main bearings, and to the piston cooling jets. When the covers are removed, all the openings can be used for inspection and for service.

i02124288

Pistons, Rings and Connecting Rods (One-Piece Piston)

SMCS Code: 1214; 1218

S/N: S2A1-Up

S/N: S2B1-Up

S/N: S2D1-Up

S/N: S2E1-Up

S/N: S2F1-Up

S/N: S2G1-Up

S/N: S2H1-Up

S/N: S2K1-Up

S/N: S2L1-Up

S/N: S2M1-Up

S/N: S2P1-Up

S/N: S2R1-Up

S/N: S2S1-Up

S/N: S2W1-Up

S/N: S2Y1-Up

S/N: S2Z1-Up

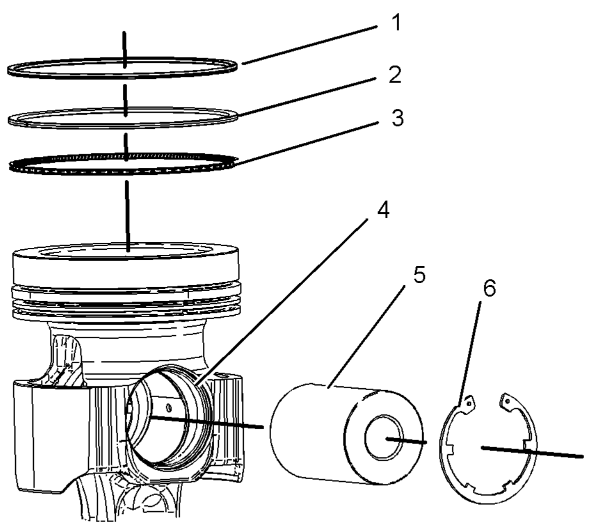


Illustration 27 g01084288

(1) Top ring
(2) Intermediate ring
(3) Oil control ring
(4) Piston pin bore
(5) Piston pin
(6) Piston pin retainer

The piston is a one-piece piston that is made of forged steel. A large circumferential slot separates the crown and the skirt. The crown and the skirt remain attached by the strut for the pin bore. The crown carries all three piston rings. Oil from the piston cooling jets flows through a chamber which is located directly behind the rings. The oil cools the piston which improves the life of the rings. The pistons have three rings which include two compression rings and one oil ring. All the rings are located above the piston pin bore. Oil returns to the crankcase through holes in the oil ring groove.

The connecting rod has a taper on the pin bore end. This taper gives the rod and the piston more strength in the areas with the most load. Four bolts, which are set at a small angle, hold the rod cap to the rod. This design keeps the rod width to a minimum, so that a larger rod bearing can be used and the rod can still be removed through the liner.

i02015655

Pistons, Rings and Connecting Rods (Two-Piece Piston)

SMCS Code: 1214; 1218

S/N: B5G1-Up

S/N: MRG1-Up

S/N: PAG1-Up

S/N: MKH1-Up

S/N: S2J1-Up

S/N: S2N1-Up

S/N: S2T1-Up

S/N: S2X1-Up

The piston is a two-piece, articulated design. The piston consists of a forged, steel crown and a cast, aluminum skirt. The two pieces of the piston assembly are connected to the piston pin. The two pieces of the piston assembly pivot about the piston pin. The steel crown carries all three piston rings. Oil from the piston cooling jets flows through a chamber which is located directly behind the rings. The oil cools the piston which improves the life of the rings. The pistons have three rings which include two compression rings and one oil ring. All the rings are located above the piston pin bore. The oil ring is a standard ring. Oil returns to the crankcase through holes in the oil ring groove. The top two rings are the Keystone rings, which are tapered.

The connecting rod has a taper on the pin bore end. This taper gives the rod and the piston more strength in the areas with the most load. Four bolts, which are set at a small angle, hold the rod cap to the rod. This design keeps the rod width to a minimum, so that a larger rod bearing can be used and the rod can still be removed through the liner.

i01938906

Crankshaft

SMCS Code: 1202

The crankshaft changes the combustion forces in the cylinder into usable rotating torque. A vibration damper is used at the front of the crankshaft in order to reduce torsional vibrations (twist) that can cause damage to the engine.

The crankshaft drives a group of gears on the front and on the rear of the engine. The gear group on the front of the engine drives the oil pump, the jacket water pump, the fuel transfer pump, and the accessory drives.

The rear gear group drives the camshafts and the accessory drives.

Seals and wear sleeves are used at both ends of the crankshaft. The 3508B crankshaft is held in place by five main bearings. The 3512B crankshaft is held in place by seven main bearings. The 3516B crankshaft is held in place by nine main bearings. A thrust plate at either side of the center main bearing controls the end play of the crankshaft.

i01938909

Camshaft

SMCS Code: 1210

There is one camshaft per side. The 3508B camshaft is supported by five bearings. The 3512B camshaft is supported by seven bearings. The 3516B camshaft is supported by nine bearings. Each camshaft is driven by the gears at the rear of the engine.

The camshafts must be in time with the crankshaft. The relation of the camshaft lobes to the crankshaft position causes the valves and unit injectors in each cylinder to operate at the correct time.

Air Starting System

i02388307

Air Starting System

SMCS Code: 1450

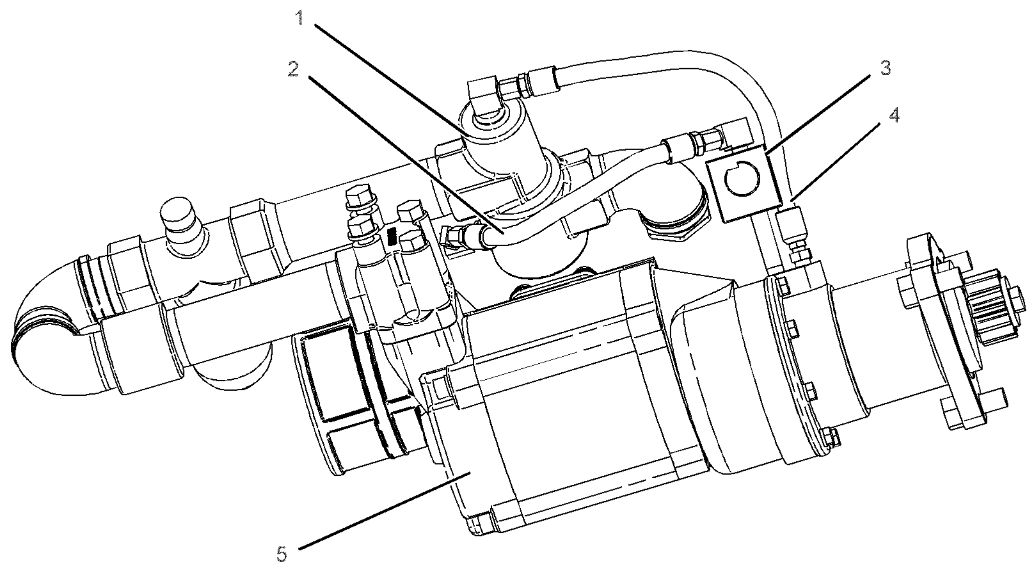


Illustration 28

g01013593

Air starting system (typical example)

(1) Relay valve
(2) Hose
(3) Starting motor solenoid
(4) Hose
(5) Air starting motor

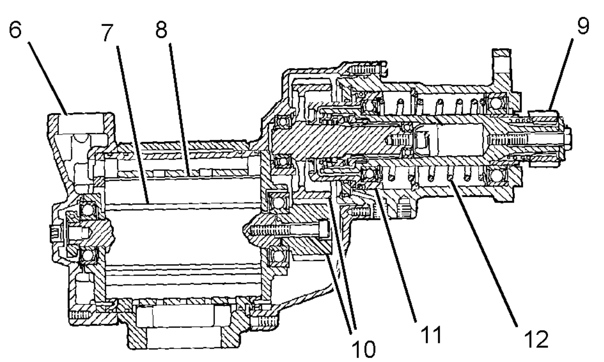


Illustration 29

g01192361

Air starting motor

(6) Air inlet
(7) Vanes
(8) Rotor
(9) Pinion
(10) Reduction gears
(11) Piston
(12) Piston spring

When the main supply of pressurized air is ON, pressurized air is provided to relay valve (1). The main supply of pressurized air is blocked by the relay valve. The relay valve allows some control air pressure to flow through hose (2) from the bottom of the relay valve to another valve that is connected to starting motor solenoid (3).

When the normally closed starting motor solenoid is activated for start-up, the solenoid opens the connected valve. The valve allows the control air pressure to flow behind piston (11) inside air starting motor (5).

The control air pressure pushes the piston. The piston compresses piston spring (12) and the piston moves the drive shaft for pinion (9) outward in order to engage the pinion with the flywheel ring gear. The starting motor does not crank the engine yet.

After the pinion is engaged with the flywheel ring gear, a port in the starting motor is opened in order to allow the control air pressure to flow through hose (4) to the top of relay valve (1). The relay valve opens in order to allow the main supply of pressurized air to flow through the starting motor's air inlet (6).

The pressurized air causes vanes (7) and rotor (8) to rotate. The rotor uses reduction gears (10) to rotate the drive shaft for the pinion and the pinion rotates the flywheel in order to crank the engine.

When the engine starts to run, the flywheel will begin to rotate faster than the pinion. The design of the drive shaft for the pinion allows the pinion to move away from the flywheel. This prevents damage to the air starting motor, to the pinion, and to the flywheel ring gear.

When the engine control senses the crank terminate speed, starting motor solenoid (3) is de-energized. The solenoid closes the attached valve and the control air pressure is removed from piston (11). Piston spring (12) retracts the piston, the drive shaft, and pinion (9).

The retraction of piston (11) closes the passage for the control air pressure to relay valve (1). The relay valve closes in order to shut off the main supply of pressurized air to the starting motor.

Electrical System

i02060367

Electrical System Operation

SMCS Code: 1400; 1450

Power Supply

The engine must be supplied with a reliable source of direct current electricity. There should be a minimum of one alternative power source. The Electronic Control Module (ECM) needs 10 amp of 24 VDC that is supplied by a dedicated battery set. The following components will work as an alternative power supply: back up battery sets, engine driven alternators, and battery chargers. If a battery charger is used as an alternative power supply, the battery charger must have a regulated power supply.

Power Distribution Panel

The power distribution panel distributes power to the various systems on the engine. The power distribution panel has two external connections for the battery. The power distribution panel has multiple breakers that are mounted externally. The power distribution panel contains the following controls on the inside of the panel: control relays, circuit breakers, diodes, control switches, and timer.

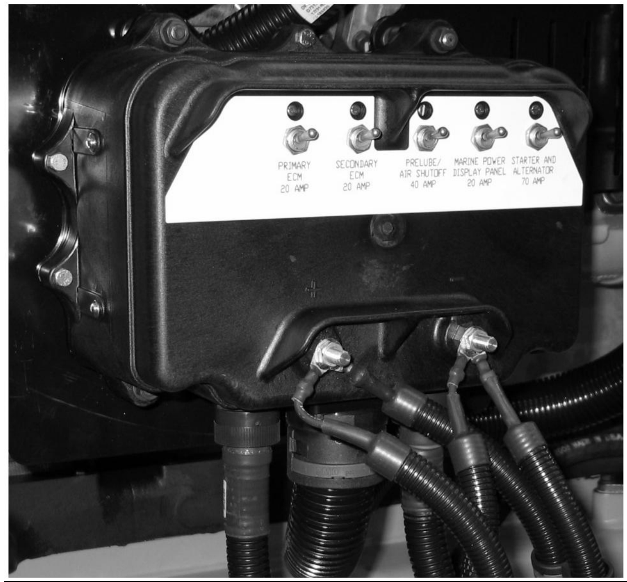


Illustration 30 g01055916

Power distribution panel

i02393241

Grounding Practices

SMCS Code: 1400

Proper grounding for the engine electrical system is necessary for performance and reliability. Improper grounding will cause the electrical circuits to be uncontrolled. The paths will be unreliable.

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

Uncontrolled electrical circuit paths can cause electrical noise. This noise may degrade the engine performance.

A direct path to the battery must be used in order to ensure the proper functioning of the engine electrical systems.

Ground wires and straps should be combined at ground studs. The ground studs should be dedicated for ground use only. At every 250 hours, inspect all of the engine grounds. All grounds should be tight and free of corrosion.

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

Unlike many electronic systems of the past, this engine is tolerant to common external sources of electrical noise. However, electromechanical alarms can cause disruptions in the power supply. The engine's electronic control module (ECM) is powered through two power sources. One power source comes directly from the battery through a circuit breaker. The other power source comes through the keyswitch and another circuit breaker. Disconnect the power with the disconnect switch for the main power.

i02388508

Electronic Circuits

SMCS Code: 1901

The Electronic Control Module (ECM) allows the ordinary switch input circuits to the ECM to have a tolerance for resistance and shorts between wires. These tolerances are the following items:

- The ECM will tolerate resistance in any ordinary switch up to 2.5 ohms without malfunctioning.
- The ECM will tolerate shorts to the ground. The ECM will also tolerate shorts between wires in any ordinary switch input that is 5000 ohms or more without malfunctioning.

The ECM draws a maximum of 10 amp at 24 volts from the electrical system. However, the ECM will function with less than 12 volts. A minimum of 9 volts is required by the ECM while the engine is cranking or running. Power enters the ECM through the +Battery wire. Power exits through the −Battery wire.

The ECM is protected against power surges on the 24 volt power supply.

i02475511

Charging System

SMCS Code: 1400

NOTICE

Never operate the alternator without the battery in the circuit. Making or breaking an alternator connection with heavy load on the circuit can cause damage to the regulator.

Alternator

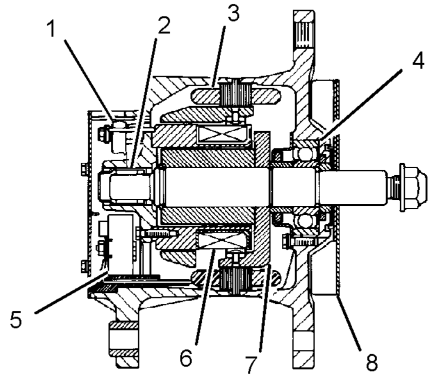


Illustration 31 g01192436

Alternator components (typical example)

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

The alternator is driven by a belt from an auxiliary drive at the front right corner of the engine. This alternator is a three-phase, self-rectifying charging unit, and the regulator is part of the alternator.

The voltage regulator is a solid-state, electronic switch. The regulator turns on and the regulator turns off many times in one second in order to control the field current to the alternator. The output voltage from the alternator will now supply the needs of the battery and the other components in the electrical system. No adjustment can be made in order to change the rate of charge on these alternator regulators.

i02388664

Starting System

SMCS Code: 1450

Starting solenoid

A solenoid is an electromagnetic switch that does two basic operations.

- Close the high current starting motor circuit with a low current start switch circuit.
- Engage the starting motor pinion with the ring gear.

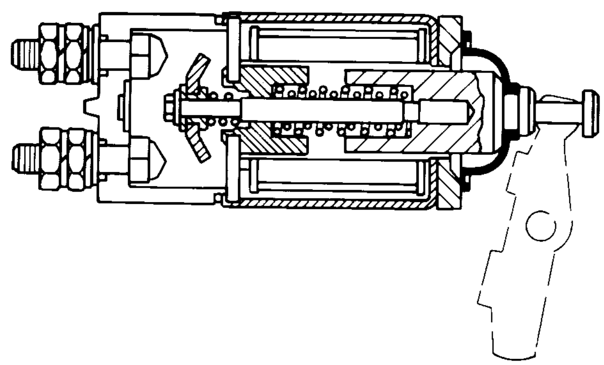


Illustration 32 g00285112

Typical solenoid

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

When the start switch is opened, current no longer flows through the windings. The spring pushes the plunger back to the original position. The spring simultaneously 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 winding have the same number of turns around the cylinder. However, the pull-in winding uses a wire with a larger diameter in order to produce a greater magnetic field. When the start switch is closed, part of the current flows from the battery through the hold-in windings. The rest of the current flows through the pull-in windings to the motor terminal. The current then goes through the motor to the ground. When the solenoid is fully activated, current is shut off through the pull-in windings. Only the smaller hold-in windings are in operation for the extended period of time. This period of time is the amount of time that is needed for the engine to start. The solenoid will now take less current from the battery. The heat that is made by the solenoid will be kept at an acceptable level.

Starting Motor

The starting motor is used to turn the engine flywheel in order to get the engine running.

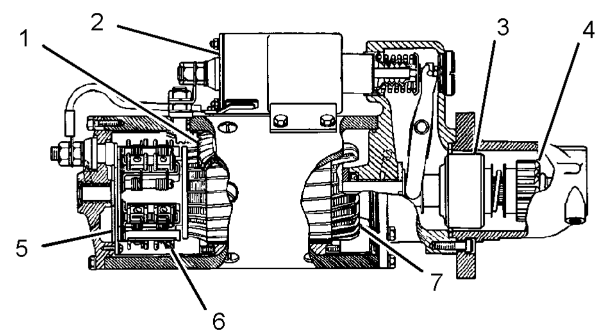


Illustration 33 g01192489

Cross section of the starting motor (typical example)

(1) Field
(2) Solenoid
(3) Clutch
(4) Pinion
(5) Commutator
(6) Brush assembly
(7) Armature

The starting motor has a solenoid. When the start switch is activated, electricity will flow through the windings of the solenoid. The solenoid core will move in order to push the starting motor pinion with a mechanical linkage. This will engage with the ring gear on the flywheel of the engine. The starting motor pinion will engage with the ring gear before the electric contacts in the solenoid close the circuit between the battery and the starting motor. When the circuit between the battery and the starting motor is complete, the pinion will turn the engine flywheel. A clutch gives protection to the starting motor. The engine can not turn the starting motor too fast. When the start switch is released, the starting motor pinion will move away from the flywheel ring gear.

Starting Motor Protection

The starting motor is protected from damage in two ways:

- The starting motor is protected from engagement with the engine when the starting motor is running. The control feature will not allow the starting motor to engage if the speed is above 0 rpm.

- The starting motor is protected from continued operation by holding the key in the “start” position after the engine starts. This is accomplished by disengaging the starting motor solenoid after engine speed reaches 300 rpm.

i02388736

Engine Speed Sensor

SMCS Code: 1907

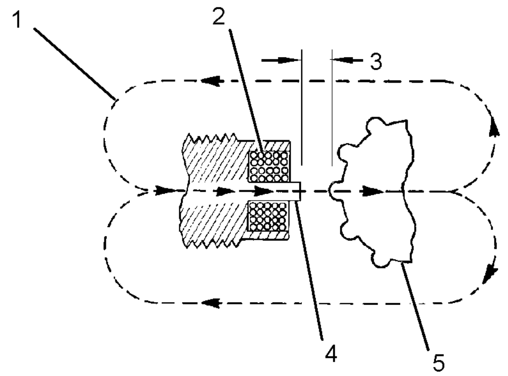


Illustration 34 g01192553

Schematic of engine speed sensor

(1) Magnetic lines of force
(2) Wire coils
(3) Gap
(4) Pole piece
(5) Flywheel ring gear

The engine speed sensor is a permanent magnet generator. This engine speed sensor has a single pole. The engine speed sensor is made of wire coils (2). The wire coils go around a permanent magnet pole piece (4).

As the teeth of flywheel ring gear (5) cut through magnetic lines of force (1) that are generated by the permanent magnet, an AC voltage is generated in wire coils (2). The frequency of this voltage is directly proportional to engine speed.

Testing and Adjusting Section

Electronic Control System

i01930369

Calibration

SMCS Code: 1901

Calibration for Electronic Injection Timing with the Electronic Service Tool

Refer to Troubleshooting, "Engine Speed/Timing Sensor - Calibrate" for the proper procedure in order to calibrate the electronic injection timing.

i01938932

Configuration Parameters

SMCS Code: 1901

Configuration parameters are those parameters that affect engine power or various engine features. The configuration parameters for the crank duration and the maximum number of cycles must be reprogrammed from the factory settings before the engine will start.

The configuration parameters may be programmed with the Caterpillar Electronic Technician (ET). Refer to Troubleshooting for additional information in order to program the configuration parameters.

Some parameters may not be available on all applications. If a parameter is unavailable the Cat ET will indicate "unavailable" when the parameter is selected. The Electronic Control Module (ECM) must be programmed. Make sure that the "Air Shutoff", the "Ether Control" and the "Plt Hse EMS Status" parameters are "ENABLED/ON" if the engine is equipped with these attachments. Make sure that the "DISABLED/OFF" is used if the engine is not equipped. The "Eng. Prelube Duration" must be programmed to a value that is not zero seconds if the engine is equipped with the prelube. The prelube motor will not run if this value is not programmed. If the engine is not equipped with the prelube then the parameter must be programmed to "0". The correct configuration for the aftercooling system must be programmed.

i01938925

Monitoring System Parameters

SMCS Code: 1901

A programmable engine monitoring system is provided. The Electronic Control Module (ECM) can monitor parameters. The ECM can initiate an action if a specific parameter for engine operation exceeds an acceptable range. Three possible actions from the ECM may be available: "WARNING", "DERATE", and "SHUTDOWN". All actions are not available for some parameters. The Caterpillar Electronic Technician (ET) is used to select the actions from the ECM. The Cat ET will program the level for monitoring and the delay times for each action.

Note: The parameters must be programmed with the Cat ET when the customer requires any of the parameters to be different from the factory settings.

Monitoring system parameters must be programmed with the Cat ET. In order to program the monitoring system parameters, select "monitoring" from the Cat ET menu. Screens in Cat ET provide guidance through the steps for programming in order to select the "OFF/WARNING/DERATE/SHUTDOWN" options that are available for the selected parameter. Screens in Cat ET also provide guidance for changing "WARNING/DERATE/SHUTDOWN" setpoints. Some parameters will require a password to be programmed. Refer to the Cat ET and the Troubleshooting manual for additional information on programming the monitoring system parameters.

The engine monitoring system is enabled after the engine is started. When the engine rpm exceeds a point that is 50 rpm below the low idle speed the ECM checks the parameter levels. The ECM checks the parameter levels in order to determine if the levels exceed the setpoints for the monitoring system.

Any action of the monitoring system will log an event. These actions are "WARNING", "DERATE" or "SHUTDOWN". A warning event will still be logged if the setpoint is exceeded and these actions are turned off.

Any failure of a sensor will result in the disabling of the corresponding portion of the monitoring system. There will be an active diagnostic for the failed sensor, but an event is not logged. Refer to Troubleshooting for additional information on sensors.

i01946291

Engine Governing - Adjust

SMCS Code: 1901-025

S/N: S2A1-Up

S/N: S2B1-Up

S/N: S2G1-Up

S/N: S2H1-Up

S/N: S2P1-Up

S/N: S2R1-Up

S/N: S2Z1-Up

Programming Governor Gain Parameters

The governor gain parameters are set at the factory. The factory default settings are recommended for most applications. The default settings should allow the engine to respond quickly to transient load changes. The default settings should allow the engine to remain stable during all operating conditions. If the factory default setting does not provide satisfactory performance, the governor gain parameters can be adjusted.

The parameters in Table 1can be adjusted.

Table 1

Parameter	Valid Range
Governor Gain Factor	0 - 39999
Governor Minimum Stability Factor	0 - 39999
Governor Maximum Stability Factor	0 - 39999

Note: No engineering units are associated with the numbers in table 1.

Note: The range of the programmable setting is wide for flexibility. Do not expect to use the whole range. If the programmable setting is greater than the valid range, the system will revert to the factory default value.

Do not perform this procedure until you read this information and you understand this information.

Gain Explanations

Governor Gain Factor

The "Governor Gain Factor" is multiplied by the engine speed error. This value is derived by calculating the difference between the desired speed and the actual speed.

- If the "Governor Gain Factor" value is too large, the engine speed can overshoot the desired speed.
- If the "Governor Gain Factor" value is too small, the engine will accelerate slowly.

Governor Minimum/Maximum Stability Factor

The "Governor Minimum Stability Factor" functions in order to eliminate steady state speed error. The "Governor Minimum Stability Factor" is used by the Electronic Control Module (ECM) when the steady state speed error is less than 20 rpm.

The "Governor Maximum Stability Factor" functions in order to eliminate steady state speed error. The "Governor Maximum Stability Factor" is used by the ECM when the steady state speed error is increasing and the engine speed error is greater than 20 rpm.

- If the "Governor Minimum Stability Factor" or the "Governor Maximum Stability Factor" is set too high, the ECM will provide additional fuel. The additional fuel will cause the engine speed to overshoot. The additional fuel will also cause the engine speed to oscillate.
- If the "Governor Minimum Stability Factor" or the "Governor Maximum Stability Factor" is set too low, the engine will not achieve a steady state operation quickly.

Tuning Procedure

1. Turn the Engine Control Switch (ECS) to the COOLDOWN/STOP position. Connect the Caterpillar Electronic Technician (ET). Enable the engine overspeed protection prior to the adjustment procedure. Adjusting governor gain parameters without engine overspeed protection can result in serious engine damage. Ensure that engine overspeed protection is ON. Engine overspeed is configured on the setup screen of "Service Monitoring System" in Cat ET.

⚠ WARNING

Personal injury or death can result from engine overspeed.

If the engine overspeeds, it can cause injury or parts damage. The engine should be equipped with a separate shutdown device, to protect against engine overspeed. Do not use for emergency shutdown.

2. Start the engine. Observe the control panel to ensure that the engine has reached the rated speed. The control panel will serve as the reference point for engine speed during this procedure.

3. Go to the configuration parameters screen in Cat ET.

Note: A factory password is required for adjustment of the governor gain parameters. Once the password is entered, the values for the governor gain parameters can be adjusted. If a parameter value that is not a governor gain parameter is altered, a new password will be required. If the configuration parameters screen is stopped during the adjustment of a governor gain parameter, a new factory password will be required.

Note: Any value may be returned to the factory default setting by typing a number that is greater than the valid range. For example, typing 40,000 will reset a value to the factory default.

4. Set up a field performance test. For example, the engine has poor response during specific load changes.

5. Perform the desired load change from step 4. Observe the response of the engine by viewing the engine speed on the control panel. Observe the engine response by looking at the frequency meter or by listening to the response of the engine.

6. Determine the setting to adjust. Refer to “Gain Explanations” and “Governor Minimum/Maximum Stability Factor”.

Note: Usually, the “Governor Gain Factor” should be somewhat lower than the “Governor Minimum Stability Factor” for optimum performance. The “Governor Maximum Stability Factor” is typically a smaller value than the “Governor Minimum Stability Factor” and “Governor Gain Factor”.

7. Repeat steps 5, 6, and 7until a desired engine response can be met. Use large adjustments (ten percent of original gain) initially for a coarse adjustment to engine response. Use smaller adjustments (one percent of total gain) as the engine response is closer to the desired response.

Fuel System

i01938966

General Information (Fuel System)

SMCS Code: 1250

Either too much fuel or not enough fuel for combustion can be the cause of a problem in the fuel system. Work is often done on the fuel system when the problem is really with some other part of the engine. It is difficult to find the cause of the problem, especially when smoke comes from the exhaust. Smoke that comes from the exhaust can be caused by a faulty fuel injector. Smoke can also be caused by one or more of the reasons that follow:

- Not enough air for good combustion
- Oil leakage into combustion chamber
- Air inlet and exhaust leaks
- Not enough compression

i02060808

Fuel Ratio Control

SMCS Code: 1278

The Electronic Control Module (ECM) provides automatic control of the engine's fuel to air ratio. This automatic control will achieve good engine performance, control of black exhaust smoke, and improved fuel consumption. The ECM regulates the fuel delivery. The fuel delivery is based upon the air inlet manifold pressure (boost). As boost pressure increases, more air is available for combustion in the cylinders. The ECM responds by delivering more fuel. More fuel is delivered in order to maintain the optimum air/fuel ratio throughout the engine's operating range.

The engine's electronic control system allows you to make a slight adjustment of the fuel ratio control. Adjustment of the fuel ratio control in the ECM is accomplished by using the Caterpillar Electronic Technician (ET). Changing the "Fuel Ratio Control Offset" parameter allows custom tailoring of the fuel to air ratio. Setting the "Fuel Ratio Control Offset" value in the positive direction will provide a richer air/fuel ratio. This setting will yield a quicker engine response during accelerations. The setting will also yield more black smoke. Setting the "Fuel Ratio Control Offset" value in the negative direction will provide a leaner air/fuel ratio. The result is a somewhat slower engine response and less black smoke.

i02391941

Fuel System Inspection

SMCS Code: 1250-040

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

1. Check the fuel level in the fuel tank. Look at the cap for the fuel tank. Make sure that the vent is not filled with debris.
2. Check the fuel lines for fuel leakage. Be sure that none of the fuel lines have a restriction or a faulty bend.
3. Install new main fuel filters. Clean the primary fuel filter.
4. Inspect the fuel pressure relief valve in the fuel transfer pump. Make sure that there is no restriction.

i02393248

Checking Engine Cylinders

SMCS Code: 1290-535

When the engine is under load, the temperature of an exhaust manifold port can indicate the condition of a fuel injector. Low temperature at an exhaust manifold port is an indication of no fuel to the cylinder. This can possibly indicate an injector with a defect or a problem with the control system. An extra high temperature at an exhaust manifold port can indicate too much fuel to the cylinder. High temperatures may also be caused by an injector with a defect.

Refer to Testing And Adjusting, "Measuring Exhaust Temperature" for the procedure to check the exhaust manifold port temperatures.

i02340714

Checking Engine Cylinders with an Electronic Service Tool

SMCS Code: 1290-535

Table 1

Tools Needed	Quantity
Caterpillar Electronic Technician (ET)	1
171-4400 Communication Adapter Gp	1

The condition of individual cylinders may be checked electronically. The cylinders may be checked by cutting out the cylinders with Cat ET. A weak cylinder or a cold cylinder may be found in this manner.

1. Connect Cat ET to the service tool connector.

2. Start the engine and set engine speed to low idle.

3. Select the "Diagnostic Tests" screen from the main menu and then select "1-Cylinder Cutout".

4. Observe the "Injection Duration" that is displayed on the Cat ET screen. The injection duration represents the amount of time for energizing the injector cartridge valve. The injection duration also represents the amount of fuel that is being injected at that engine speed.

5. Use the arrow keys in order to highlight each cylinder. Then press "return". The display should read "CUTOUT" next to the cylinder number. Observe the duration number with each cylinder that is cut out. Compare the number to the duration number in Step 4. When a cylinder is cut out, the other cylinders must work harder in order to maintain the current engine speed. The electronic control module (ECM) automatically increases the duration of the cylinders that are still firing in order to maintain engine rpm.

If a cylinder is cut out and the duration number does not increase, then that cylinder is producing less power or that cylinder is not producing any power.

This test may also be performed at other engine speeds and at other engine loads. When higher loads are used, the duration number will not increase when the cylinders are cut out. Instead, the engine speed will decrease. The speed will decrease because the engine is at the rated power delivery. Increasing the fuel would increase the engine's power output above the rated power.

i02388767

Fuel Pressure

SMCS Code: 1250-081

The 1U-5470 Engine Pressure Group can be used in order to check the fuel pressure of an engine.

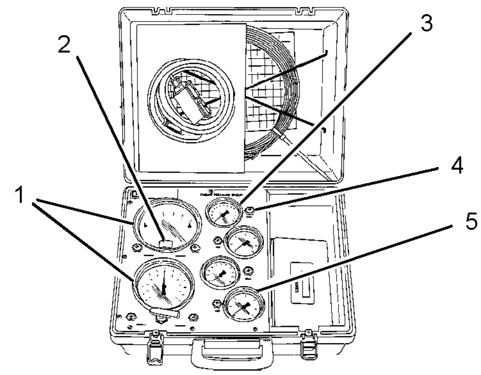


Illustration 35 g01192577

1U-5470 Engine Pressure Group

(1) Pressure indicators
(2) Zero adjustment screw
(3) Pressure indicator
(4) Pressure tap
(5) Pressure indicator

The Special Instruction, SEHS8907 is provided with the tool group.

The fuel pressure regulating valve keeps the pressure in fuel manifolds between 415 to 450 kPa (60 to 65 psi).

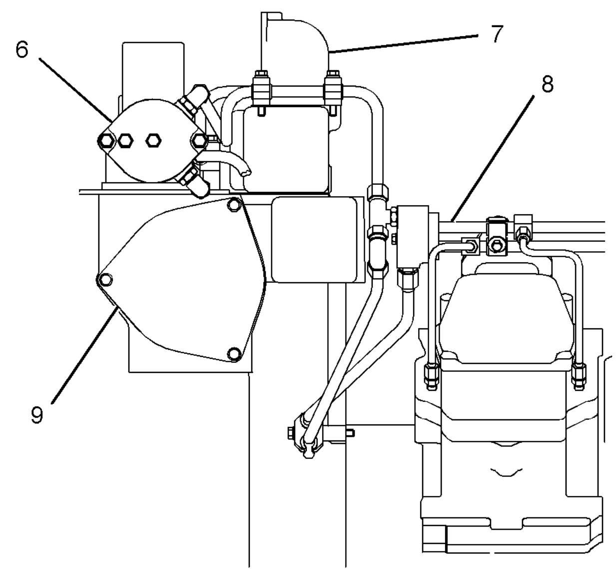


Illustration 36 g01192601

(6) Secondary fuel filter
(7) Regulator housing
(8) Fuel manifold
(9) Oil filter

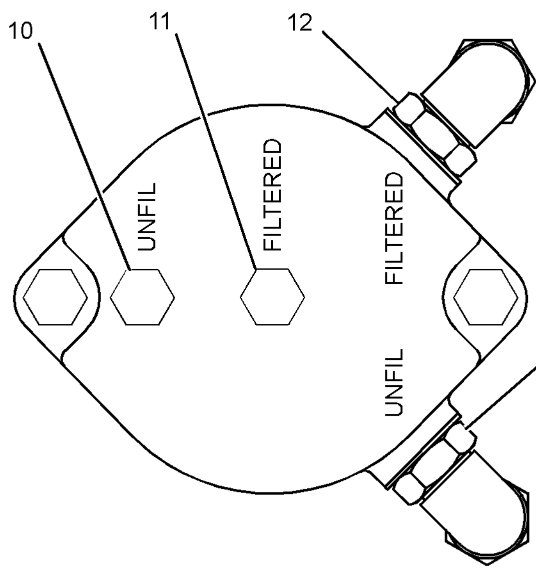


Illustration 37 g01192612

(10) Plug (port for unfiltered fuel pressure)
(11) Plug (port of filtered fuel pressure)
(12) Fuel outlet to the fuel manifolds (filtered fuel)
(13) Fuel inlet from the fuel transfer pump (unfiltered fuel)

Use the following procedure to connect the 1U-5470 Engine Pressure Group:

1. Remove plugs (10) and (11) from the secondary fuel filter housing cover.

2. Install 5P-5528 O-Ring Adapters at the location for the plugs.

3. Connect the 1U-5470 Engine Pressure Group to the O-Ring Adapters at the location of the plugs (10) and (11). Use the fittings and the nylon tubing that is provided with the Engine Pressure Group in order to connect to the O-Ring Adapters.

The fuel pressure from the fuel transfer pump can be checked at the location of plug (10). The fuel pressure to the fuel manifold can be checked at the location of plug (11). The fuel filter differential pressure can be checked from the difference in fuel pressure between the location of plug (10) and the location of plug (11).

i02344914

Fuel Injector Trim Code

SMCS Code: 1290

During the manufacturing process, a four digit code is etched on the top surface of the injector's tappet in order to designate the trim code of the injector.

The code for each injector is programmed into the engine's ECM during the manufacture of the engine.

When an injector is serviced, the new injector's trim code must be programmed into the engine's ECM. The trim code is programmed within the calibration menu that is in the Caterpillar Electronic Technician (ET). If the new code is not entered, the previous injector's characteristics are assumed.

Note: Reprogram the new code as soon as possible. This will optimize the engine's performance. This will also prevent any detrimental effects.

i02389395

Finding the Top Center Position for the No. 1 Piston

SMCS Code: 1105-531

Table 2

Tools Needed	Quantity
9S-9082 Engine Turning Tool	1

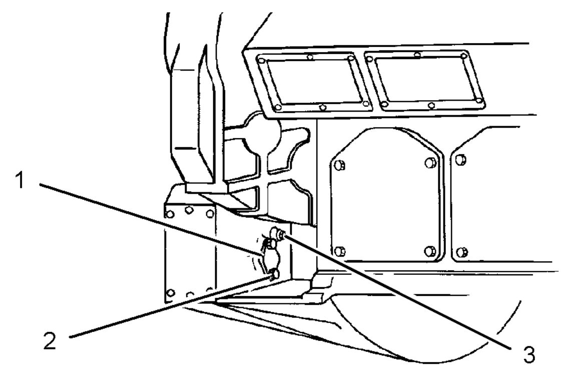


Illustration 38 g01193047

Timing bolt location (typical example)

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

1. Remove cover (1) and plug (3) from the right front side of the flywheel housing.

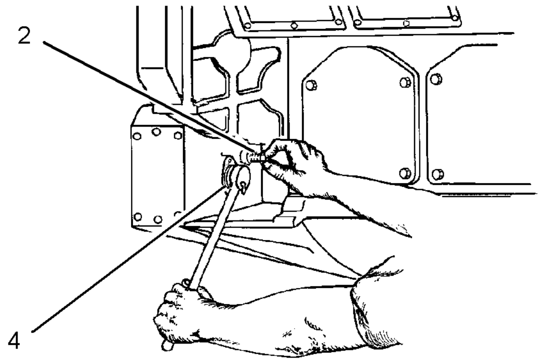


Illustration 39 g01193048

Timing bolt installation (typical example)

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

2. Put timing bolt (2) through the timing hole in the flywheel housing. Use the 9S - 9082 Engine Turning Tool (4) and a ratchet wrench with a 1/2 inch drive in order to turn the flywheel in the direction of normal engine rotation. Turn the flywheel until the timing bolt engages with the hole in the flywheel.

Note: If the flywheel is turned beyond the point of engagement, the flywheel must be turned in the direction that is opposite of normal engine rotation. Turn the flywheel by approximately 30 degrees. Then turn the flywheel in the direction of normal engine rotation until the timing bolt engages with the threaded hole. This procedure will remove the play from the gears when the No. 1 piston is on the top center.

3. Remove the valve cover for the No. 1 cylinder head.

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 cannot be moved and the valves are slightly open, the No. 1 piston is on the exhaust stroke. Find the cylinders that need to be checked or adjusted for the stroke position of the crankshaft after the timing bolt has been installed in the flywheel. Refer to Testing and Adjusting, “Crankshaft Position for Fuel Injector Adjustment and Valve Lash Setting”.

Note: When the actual stroke position is identified and the other stroke position is needed, remove the timing bolt from the flywheel. Turn the flywheel by 360 degrees in the direction of normal engine rotation.

i01939027

Camshaft Timing

SMCS Code: 1210

Timing Check

Table 3

Tools Needed	Quantity
9S - 9082 Engine Turning Tool	1

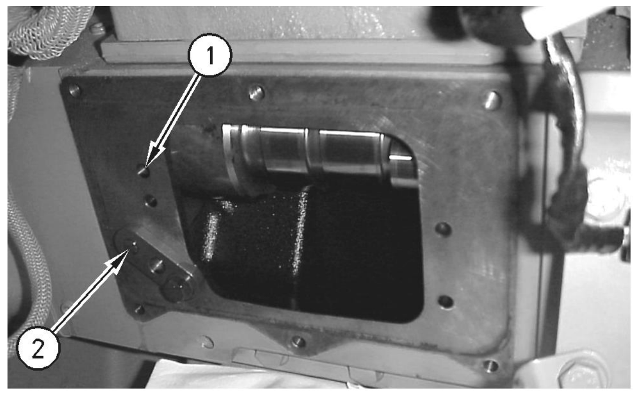


Illustration 40 g00793695

Location of timing pins (typical example)

(1) Timing hole
(2) Timing pin

1. Remove the rear camshaft covers from both sides of the engine.

2. Refer to Testing and Adjusting, “Finding the Top Center Position for the No. 1 Piston”.

Note: When the timing bolt is installed in the flywheel, it is not necessary to remove the No. 1 valve cover in order to find the compression stroke. Both of the rear camshaft covers must be removed in order to check the timing.

3. When the timing bolt is installed in the flywheel, look at the rear end of the camshaft. If the timing ring is visible, then the No. 1 piston is on the compression stroke. If the timing ring is not visible, then feel the back of the camshaft for the groove. If the groove is at the back of the camshaft, then the flywheel must be turned by 360 degrees in order to put the No. 1 piston on the compression stroke.

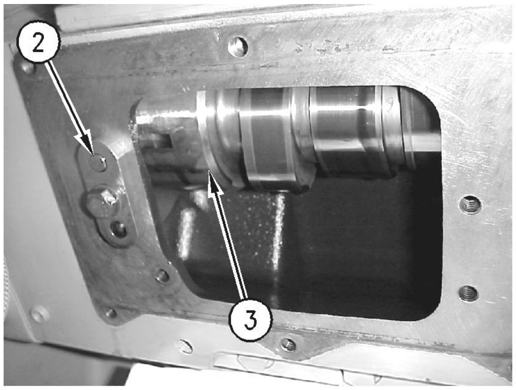


Illustration 41 g00793673

Installation of timing pins (typical example)

(2) Timing pin
(3) RH Camshaft

4. When the timing bolt is installed in the flywheel and the No. 1 piston is on the compression stroke, remove timing pins (2) from the storage positions.

5. Install timing pins (2) through timing holes (1) in the engine block. Install timing pins (2) into the groove in camshaft (3) on each side of the engine. In order to time the engine correctly, the timing pins must fit into the groove of each camshaft.

6. If timing pins (2) do not engage in the grooves of both camshafts, then the engine is not in time, and one or both camshafts must be adjusted.

7. Both camshafts are adjusted in the same manner. See "Timing Adjustment" for the procedure to put the camshafts in time with the crankshaft.

NOTICE

If a camshaft is out of time more than 18 degrees (approximately 1/2 the diameter of timing pin out of groove), the valves can make contact with the pistons. This will cause damage that will make engine repair necessary.

Timing Adjustment

Table 4

Tools Needed	Quantity
9S-9082 Engine Turning Tool	1
6V-3010 Puller Group	1
8S-9089 Bolts	2
5P-1076 Hard Washers	2

Note: The timing must be checked before the timing adjustments are made. See "Timing Check" for this procedure.

After the Timing Check procedure is complete, the timing bolt will be engaged in the flywheel. The No. 1 piston will be at the top center (TC) position.

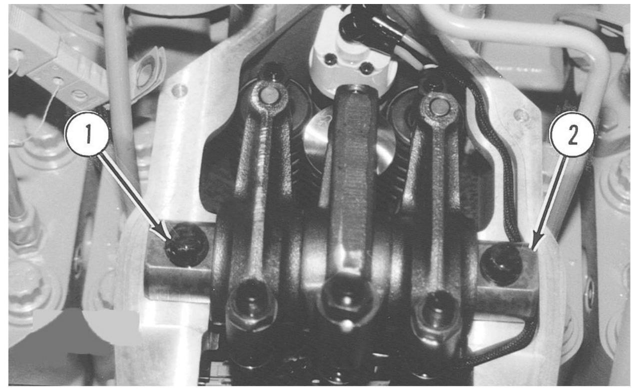


Illustration 42 g00284803

Rocker shafts (typical example)

(1) Bolt
(2) Rocker shaft

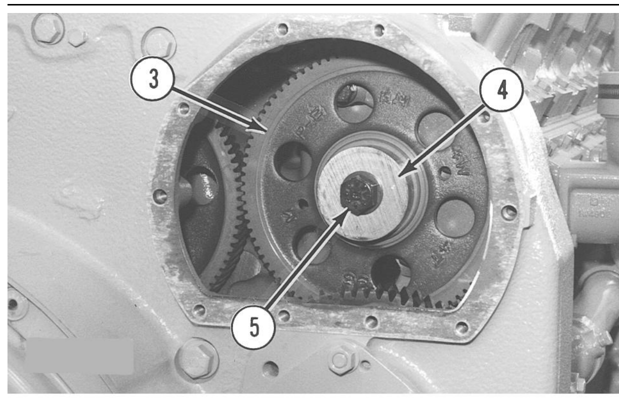


Illustration 43 g00284804

Camshaft drive gears (RH side)

(3) Drive gear
(4) Plate
(5) Bolt

1. Remove all of the valve covers on the side for the camshaft adjustment. Loosen bolts (1) that hold rocker shafts (2) to the valve cover bases until all rocker arms are free from the injectors and the valves.

Note: The above procedure must be done before camshaft drive gear (3) is pulled off the camshaft taper.

2. Remove the covers from the flywheel housing.

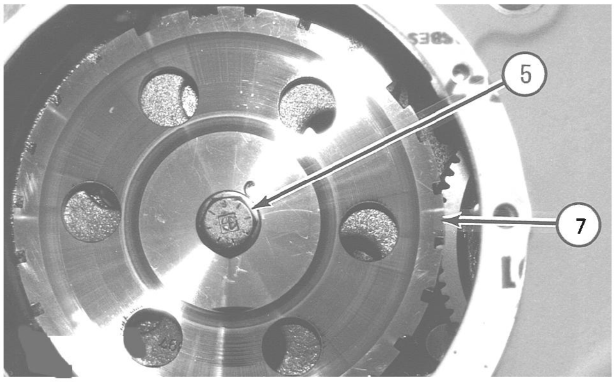


Illustration 44 g00793811

Camshaft drive gears (LH side)

(5) Bolt
(7) Timing ring

3. Remove bolts (5) and plate (4) on the RH side, and timing ring (7) on LH side.

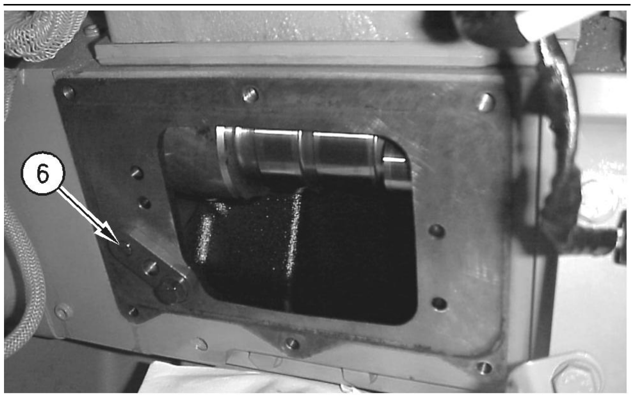


Illustration 45 g00793793

Storage position for timing pins (typical example)

(6) Timing pin

4. Install the 6V-3010 Puller Group, two 8S-9089 Bolts, and two 5P-1076 Hard Washers. Loosen drive gears (3) from the taper on the camshafts. Remove the engine turning tool and the gears.

5. Remove timing pins (6) from the storage position on each side of the engine.

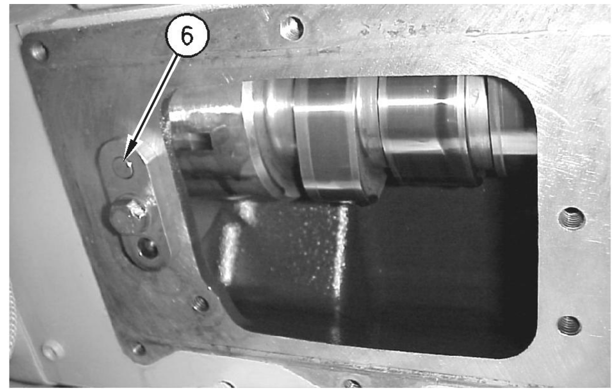


Illustration 46 g00793706

Installed camshaft timing pin (typical example)

(6) Timing pin

6. Turn the camshafts until timing pins (6) can be installed through the engine block and into the grooves (slots) in the camshafts.

7. Clean the camshaft taper and the inside diameter of the camshaft gear in order to remove any oil that may be present.

8. Put camshaft drive gears (3) in position on the camshafts.

9. Use hand pressure to turn and hold the camshaft drive gears in the opposite direction of the rotation. This removes all gear clearance (backlash) between the camshaft drive gears (3) and the idler gears.

10. Install plate (4) on the RH side. Install timing ring (7) on the LH side in order to hold camshaft drive gears (3) to each camshaft.

11. Tighten bolts (5) in steps to a torque of 360 ± 40 N·m (270 ± 30 lb ft).

12. Tap bolts (5). Tighten the bolts (5) to a torque of 360 ± 40 N·m (270 ± 30 lb ft).

Note: If necessary, repeat Step 12until the torque does not change.

13. Install the gaskets and covers on the flywheel housing.

14. Remove timing pins (6) from the camshafts. Install timing pins (6) in the storage positions. Install the covers over the camshafts and timing pins (6).

15. Remove the timing bolt from the flywheel housing. Install the 8T-6765 Pipe Plug in the flywheel housing timing hole. Remove the engine turning tool. Install the cover and the gasket.

16. Be certain that the rocker arms are correctly engaged with the pushrods. Tighten the bolts in order to hold all of the rocker shafts in position.

17. Make adjustments to the valves and to the lash of the electronic fuel injector. See Testing And Adjusting, "Valve Lash and Valve Bridge Adjustment" and Testing And Adjusting, "Fuel Injector Adjustment" for the correct procedures.

i02495030

Fuel Injector Adjustment

SMCS Code: 1290-025

Table 5

Tools Needed	Quantity
9U-5132 Engine Timing Tool Group	1
6V-3075 Dial Indicator	1
8S-3675 Indicator Contact Point	1
9U-5138 Setting Gauge	1
9U-5137 Magnetic Fixture	1
122-0451 Timing Fixture Rod	1
122-0449 Rod Sleeve Extension	1
9U-6272 Nylon Screw	1

NOTICE

The camshafts must be correctly timed with the crankshaft before an adjustment of the unit injector lash is made. The timing pins must be removed from the camshafts before the crankshaft is turned or damage to the cylinder block will be the result.

⚠ WARNING

The Electronic Control module produces high voltage. To prevent personal injury make sure the Electronic Control Module is not powered and the unit injector solenoids are disconnected.

Note: Calibration of the engine speed/timing sensor is not required unless the timing wheel has been removed from the camshaft or the Electronic Control Module (ECM) has been changed.

This adjustment is critical. Ensure that the adjustment of the fuel injector is made properly.

1. Refer to Testing and Adjusting, "Crankshaft Position for Fuel Injector Adjustment and Valve Lash Setting". All of the injectors can be checked or adjusted with the two crankshaft positions in the chart. This will make sure that the pushrod lifters are off of the lobes and on the base circles of the camshaft.

Before a check or an adjustment can be made, the tooling must be set to the correct dimension.

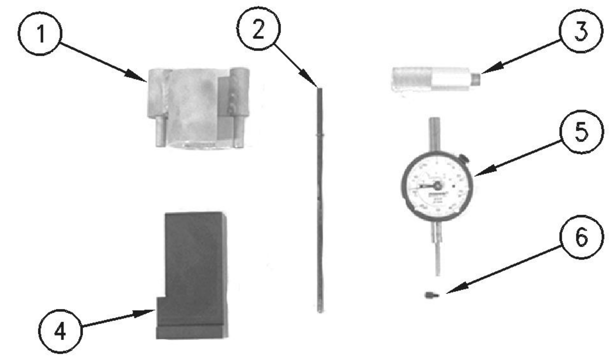


Illustration 47 g00284808

(1) 9U-5137 Magnetic Fixture
(2) 122-0451 Timing Fixture Rod
(3) 122-0449 Rod Sleeve Extension
(4) 9U-5138 Setting Gauge
(5) 6V-3075 Dial Indicator
(6) 8S-3675 Indicator Contact Point

2. Place rod (2) in fixture (1). Install extension (3) on fixture (1). Install contact point (6) on dial indicator (5). Install dial indicator (5) in extension (3).

3. Make sure that the surfaces of the fixture (1) and gauge (4) are clean and dry.

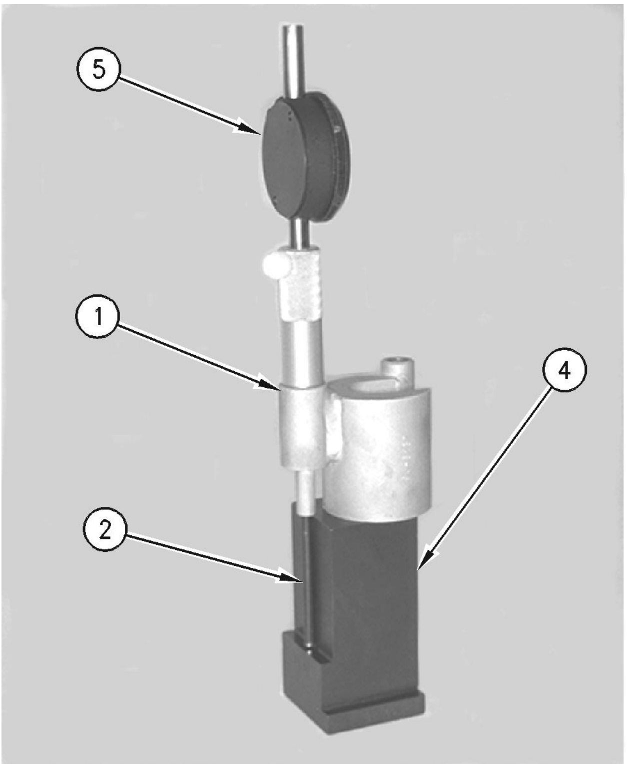


Illustration 48 g00284810

Adjustment of the fuel timing tools

(1) 9U-5137 Magnetic Fixture
(2) 122-0451 Timing Fixture Rod
(4) 9U-5138 Setting Gauge
(5) 6V-3075 Dial Indicator

4. Place dial indicator assembly from Step 2on the top surface of gauge (4). Rod (2) must be on the top step of gauge (4).

Note: Gauge (4) has two steps. Make sure that the step designation is for the 64.34 mm (2.53 inch) dimension.

5. Loosen the nylon screw for the dial face of dial indicator (5). Move the dial face of the dial indicator (5) in rod sleeve extension (3) until all of the pointers indicate zero. Tighten the nylon screw for the dial face of dial indicator (5).

6. Make sure that the top surfaces of injector follower (7) and shoulder (8) are clean and dry.

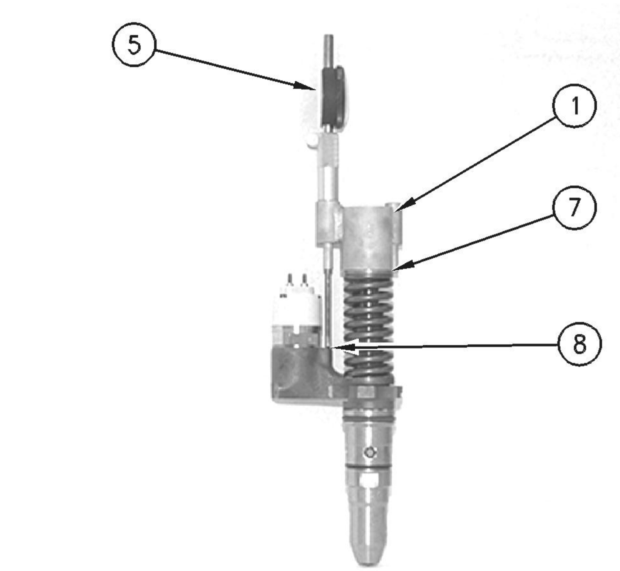


Illustration 49 g00284831

Fuel timing tools in position

(1) 9U-5137 Magnetic Fixture
(5) 6V-3075 Dial Indicator
(7) Injector follower
(8) Shoulder

7. Place dial indicator (5) and fixture (1) in position on the injector that will be checked. Make sure that the magnetic base of the fixture is on the top surface of injector follower (7). Rod (2) must be on the top surface of shoulder (8).

8. The dial indicator pointers must indicate 0.00 ± 0.20 mm (0.000 ± 0.008 inch).

9. If the dial indicator pointers indicate 0.00 ± 0.20 mm (0.000 ± 0.008 inch), no adjustment is necessary. Proceed to the next injector to be checked. Repeat the procedure from Step 4. If the dial indicator pointers do not indicate 0.00 ± 0.20 mm (0.000 ± 0.008 inch), proceed to Step 10and Step 11.

10. Loosen the adjustment screw locknut for the injector that is being adjusted.

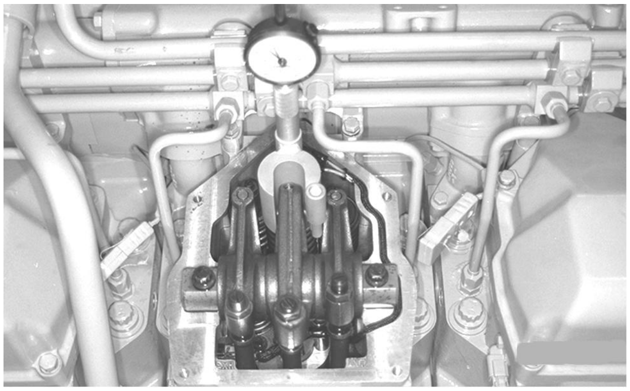


Illustration 50 g00284832

The installed timing and fuel setting tool group

11. Turn the adjustment screw until the dial indicator pointers indicate 0.00 ± 0.20 mm (0.000 ± 0.008 inch). Tighten the adjustment screw locknut to the torque that is listed in the engine's Specifications manual. Then check the adjustment in order to be certain that the adjustment has not changed. If necessary, repeat this procedure until the adjustment is correct. When the adjustment is correct, proceed to the next injector to be checked. Repeat the procedure from Step 3.

12. After all injectors are checked and/or adjusted, remove the timing bolt from the flywheel.

i02458438

Crankshaft Position for Fuel Injector Adjustment and Valve Lash Setting

SMCS Code: 1202

Table 6

Counterclockwise rotation (Standard) from the flywheel end of the engine				
Cylinders to Check/Adjust				
Engine	**Correct Stroke For No. 1 Piston At Top Center Position(1)**	**Inlet Valves**	**Exhaust Valves**	**Injectors**
3508	Compression	1-2-6-8	1-2-3-7	2-3-4-7
	Exhaust	3-4-5-7	4-5-6-8	1-5-6-8
3512	Compression	1-3-6-7-10-12	1-4-5-6-9-12	2-4-5-8-9-11
	Exhaust	2-4-5-8-9-11	2-3-7-8-10-11	1-3-6-7-10-12
3516	Compression	1-2-5-7-8-12-13-14	1-2-3-4-5-6-8-9	3-4-6-9-10-11-15-16
	Exhaust	3-4-6-9-10-11-15-16	7-10-11-12-13-14-15-16	1-2-5-7-8-12-13-14

(1) Put the No. 1 Piston at the top center (TC) position and identify the correct stroke. Refer to Testing and Adjusting, "Finding the Top Center Position for the No 1 Piston". Find the top center position for a particular stroke and make the adjustment for the correct cylinders. Remove

(Table 6, contd)

the timing bolt . Turn the flywheel by 360 degrees in the direction of normal engine rotation. This will put the No. 1 piston at the top center (TC) position on the other stroke. Install the timing bolt in the flywheel and complete the adjustments for the cylinders that remain.

Table 7

Clockwise rotation (Reverse) from the flywheel end of the engine				
Cylinders To Check/Adjust				
Engine	**Correct Stroke For No. 1 Piston At Top Center Position**(1)	**Inlet Valves**	**Exhaust Valves**	**Injectors**
3508	Compression	1-3-4-8	1-2-7-8	2-6-7-8
	Exhaust	2-5-6-7	3-4-5-6	1-3-4-5
3512	Compression	1-3-4-6-7-12	1-4-5-8-9-12	2-5-8-9-10-11
	Exhaust	2-5-8-9-10-11	2-3-6-7-10-11	1-3-4-6-7-12
3516	Compression	1-2-5-6-7-8-13-14	1-2-3-4-5-6-9-10	3-4-9-10-11-12-15-16
	Exhaust	3-4-9-10-11-12-15-16	7-8-11-12-13-14-15-16	1-2-5-6-7-8-13-14

(1) Put the No. 1 Piston at the top center (TC) position and identify the correct stroke. Refer to Testing and Adjusting, "Finding the Top Center Position for the No 1 Piston". Find the top center position for a particular stroke and make the adjustment for the correct cylinders. Remove the timing bolt . Turn the flywheel by 360 degrees in the direction of normal engine rotation. This will put the No. 1 piston at the top center (TC) position on the other stroke. Install the timing bolt in the flywheel and complete the adjustments for the cylinders that remain.

Air Inlet and Exhaust System

i02006852

Restriction of Air Inlet and Exhaust

SMCS Code: 1050-040

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

The air flow through the air cleaner may have a restriction. The maximum inlet air restriction is 6.2 kPa (25 inch of H_2O).

Back pressure is the difference in the pressure between the exhaust at the outlet elbow and the atmospheric pressure. The maximum exhaust back pressure is 6.5 kPa (27 inch of H_2O).

i01939065

Measuring Inlet Manifold Pressure

SMCS Code: 1058-082

The performance of an engine can be checked. Determine the boost pressure in the inlet manifold during a load test. Compare this pressure with the specifications that are given in the Fuel Setting and Related Information in the Technical Marketing Information (TMI). This test is used when there is an increase in exhaust temperature to the turbocharger on the engine, yet there is no real sign of a problem with the engine.

The performance and correct pressure for the inlet manifold is given in the Fuel Setting and Related Information in the TMI. Development of this information is done with these conditions:

- The dry barometric pressure measures 96 kPa (28.8 inches Hg).
- 25 °C (77 °F) outside air temperature
- 35 API rated fuel

Any change from these conditions can change the pressure in the inlet manifold. The outside air may have a higher temperature and a lower barometric pressure than the values that are given above. This will cause a lower inlet manifold pressure measurement than the pressure that is given in the TMI. Outside air that has a lower temperature and a higher barometric pressure will cause a higher inlet manifold pressure measurement.

A difference in fuel density will change horsepower and boost. If the fuel is rated above 35 API, the pressure in the inlet manifold can be less than the pressure that is given in the TMI. If the fuel is rated below 35 API, the pressure in the inlet manifold can be more than the pressure that is given in the TMI.

Be sure that the air inlet or the exhaust does not have a restriction when you are making a check of the pressure.

Note: The electronic service tool may be used to check the pressure in the inlet manifold.

i02392188

Measuring Exhaust Temperature

SMCS Code: 1088-082

Table 8

Tools Needed	Qty
4C-6090 Temperature Selector Group	1
6V-9130 Temperature Adapter	1
237-5130 Digital Multimeter Gp	1

Use the Caterpillar Electronic Technician (ET) to monitor individual cylinder exhaust temperatures, the exhaust temperature to the turbocharger, and the exhaust temperature after the turbocharger.

The temperatures can be verified with the 4C-6090 Temperature Selector Group, with the 6V-9130 Temperature Adapter, and with the 237-5130 Digital Multimeter. Refer to Operating Manual, NEHS0537 for the complete operating instructions for the 4C-6090 Temperature Selector Group.

i01939100

Crankcase Pressure

SMCS Code: 1215; 1317-082

The Caterpillar Electronic Technician (ET) can be used to measure crankcase pressure. Crankcase pressure is given on the display status screen in Cat ET. The Electronic Control Module (ECM) will perform any of the following functions if the crankcase pressure is high in the engine: warning, derate, and shutdown. The response will depend on the programming and the availability of the parameter of the monitoring system. Refer to the Testing and Adjusting, "Monitoring System Parameters" in this manual for information on programming the monitoring system.

Pistons or rings that have damage can be the cause of too much pressure in the crankcase. This condition will cause the engine to run rough. There will be more than the normal amount of fumes coming from the crankcase breather. This crankcase pressure can also cause the element for the crankcase breather to have a restriction in a very short time. This crankcase pressure can also be the cause of any oil leakage at the gaskets and at the seals that would not normally have leakage.

i02013998

Valve Lash and Valve Bridge Adjustment

SMCS Code: 1102-036

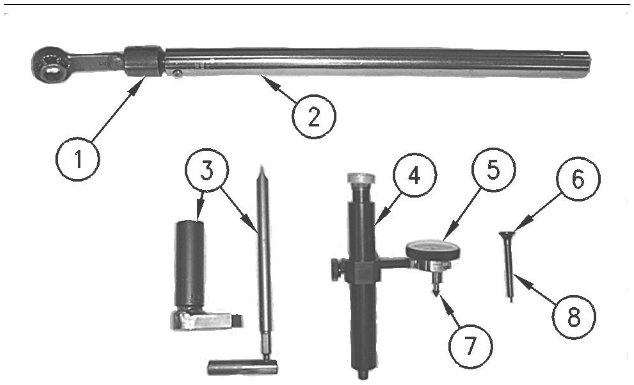


Illustration 51 g00286271

(1) 147-2060 Wrench
(2) 147-2059 Torque Wrench
(3) 148-7211 Bridge Nut Socket
(4) 145-5191 Gauge Support
(5) 147-2056 Dial Indicator
(6) 147-5536 Indicator Contact Point
(7) 147-2057 Indicator Contact Point
(8) 147-2058 Indicator Extension

Table 9

Tools Needed	Quantity
147-2060 Wrench	1
147-2059 Torque Wrench	1
148-7211 Bridge Nut Socket	1
145-5191 Gauge Support	1
147-2056 Dial Indicator	1
147-5536 Indicator Contact Point	1
147-2057 Indicator Contact Point	1
147-2058 Indicator Extension	1
147-5537 Dial Indicator (not shown)	1

Note: The 145-5191 Gauge Support (4), the 147-2057 Indicator Contact Point (7), the 147-2058 Indicator Extension (8), and the 147-5536 Indicator Contact Point (6) are included in the 147-5482 Valve Lash Gauge Group.

Note: The 147-2056 Dial Indicator or the 147-5537 Dial Indicator (Metric, not shown) can be used with the 147-5482 Valve Lash Gauge Group.

There are two different design of valve bridges that are used. If the engine is equipped with an adjustable valve bridge (Illustration 52), proceed to the "Valve Bridge Adjustment". If the engine is equipped with a nonadjustable valve bridge (Illustration 53), proceed to the "Valve Lash Adjustment".

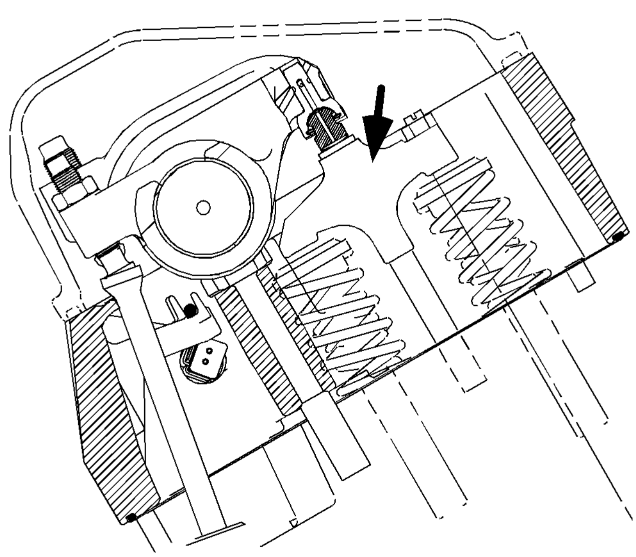


Illustration 52 g01034327

Adjustable valve bridge

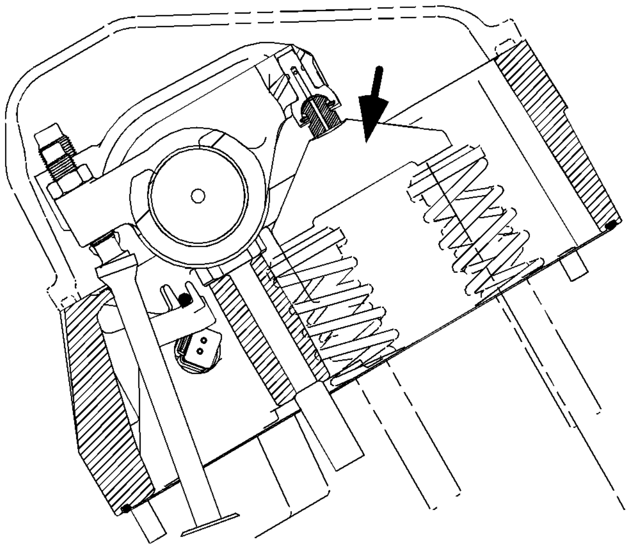


Illustration 53 g01034328

Nonadjustable valve bridge

Valve Bridge Adjustment

⚠ WARNING

The Electronic Control Module produces high voltage. To prevent personal injury make sure the Electronic Control Module is not powered and do not come in contact with the fuel injector solenoid terminals while the engine is running.

Note: When the 147-5482 Valve Lash Gauge Group is used, it is not necessary for you to remove the rocker arm shaft assemblies. The valves must be fully closed when the adjustment is made. Refer to Testing and Adjusting, "Finding the Top Center Position for the No. 1 Piston".

Installation

1. Assemble the 147-2058 Indicator Extension and the 147-5536 Indicator Contact Point on the 147-2056 Dial Indicator or on the 147-5537 Dial Indicator.

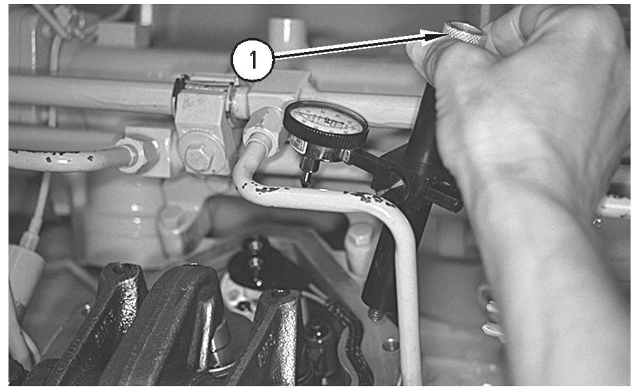


Illustration 54 g00286279

145-5191 Gauge Support

(1) Knurled knob

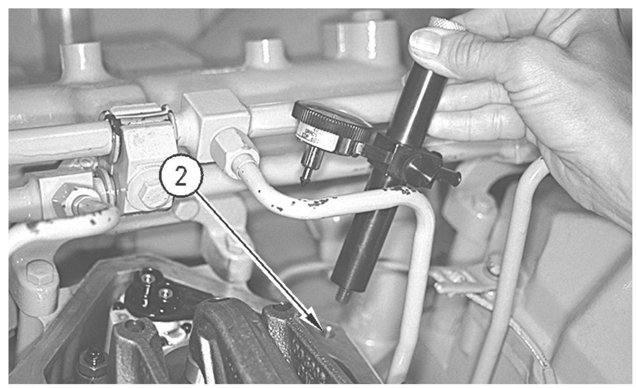


Illustration 55 g00286280

(2) Valve cover base rear bolt hole

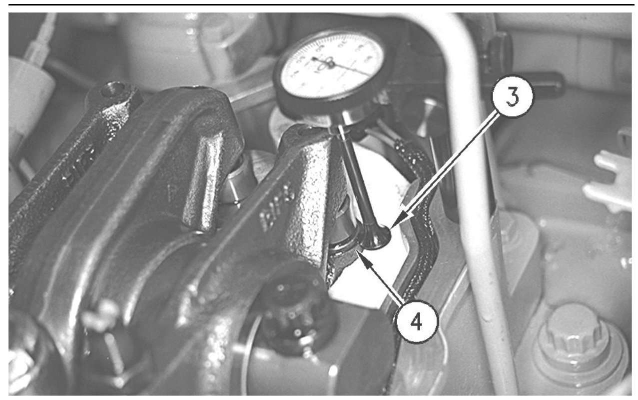


Illustration 56 g00286281

(3) 147-5536 Indicator Contact Point
(4) Top edge of the valve bridge

2. Install the 145-5191 Gauge Support in the rear bolt hole (2). The rear bolt hole is located in the valve cover base. Adjust contact point (3) on the top edge of valve bridge (4).

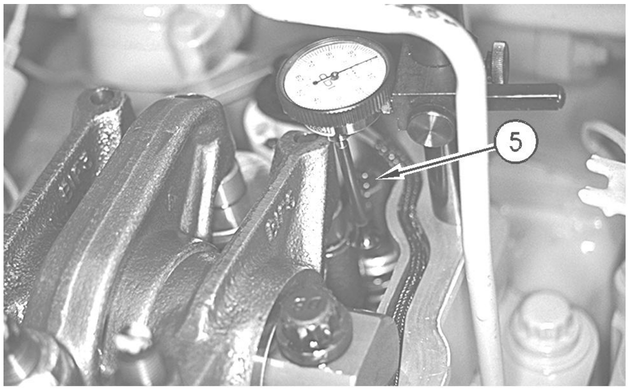


Illustration 57 g00286283

(5) Adjustment screw

3. Loosen the locknut for the adjustment screw. Loosen the adjustment screw (5) by several turns.

4. Apply a force of 5 N (1 lb) to 45 N (10 lb). Push down on the top contact surface of the valve bridge. Zero the indicator.

5. Turn adjustment screw (5) in the clockwise direction until the dial indicator reads 0.038 mm (0.0015 inch). This measurement is equal to turning the adjustment screw 20 to 30 degrees clockwise after the screw contacts the end of the valve.

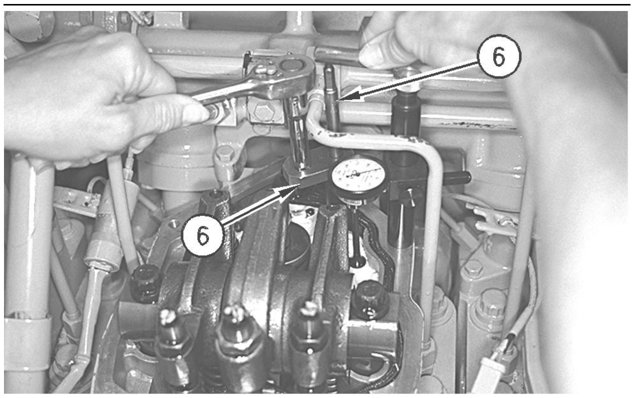


Illustration 58 g00286364

(6) 148 - 7211 Bridge Nut Socket

6. Hold the adjustment screw with the 148 - 7211 Bridge Nut Socket (6) in order to tighten the locknut to 30 ± 4 N·m (22 ± 3 lb ft). You may use a sliderule torque computer in order to determine the torque wrench dial reading for the different extensions. Refer to Special Instruction, SEHS7150, “Snap On Torque Computer”.

Valve Lash Adjustment

WARNING

The Electronic Control Module produces high voltage. To prevent personal injury make sure the Electronic Control Module is not powered and do not come in contact with the fuel injector solenoid terminals while the engine is running.

Note: Adjust the valve bridges before you make the valve lash adjustments.

Table 10

Valve Lash Setting: Engine Stopped	
Valves	**Gauge Dimension**
Inlet	0.50 mm (0.020 inch)
Exhaust	1.00 mm (0.040 inch)

1. Ensure that the number 1 piston is at the top center position. Refer to Testing and Adjusting , “Finding the Top Center Position for the No. 1 Piston”.

2. The number 1 piston should be at the top center position of the correct stroke. Make adjustments to the valves according to the chart: Refer to Testing and Adjusting, “Crankshaft Positions for Fuel Injector Adjustment and Valve Lash Setting”.

Note: Tap each rocker arm on the top of the adjustment screw before you make any adjustments. Use a soft hammer. Make sure that the lifter roller is seated against the base circle of the camshaft.

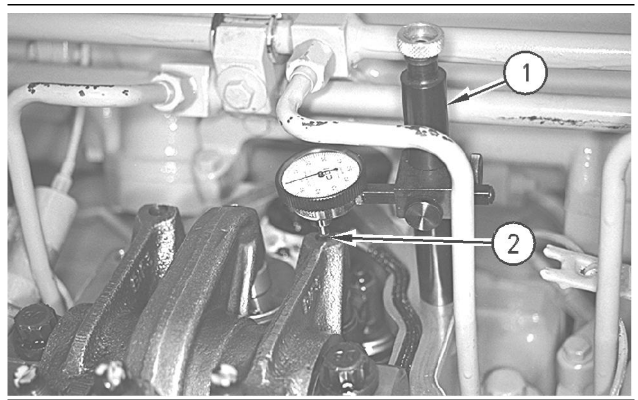


Illustration 59 g00286365

(1) 145 - 5191 Gauge Support
(2) 147 - 2057 Indicator Contact Point

3. Install the 145 - 5191 Gauge Support (1). Use the 147 - 2056 Dial Indicator or use the 147 - 5537 Dial Indicator. Use the 147 - 2057 Indicator Contact Point (2). Install the tool in the rear bolt hole. The rear bolt hole is located on the valve cover base.

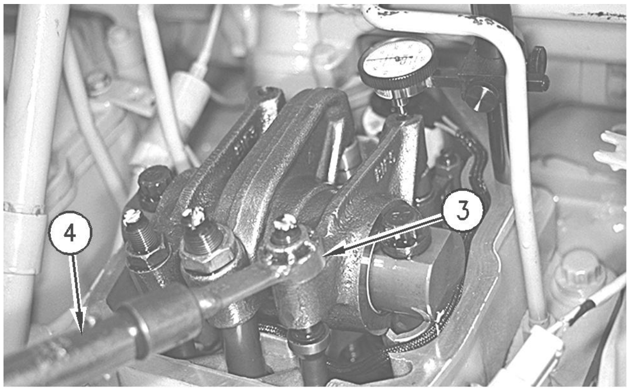


Illustration 60 g00286366

(3) 147-2060 Wrench
(4) 147-2059 Torque Wrench

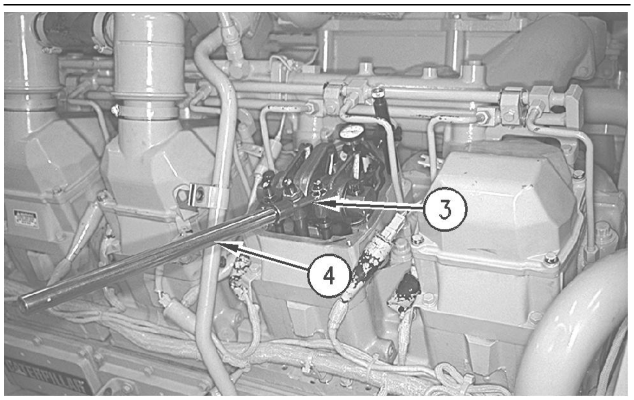


Illustration 61 g00286367

(3) 147-2060 Wrench
(4) 147-2059 Torque Wrench

4. Move the rocker assembly upward and move the rocker arm assembly downward. Move the rocker assembly several times. The oil film is removed in order to get a true zero reading on the dial indicator. Use the 147-2060 Wrench (3) and use the 147-2059 Torque Wrench (4). Install the socket wrench and install the torque wrench on the nut of the rocker arm. Apply upward pressure to the front of the rocker assembly. Set the dial indicator to zero. The weight of the torque wrench (4) allows the valve lash to be read. Do not apply any pressure on the torque wrench.

5. Loosen the locknut. The locknut is located on the adjustment screw of the pushrod. Turn the adjustment screw until the valve lash is set to specifications. Tighten the nut for the adjustment screw to 70 ± 15 N·m (50 ± 11 lb ft). The 147-2059 Torque Wrench is preset to the torque that is required. Check the adjustment again.

Lubrication System

i01574160

General Information (Lubrication System)

SMCS Code: 1300

The following problems generally indicate a problem in the engine's lubrication system.

- Excessive consumption of engine oil
- Low engine oil pressure
- High engine oil pressure
- Excessive bearing wear
- Increased engine oil temperature

i01939128

Engine Oil Pressure - Test

SMCS Code: 1304-081

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 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.

Table 11

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

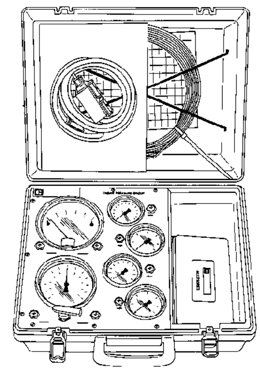


Illustration 62 g00296486

1U-5470 Engine Pressure Group

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

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

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

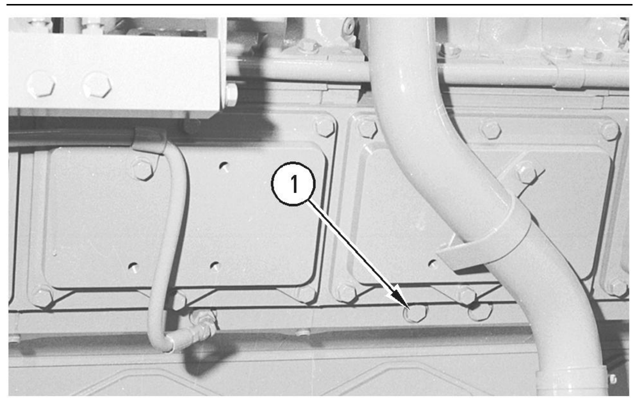


Illustration 63 g00751796

Location of the oil gallery plug

Typical example

(1) Plug

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

Note: Engine oil pressure to the camshaft and main bearings should be checked on each side of the cylinder block at 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, "Engine Oil" 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 engine oil pressure on the engine oil pressure graph.

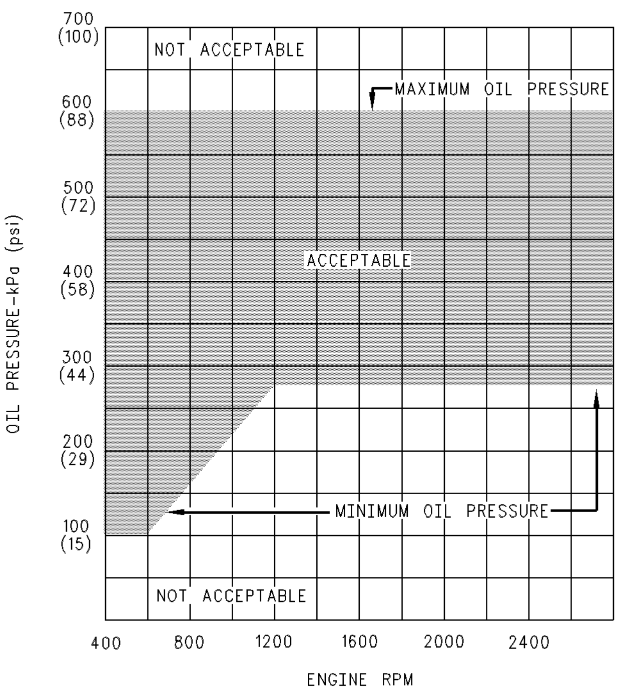


Illustration 64 g00293198

Engine oil pressure graph

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 engine oil pressure suddenly increases or decreases 70 kPa (10 psi) and the engine 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 engine oil pressure indicators on the instrument panel and the engine oil pressure that is displayed on the 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 engine oil pressure or a high engine oil pressure. If there is a notable difference between the engine oil pressure readings make necessary repairs.

8. If the engine oil pressure is low, refer to Testing and Adjusting, "Engine Oil Pressure is Low" for the possible causes of low engine oil pressure.

9. If the engine oil pressure is high, refer to Testing and Adjusting, "Engine Oil Pressure is High" for the possible causes of high engine oil pressure.

i01563191

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 a passage for engine oil.

An indicator for the engine oil pressure may show that there is enough engine oil pressure, but a component is worn due to a lack of lubrication. In such a case, look at the passage for the engine oil supply to the component. A restriction in an engine 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.

i01727302

Increased Engine Oil Temperature - Inspect

SMCS Code: 1348-040

If the engine oil temperature is higher than normal, the engine oil cooler may have a restriction. Look for a restriction in the passages for engine oil in the engine oil cooler. The engine oil pressure will not necessarily decrease due to a restriction in the engine oil cooler.

Determine if the engine oil cooler bypass valve is held in the open position. This condition will allow the engine oil to flow through the valve rather than through the engine oil cooler. The engine oil temperature will increase.

Make sure that the cooling system is operating properly. A high coolant temperature in the engine oil cooler will cause high engine oil temperature.

i01220083

Engine Oil Pressure is Low

SMCS Code: 1304-081

Crankcase Oil Level

Check the level of the oil in the crankcase. Add oil if oil is needed. It is possible for the oil level to 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.

This engine also uses a scavenge oil pump to move trapped oil from the rear of the engine back to the main sump at the front. Be sure that this oil pump operates correctly in order to maintain a sufficient oil level for the main oil pump supply tube.

The Oil Pump Does Not Work Correctly

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

Oil Filter Bypass Valve

If the bypass valve for one or more of the oil filters is held in the open position due to a restriction, an increase in the oil pressure can be the result. 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 Caterpillar oil filters. New filters will prevent more debris from causing this problem.

Too Much Clearance At Engine Bearings Or Open Lubrication System

Components that are worn and components that have too much bearing clearance can cause low oil pressure. Low oil pressure can also be caused by an oil line or an oil passage that is open, broken, or disconnected.

Piston Cooling Jets

When the engine is operating, piston cooling jets direct oil toward the bottom of the piston in order to cool the piston. This also provides lubrication for the piston pin. If a jet is broken, plugged, or installed incorrectly, a seizure of the piston will occur quickly.

i01563187

Engine Oil Pressure is High

SMCS Code: 1314

The following conditions can cause high engine oil pressure:

- The engine oil level is too high. Drain the excess engine oil.
- The engine oil temperature is too low. Low engine oil temperature increases the viscosity of the engine oil.
- The engine oil filter bypass valve is stuck in the closed position. Thoroughly clean the valve. Replace the engine oil filters.
- A line or a passage for the engine oil is restricted. Clean the component.

i01939177

Indicators for Engine Oil Pressure

SMCS Code: 7485

An oil pressure indicator that has a defect or a sender that has a defect can give an indication of a low oil pressure or of a high oil pressure.

The 1U-5470 Engine Pressure Group can be used to compare the indicators on the instrument panel with the oil pressure that is displayed on the Caterpillar Electronic Technician (ET).

i01938599

Duplex Oil Filter - Adjust

SMCS Code: 1318-025

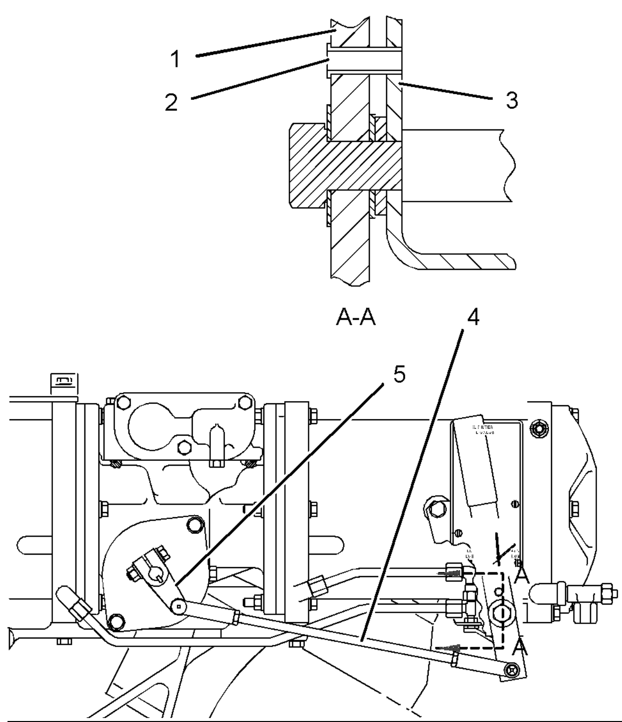


Illustration 65 g01008687

Front view

(1) Selector lever
(2) Plunger
(3) Bracket
(4) Rod
(5) Lever

Use the following procedure to adjust the changeover valve:

1. Rotate selector lever (1) to the "MAIN RUN" position until the changeover valve touches the stop pin that is inside of the cover assembly.

2. Screw plunger (2) into the selector lever until the plunger's ball seats into the top hole of bracket (3).

3. Adjust rod (4) and the rod ends in order to provide the linkage between the selector lever and lever (5).

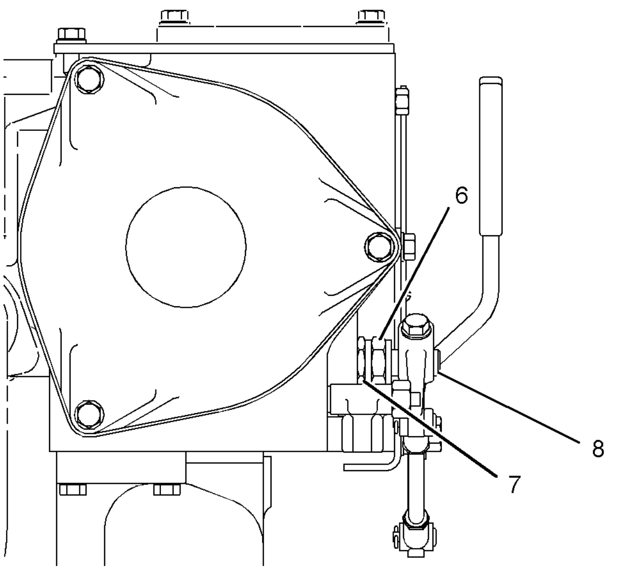


Illustration 66 g01008688

Right view

(6) Jam nut
(7) Nut
(8) Shaft

4. Loosen jam nut (6) and nut (7).

5. Tighten nut (7) to approximately 3 N·m (27 lb in). Scribe a mark in order to locate a corner of the nut. Unscrew the nut for 30 degrees in order to provide axial movement of shaft (8).

   Axial movement of shaft .... 0.22 ± 0.08 mm (0.009 ± 0.003 inch)

6. Use a wrench to hold nut (7) in place and tighten jam nut (6).

   Torque .... 45 ± 7 N·m (33 ± 5 lb ft)

7. Move the selector lever in order to move the changeover valve through the full range of travel.

   The properly adjusted changeover valve will move freely without binding.

   Readjust the changeover valve, if necessary.

Cooling System

i02225295

General Information (Cooling System)

SMCS Code: 1350

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

- The pressure helps prevent cavitation.
- The risk of boiling is reduced.

Cavitation occurs when mechanical forces cause the formation of air bubbles in the coolant. The bubbles can form on the cylinder liners. Collapsing bubbles can remove the oxide film from the cylinder liner. This allows corrosion and pitting to occur. If the pressure of the cooling system is low, the concentration of bubbles increases. The concentration of bubbles is reduced in a pressure type cooling system.

The boiling point is affected by three factors: pressure, altitude, and concentration of glycol in the coolant. The boiling point of a liquid is increased by pressure. The boiling point of a liquid is decreased by a higher altitude. Illustration 67shows the effects of pressure and altitude on the boiling point of water.

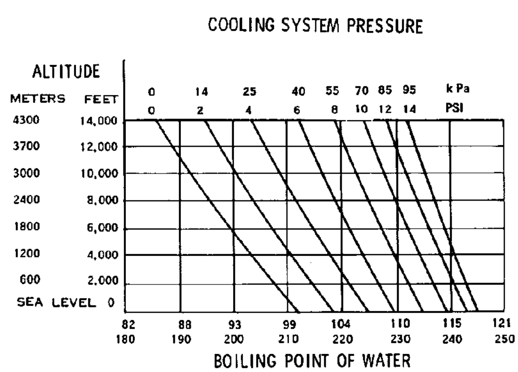


Illustration 67 g00286266

The boiling point of the coolant also depends on the type of coolant and the concentration of glycol. A greater concentration of glycol has a higher boiling temperature. However, glycol transfers heat less effectively than water. Because of the boiling point and the efficiency of heat transfer, the concentration of glycol is important.

Three basic problems can be associated with the cooling system:

- Overheating
- Coolant loss
- Overcooling

If the cooling system is not properly maintained, solids such as scale and deposits reduce the ability of the cooling system to transfer heat. The engine operating temperature will increase.

When the engine is overloaded, the engine will run in the lug condition. When the engine is running in the lug condition, the engine is operating at a lower engine rpm that reduces the coolant flow. Decreased coolant flow during high load will cause overheating.

Coolant can be lost by leaks. Overheated coolant can be lost through the cooling system's pressure relief valve. Lower coolant levels contribute to additional overheating. Overheating can result in conditions such as cracking of the cylinder head and piston seizure.

A cracked cylinder head or cylinder liner will force exhaust gas into the cooling system. The additional pressure causes coolant loss, cavitation of the water pump, less circulation of coolant, and further overheating.

Overcooling is the result of coolant that bypasses the water temperature regulators and flows directly to the radiator or to the heat exchanger. Low load operation in low ambient temperatures can cause overcooling. Overcooling is caused by water temperature regulators that remain open. Overcooling reduces the efficiency of operation. Overcooling enables more rapid contamination of the engine oil. This results in the formation of sludge in the crankcase and carbon deposits on the valves.

Cycles of rapid heating and cooling can result in cracked cylinder heads, gasket failure, accelerated wear, and excessive fuel consumption.

If a problem with the cooling system is suspected, perform a visual inspection before you perform any tests on the system.

i02577859

Visual Inspection

SMCS Code: 1350-535

Perform a visual inspection of the cooling system before a test is made with test equipment.

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. Add coolant, if necessary.

   If the coolant level is too low, air will get into the cooling system. Air in the cooling system reduces coolant flow. Air creates bubbles that contribute to cavitation. Bubbles in the coolant also reduce the cooling capability.

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 contamination
   - Properties that are recommended by the engine's Operation and Maintenance Manual

   If the coolant does not have these properties, drain the system and flush the system. Refill the cooling system according to the engine's Operation and Maintenance Manual.

3. Check for air in the cooling system. Air can enter the cooling system in different ways. The following conditions cause air in the cooling system:

   - Filling the cooling system incorrectly
   - Combustion gas leakage into the cooling system

   Combustion gas can get into the system through the following conditions: internal cracks, damaged cylinder head, and damaged cylinder head gasket.

4. Inspect the radiator (if equipped) and the air-to-air aftercooler (if equipped). Make sure that the air flow is not restricted. Look for the following conditions. Make corrections, if necessary:

   - Bent fins
   - Debris between the folded cores
   - Damaged fan blades

5. Check the heat exchanger (if equipped) for internal blockage. Make sure that the filters for the water are not clogged.

   The condition of the water that is circulated through the heat exchanger can decrease the effectiveness of the heat exchanger. Operating with water that contains the following types of debris will adversely affect the heat exchanger system: silt, sediment, salt, and algae. In addition, intermittent use of the engine will adversely affect the heat exchanger system.

6. Check the pressure cap.

   If the pressure cap does not maintain the correct pressure on the cooling system, the engine could overheat. A decrease in cooling system pressure reduces the temperature of the water's boiling point.

7. Inspect 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 restrict the coolant flow. Hoses can crack after a period of time. The inside of a hose can deteriorate and the loose particles of the hose can restrict the coolant flow.

8. Check the water temperature regulators.

   A water temperature regulator that does not open or a water temperature regulator that only opens part of the way can cause overheating.

   A water temperature regulator that does not close enables overcooling.

9. Check the engine water pump and check the auxiliary pump.

   A water pump with a damaged impeller does not pump enough coolant for correct coolant flow. This affects the engine's operating temperature. Remove the water pump and check for damage to the impeller.

10. Check the aftercooler.

    A restriction of water flow through the aftercooler can cause overheating. Check for debris or deposits which restrict the free flow of water through the aftercooler.

i02605557

Test Tools for the Cooling System

SMCS Code: 0781; 1350

Table 12

Tools Needed		Quantity
4C-6500	Digital Thermometer	1
285-0901	Blowby Tool Gp	1
285-0910	Multi-Tool Gp	1
9U-7400	Multitach Tool Gp	1
9S-8140	Pressurizing Pump	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 68 g00286267

4C-6500 Digital Thermometer

The 4C-6500 Digital Thermometer is used in the diagnosis of overheating conditions or overcooling problems. This group can be used to check temperatures in several different parts of the cooling system. Refer to the testing procedure in the Operating Manual, NEHS0554.

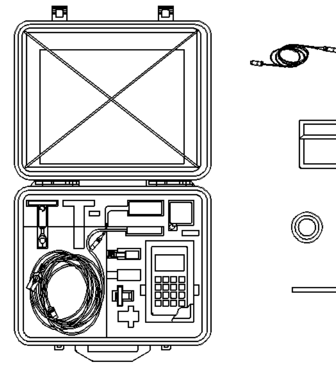


Illustration 69 g00286276

9U-7400 Multitach

The 9U-7400 Multitach is used to check the fan speed. Refer to the testing procedure in Operator Manual, NEHS0605.

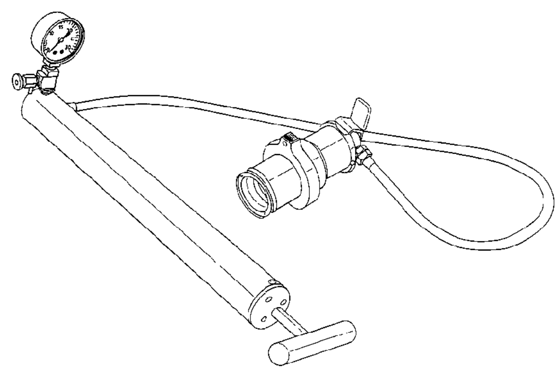


Illustration 70 g00286369

9S-8140 Pressurizing Pump

The 9S-8140 Pressurizing Pump is used to test pressure caps. The 9S-8140 Pressurizing Pump is used to pressure check the cooling system for leaks.

WARNING

Steam or hot coolant can cause severe burns.

Do not loosen the filler cap or the pressure cap on a hot engine.

Allow the engine to cool before removing the filler cap or the pressure cap.

i02492662

Testing the Cooling System

SMCS Code: 1350-081

Testing for Freeze Protection

Table 13

Tools Needed	Qty
245-5829 Coolant/Battery Tester Gp	1

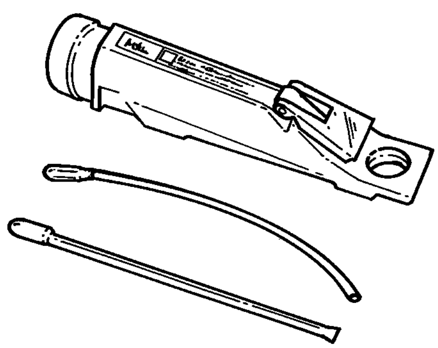


Illustration 71 g00439083

245-5829 Coolant/Battery Tester Gp

Check the coolant frequently in cold weather for the proper protection against freezing. Use the 245-5829 Coolant/Battery Tester Gp in order to ensure adequate freeze protection. The tester gives immediate, accurate readings. The tester can be used for antifreeze/coolants that contain ethylene or propylene glycol. The tester is also used to check the condition of batteries (specific gravity). Instructions are provided with the tester.

Making the Correct Antifreeze Mixtures

Adding pure antifreeze as a makeup solution for the cooling system top-off is an unacceptable practice. Adding pure antifreeze increases the concentration of antifreeze in the cooling system. This increases the concentration of the dissolved solids and the undissolved chemical inhibitors in the cooling system. Add the antifreeze and water mixture in the same concentration as your cooling system. Refer to the engine's Operation and Maintenance Manual.

Testing the Supplemental Coolant Additive and the Glycol

Refer to the engine's Operation and Maintenance Manual for further information about testing the cooling system.

Testing for Air and/or Exhaust Gas in the Coolant

Air and/or exhaust gas in the coolant causes foaming and aeration. Bubbles in the cooling system reduce the heat transfer and the pump flow. Pockets of air or gas can prevent coolant from contacting parts of the engine. The pockets allow hot spots to develop.

If the cooling system is not filled to the proper level or if the system is filled too quickly, air can be trapped in the system. Leaks from components such as aftercoolers and hoses can allow air to enter the system. The inlet of the water pump is a potential location for the entry of air.

To help prevent air from entering the cooling system, fill the system slowly. Make sure that all of the hoses and pipe connections are secure.

If the cylinder head is loose or cracked, exhaust gas can enter the cooling system. Exhaust gas can also enter the cooling system through internal cracks and/or defects in the cylinder head gasket.

Air and/or exhaust gas in the cooling system can cause overheating. Use the following test to check for the presence of air and/or exhaust gas in the coolant.

1. Make sure that the cooling system is filled to the proper level.

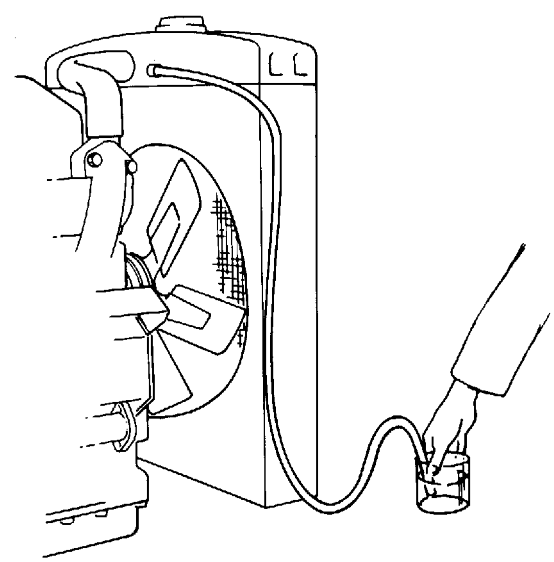


Illustration 72 g00769076

2. Remove the plug from the radiator (if equipped). Install a hose into the hole for the plug.

3. Fill a glass container with water and place the other end of the hose into the container.

4. Start the engine. Operate the engine until normal operating temperature is reached.

5. Observe the end of the hose in the glass container.

   A bubble may rise occasionally from the hose. This is normal.

   If a stream of bubbles rise from the hose, air and/or exhaust gas in the coolant is indicated.

Testing the Radiator Fan (If Equipped)

Table 14

Tools Needed	Quantity
9U-7400 Multitach Tool Gp	1

The 9U-7400 Multitach Tool Gp is used to check the fan speed. For instructions, refer to the Operating Manual, NEHS0605 that is supplied with the multitach.

Testing the Cooling System for Leaks

Table 15

Tools Needed	Qty
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. After the engine cools, carefully loosen the filler cap in order to release the pressure from the cooling system. Remove the filler cap.

2. Ensure that the cooling system is filled to the correct level.

3. Install the 9S-8140 Pressurizing Pump onto the radiator's filler tube.

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

5. Inspect the radiator, all connection points, and the hoses for leaks.

If no leaks are found and the gauge reading remains steady for a minimum of five minutes, the cooling system is not leaking.

If leaking is observed and/or the gauge reading decreases, make repairs, as needed.

i02005947

Coolant Temperature Sensor - Test

SMCS Code: 7453-081

⚠ WARNING

Personal injury can result from escaping fluid under pressure.

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

Table 16

Tools Needed		Quantity
4C-6500	Digital Thermometer	1
or		
2F-7112	Thermometer	1
6B-5072	Terminal Bushing	1

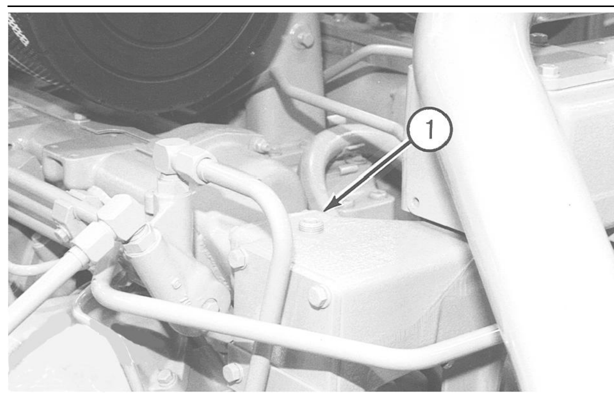


Illustration 73 g00769081

Test location

(1) Plug

If you suspect that the coolant temperature sensor is inaccurate, perform the following procedure:

Note: Ensure that the coolant level is at the correct level before performing this test.

1. Remove plug (1).

2. Install the 4C-6500 Digital Thermometer or the 2F-7112 Thermometer. Also install the 6B-5072 Terminal Bushing.

3. Connect the Caterpillar Electronic Technician (ET) to the service tool connector. Start Cat ET.

4. Start and run the engine until the temperature reaches the desired range according to the test thermometer.

5. Monitor the coolant temperature on Cat ET. Monitor the coolant temperature on the test thermometer.

6. Compare the coolant temperature on Cat ET to the coolant temperature on the test thermometer. If the two measurements are approximately equal, the sensor is okay. If the two measurements are not approximately equal, there may be a problem with the sensor. Install a new sensor and verify that the problem is resolved.

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.

Basic Engine

i01220459

Connecting Rod Bearings

SMCS Code: 1219-040

The connecting rod bearings fit tightly in the bore in the rod. If the bearing joints are fretted, check the bore size. This can be an indication of wear because of a loose fit.

Connecting rod bearings are available with 0.63 mm (0.025 inch) and 1.27 mm (0.050 inch) smaller inside diameter than the original size bearing. These bearings are for crankshafts that have been reground.

i01220466

Main Bearings

SMCS Code: 1203-040

Main bearings are available with a larger outside diameter than the original size bearings. These bearings are available for the cylinder blocks with the main bearing bore that is made larger than the bores' original size. The size that is available has a 0.63 mm (0.025 inch) outside diameter that is larger than the original size bearings.

Main bearings are available with 0.63 mm (0.025 inch) and 1.27 mm (0.050 inch) smaller inside diameter than the original size bearing. These bearings are for crankshafts that have been reground.

i01491831

Cylinder Block

SMCS Code: 1201-040

If the main bearing caps are installed without bearings, the bore in the block for the main bearings can be checked. Tighten the nuts that hold the caps to the torque that is shown in the Specifications. Alignment error in the bores must not be more than 0.08 mm (0.003 inch). Refer to Special Instruction, SMHS7606 for the use of the 1P-4000 Line Boring Tool Group for the alignment of the main bearing bores. The 1P-3537 Dial Bore Gauge Group can be used to check the size of the bores. The Special Instruction, GMG00981 is with the group.

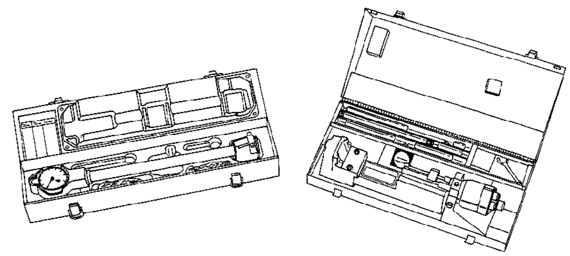


Illustration 74 g00285686

1P-3537 Dial Bore Gauge Group

i01263322

Cylinder Head

SMCS Code: 1100-040

The cylinder heads have valve seat inserts, valve guides, and bridge dowels that can be removed when the parts are worn or damaged. Refer to Disassembly And Assembly for the replacement of these components.

Valves

The removal and the installation of the valves is easier with use of the 1P-3527 Valve Spring Compressor.

Valve Seat Inserts

Use the 6V-4805 Valve Seat Extractor Tool Group for the removal and the installation of the valve seat inserts. Lower the temperature of the insert before the insert is installed in the head.

Valve Guides

The tools for the removal and for the installation of the valve guides are the 5P-1729 Valve Guide Bushing and the 7M-3975 Valve Guide Driver. The counterbore in the driver bushing installs the guide to the correct height.

Checking Valve Guide Bores

Use the 5P-3536 Valve Guide Gauge Group in order to check the bore of the valve guides. Refer to Special Instruction, GMG02562 for the instructions for the use of this tool.

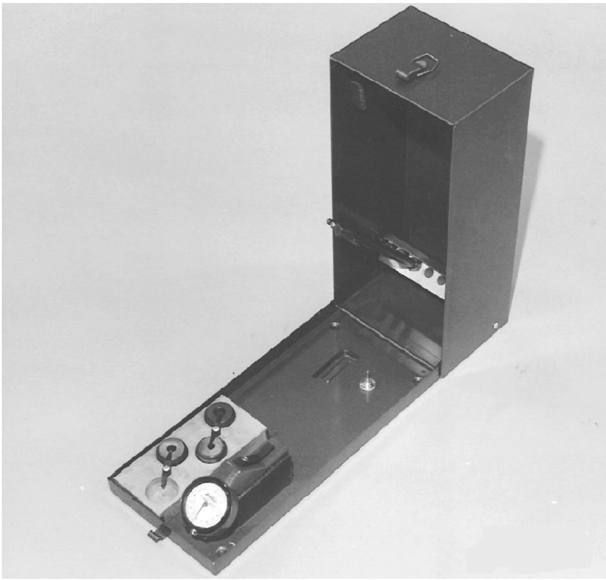


Illustration 75 g00285313

5P-3536 Valve Guide Gauge Group

Bridge Dowels

Use a 5P-0944 Dowel Puller Group and a 5P-0942 Dowel Extractor. Remove the bridge dowels. Install a new bridge dowel with a 6V-4009 Dowel Driver. This dowel driver installs the bridge dowel to the correct height.

i02388965

Cylinder Liner Projection

SMCS Code: 1216-082

Table 17

Tools Needed	Quantity
1U-9895 Crossblock	1
3H-0465 Push-Puller Plate	2
8F-6123 Bolt	2
3B-1925 Washer (COPPER)	4
0S-1575 Bolt	4
8T-0455 Liner Projection Tool Group	1

1. Make sure that the top surface of the cylinder block, the cylinder liner bores, the cylinder liner flanges, and the spacer plates are clean and dry.

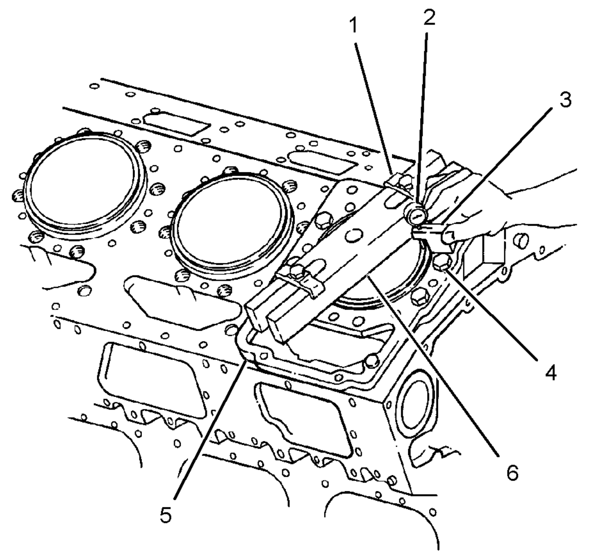


Illustration 76 g01192749

Measuring the cylinder liner projection

(1) 3H-0465 Push-Puller Plate
(2) 1P-2403 Dial Indicator
(3) 1P-2402 Gauge Body
(4) 0S-1575 Bolt and 3B-1925 Washer (COPPER)
(5) Spacer plate
(6) 1U-9895 Crossblock

2. Install a new gasket and spacer plate (5) on the cylinder block.

3. Install the cylinder liner in the cylinder block without seals or bands.

4. Hold spacer plate (5) and the cylinder liner in position according to the following procedure:

   a. Install four 3B-1925 Washers (COPPER) and four 0S-1575 Bolts(4) around the spacer plate (5). Tighten the bolts evenly to a torque of 95 N·m (70 lb ft).

   b. Install the following components: 1U-9895 Crossblock (6), two 3H-0465 Push-Puller Plates (1), and two 8F-6123 Bolts. Ensure that 1U-9895 Crossblock (6) is in position at the center of the cylinder liner. Ensure that the surface of the cylinder liner is clean. Tighten the bolts evenly to a torque of 70 N·m (50 lb ft).

   c. Check the distance from the bottom edge of 1U-9895 Crossblock (6) to the top edge of spacer plate (5). The vertical distance from both ends of the 1U-9895 Crossblock must be equal.

5. Use 8T-0455 Liner Projection Tool Group (6) to measure the cylinder liner projection.

6. Mount 1P-2403 Dial Indicator (2) in 1P-2402 Gauge Body (3). Use the back of the 1P-5507 Gauge Block to zero dial indicator (2).

7. The cylinder liner projection must be 0.059 to 0.199 mm (0.0023 to 0.0078 inch). Read the measurement on the outer flange of the cylinder liner at four equally distant positions. Do not read the measurement on the inner flange. The maximum allowable difference between the high measurements and the low measurements at four positions around each cylinder liner is 0.05 mm (0.002 inch). The maximum allowable difference between the four measurements must not exceed 0.05 mm (0.002 inch) on the same cylinder liner.

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

Note: When the cylinder liner projection is correct, put a temporary mark on the cylinder liner and the spacer plate. Be sure to identify the particular cylinder liner with the corresponding cylinder. When the seals and the filler band are installed, install the cylinder liner in the marked position.

i02391235

Flywheel - Inspect

SMCS Code: 1156-040

Table 18

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

Face Runout (Axial Eccentricity) of the Flywheel

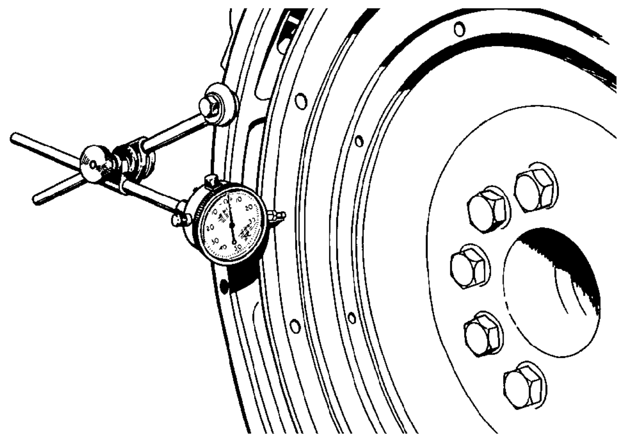


Illustration 77 g00286049

Checking face runout of the flywheel

1. Refer to illustration 77and 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. Find the difference between the lower measurements and the higher measurements. This value is the runout. The maximum permissible face runout (axial eccentricity) of the flywheel must not exceed 0.15 mm (0.006 inch).

Bore Runout (Radial Eccentricity) of the Flywheel

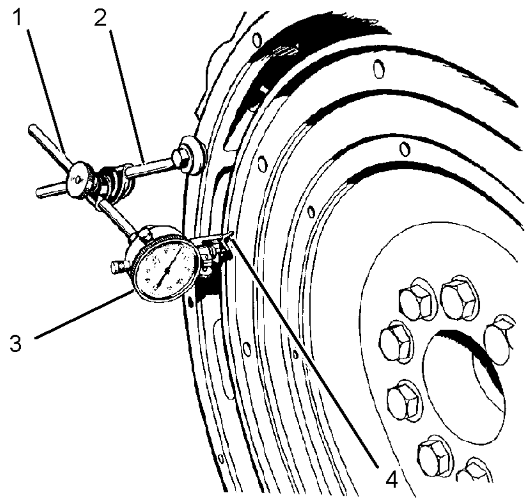


Illustration 78 g01193057

Checking bore runout of the flywheel

(1) 7H-1945 Holding Rod
(2) 7H-1645 Holding Rod
(3) 7H-1942 Dial Indicator
(4) 7H-1940 Universal Attachment

1. Install the 7H-1942 Dial Indicator (3). Make an adjustment of the 7H-1940 Universal Attachment (4) so that 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. Find the difference between the lower measurements and the higher measurements. This value is the runout. The maximum permissible bore runout (radial eccentricity) of the flywheel must not exceed 0.15 mm (0.006 inch).

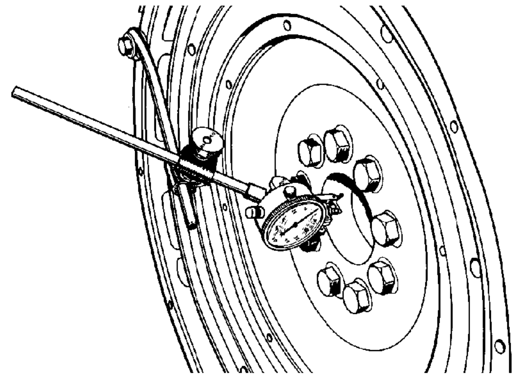


Illustration 79 g00286058

Flywheel clutch pilot bearing bore

5. Take the measurements at all four points. Find the difference between the lower measurements and the higher measurements. This value is the runout. The maximum permissible pilot bore runout of the flywheel must not exceed 0.13 mm (0.005 inch).

i02391240

Flywheel Housing - Inspect

SMCS Code: 1157-040

Table 19

Tools Needed		Quantity
8T-5096	Dial Indicator Gp	1

Face Runout (Axial Eccentricity) of the Flywheel Housing

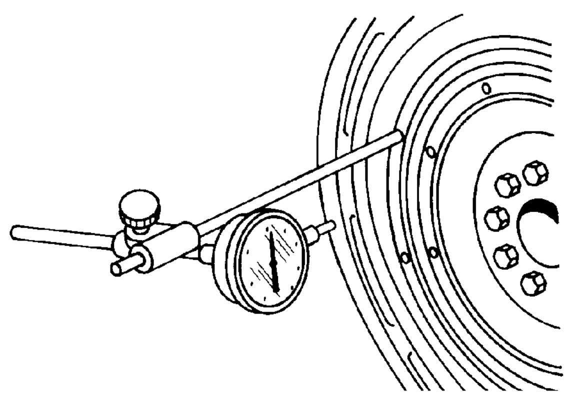


Illustration 80 g00285931

Checking face runout of the flywheel housing

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. Put a force on the crankshaft toward the rear before the dial indicator is read at each point.

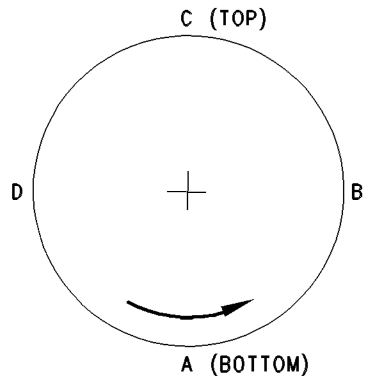


Illustration 81 g00285932

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

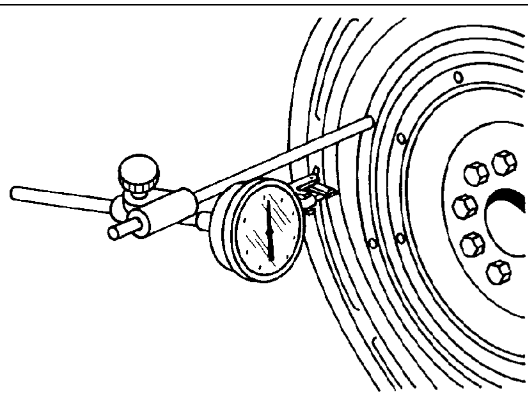


Illustration 82 g00285934

Checking bore runout of the flywheel housing

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

CHART FOR DIAL INDICATOR MEASUREMENTS					
	Position of dial indicator				
	Line No.	A	B	C	D
Correction for bearing clearance	I	0			
Dial Indicator Reading	II	0			
Total of Line 1 & 2	III	0	**	*	**

*Total Vertical eccentricity (out of round).
**Subtract the smaller No. from the larger No. The difference is the total horizontal eccentricity.

Illustration 83 g00285936

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 the illustration 83. 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 2by 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).

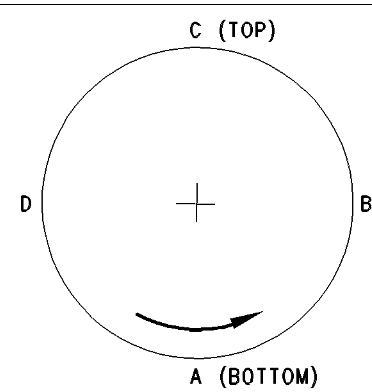


Illustration 84 g00285932

Checking bore runout of the flywheel housing

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.

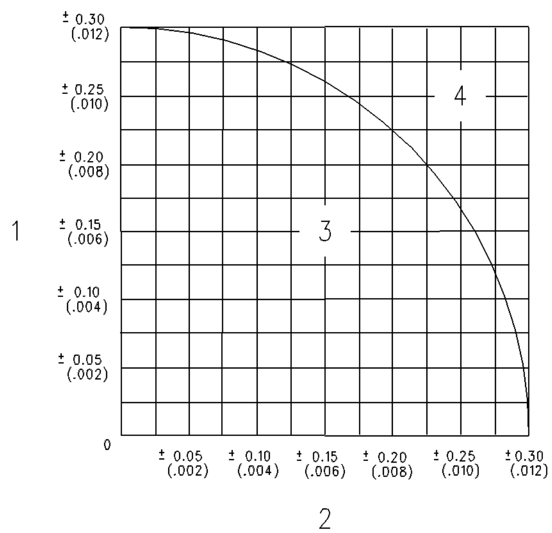


Illustration 85 g00286046

Graph for total eccentricity

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

10. On the graph for total eccentricity, find the point of intersection of the lines for vertical eccentricity and horizontal eccentricity.

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

i01220768

Vibration Damper

SMCS Code: 1205-535

Damage to the damper or failure of the damper will increase vibrations. This will result in damage to the crankshaft.

Replace the damper if the damper is bent or damaged. Replace the damper if the bolt holes are oversize. Replacement of the damper is also needed at the time of a crankshaft failure due to torsional forces.

Air/Electric Starting System

i01433812

General Information (Air/Electric Starting System)

SMCS Code: 1450; 1451; 1462

This starting system uses an electric solenoid to position an air valve in order to activate the air starting motor. If the starting motor does not function, do the procedure that follows:

1. Check the indicator reading for the air pressure.

2. If the reading is not acceptable then use a remote source to charge the system.

3. If the reading is acceptable then open the main tank drain valve for a moment. Verify the pressure that is shown on the pressure indicator. Listen for the sound of the high pressure from the discharge.

Electrical Side Of The Air System

1. Move the start control switch in order to activate the starting solenoids. Listen for the sound of the engagement of the air starter motor pinion with the flywheel gear.

   a. If the sound of the engagement can be heard, the problem is with the Air Side Of The Air System. Proceed to the Air Side Of The Air System.

   b. If no sound of the engagement can be heard, the problem could be with the Electrical Side Of The Air System.

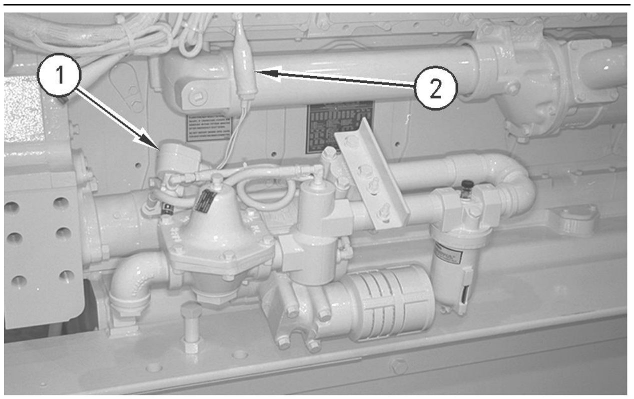


Illustration 86 g00286936

Control valve (typical example)

(1) Control valve
(2) Connector

2. Check the electrical system by disconnecting the leads from the control valve (1) at connector (2). Set the multimeter in the "DCV" range. Measure voltage across the disconnected leads that connect to the starting switch.

   a. A voltage reading shows that the problem is in the control valve (2) or the air starting motor. Go to Step 2of Air Side Of The Air System.

   b. A "ZERO" reading shows that the problem is in the control switch or the problem is in the wires for the control switch.

3. Fasten the multimeter lead to the start switch at the terminal for the wire from the battery. Fasten the other lead to a good ground.

   a. A "ZERO" reading indicates a broken circuit from the battery. With this condition, check the circuit breaker and wiring.

   b. The problem is in the control switch if either a voltage reading is found at the control switch or if a voltage reading is found in the wires from the control switch to the control valve.

Air Side Of The Air System

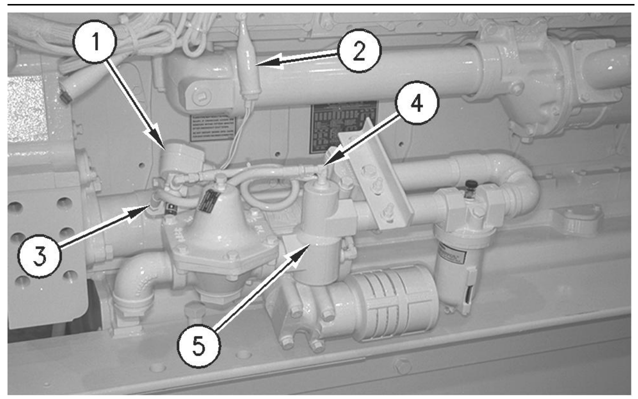


Illustration 87 g00286937

Air starting system (typical example)

(1) Control valve
(2) Connector
(3) Connection
(4) Air hose
(5) Relay valve

1. Activate the control switch. If the engagement of the air starter motor pinion with the flywheel ring gear can be heard then remove the small air hose (4) from the top of the relay valve (5).

   a. Full air pressure comes from the end of the air hose (4) when the control switch is activated. The relay valve (5) is worn or the air starting motor is damaged.

b. If no air pressure comes from the end of the air hose (4), then the problem is in the pinion nose housing for the air starting motor.

2. The sound of the air starter motor pinion is not heard when the control switch is activated. Voltage was measured at the control valve. Remove the other small air hose from the connection (3).

a. If no air comes from the end of the removed air hose, the control valve (1) is worn.

b. If the air comes from the end of the removed hose, then the problem is in the pinion nose housing for the air starting motor.

Electrical System

i02390733

Test Tools for the Electrical System

SMCS Code: 0785

Table 20

Tools Needed		Quantity
4C-4911	Battery Load Tester	1
225-8266	Ammeter Tool Gp	1
146-4080	Digital Multimeter Gp	1

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 tight. The battery must be fully charged. If the on-engine test shows a defect in a component, remove the component for more testing.

The service manual Testing And Adjusting Electrical Components, REG00636 has complete specifications and procedures for the components of the starting circuit and the charging circuit.

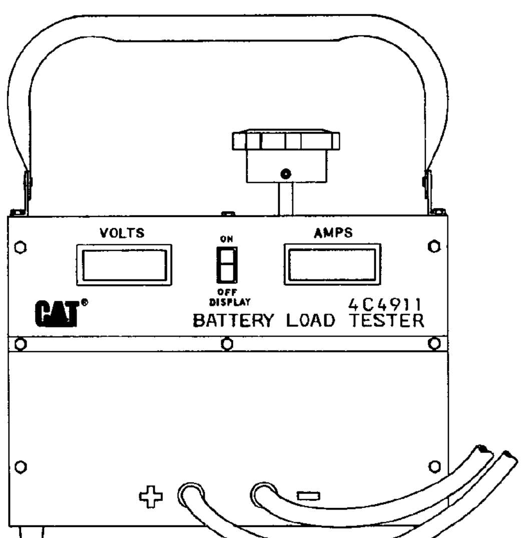


Illustration 88 g00283565

4C-4911 Battery Load Tester

The 4C-4911 Battery Load Tester is a portable unit in a metal case. The 4C-4911 Battery Load Tester 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. This measurement is taken through tracer wires that 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 for more complete information for the use of the 4C-4911 Battery Load Tester.

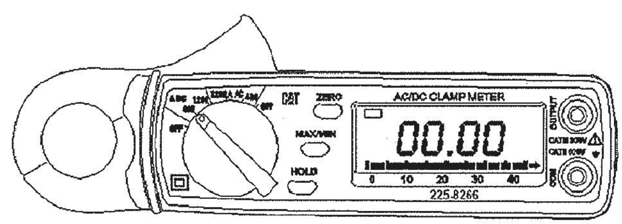


Illustration 89 g01012117

225-8266 Ammeter Tool Gp

The 225-8266 Ammeter Tool Gp is a completely portable, self-contained instrument that allows electrical current measurements to be made without breaking the circuit or without disturbing the insulation on the conductors. A digital display is located on the ammeter for reading current directly in a range from 1 to 1200 amperes. If a 6V-6014 Cable is connected between this ammeter and a digital multimeter, a current reading of less than 1 ampere can be read directly from the screen of the multimeter.

A lever is used to open the jaw over the conductor up to a diameter of 23 mm (0.90 inch). The jaw of the meter is then closed around the conductor for the measurement of current. The switch is rotated to the appropriate range. A "HOLD" button allows the last reading to be sustained on the display. This allows measurements to be taken in limited access areas. Power for the ammeter is supplied by batteries which are located inside the tool.

Note: Refer to the User's Guide for more complete information for the use of the ammeter. The guide is packaged with the unit.

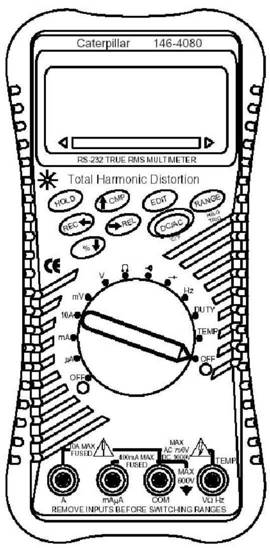


Illustration 90 g01015638

146-4080 Digital Multimeter Gp

The 146-4080 Digital Multimeter is a portable instrument with a digital display. This multimeter is built with extra protection against damage in field applications. The multimeter can display Pulse Width Modulation (PWM). The multimeter has an instant ohms indicator that permits the checking of continuity for fast circuit inspection. The multimeter can also be used for troubleshooting capacitors that have small values.

Note: Refer to Operator's Manual, NEHS0678 for complete information for the use of the multimeter. The operator's manual is packaged with the unit.

i01305428

Battery

SMCS Code: 1401-081

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 in operation. 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.

Use the 4C-4911 Battery Load Tester in order to test a battery that does not maintain a charge when the battery is active. Refer to Operating Manual, SEHS9249 for detailed instruction on the use of the 4C-4911 Battery Load Tester. See Special Instruction, SEHS7633 for the correct procedure and for the specifications to use when you test the batteries.

i01487719

Charging System

SMCS Code: 1406-081

The condition of charge in the battery at each regular inspection will indicate whether the charging system operates 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 cell per week or per every 100 service hours.

When it is possible, test the charging unit and the voltage regulator on the engine. Use wiring and components that are a permanent part of the system. 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.

To check for correct output of the alternator, see the Specifications module.

For complete service information, refer to Service Manual Module, SENR7503, “Delco-Remy Bulletin 1G-255”. This module is part of Service Manual, REG00636.

Before the start of on-engine testing, the charging system and the battery must be checked according to the following steps.

1. The battery must be at least 75 percent (1.225 Sp Gr) of the full charge. The battery must be held tightly in place. The battery holder must not put too much stress on the battery.

2. Cables between the battery, the starter, and the engine ground must be the correct size. Wires and cables must be free of corrosion. Wires and cables must have cable support clamps in order to prevent stress on battery connections (terminals).

3. Leads, junctions, switches, and panel instruments that have direct relation to the charging circuit provide correct circuit control.

4. Inspect the drive components for the charging unit in order to be sure that the components are free of grease and oil. Be sure that the drive components have the ability to operate the charging unit.

i02388966

Alternator Regulator

SMCS Code: 1405-081

The charging rate of the alternator should be checked when an alternator is charging the battery too much. The charging rate of the alternator should be checked when an alternator is not charging the battery enough. Make reference to the Specifications module in order to find all testing specifications for the alternators and regulators.

No adjustment can be made in order to change the rate of charge on the alternator regulators. If the rate of charge is not correct, a replacement of the regulator is necessary.

Tightening The Alternator Pulley Nut

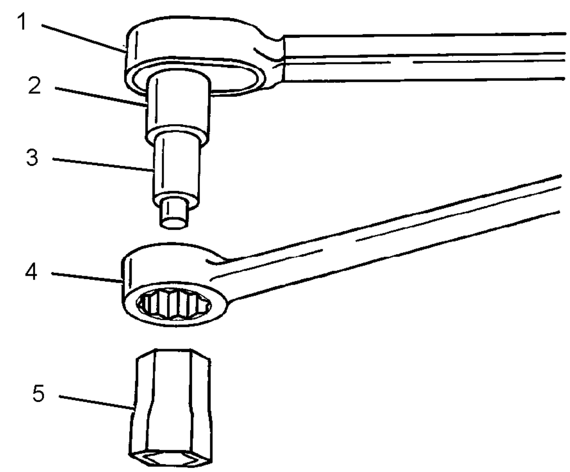


Illustration 91 g01192754

Tools for tightening the alternator pulley nut

(1) 8T-9293 Torque Wrench
(2) 8S-1588 Adapter (1/2 inch female to 3/8 inch male)
(3) 2P-8267 Socket Assembly
(4) 8H-8517 Combination Wrench (1-1/8 inch)
(5) 8T-5314 Socket

Tighten the nut that holds the pulley with the tools shown. Refer to the Specifications module for the torque.

i01487748

Electric Starting System

SMCS Code: 1450-081

Use the multimeter in the DCV range to find the starting system components which do not function.

Move the start control switch in order to activate the starting solenoids. The starting solenoid’s operation can be heard as the pinions of the starting motors are engaged with the ring gear on the engine flywheel.

If a solenoid for a starting motor will not operate, it is possible that the current from the battery did not reach the solenoid. Fasten one lead of the multimeter to the connection (terminal) for the battery cable on the solenoid. Put the other lead to a good ground. A zero reading indicates that there is a broken circuit from the battery. More testing is necessary when there is a voltage reading on the multimeter.

The solenoid operation also closes the electric circuit to the motor. Connect one lead of the multimeter to the solenoid connection (terminal) that is fastened to the motor. Fasten the other lead to a good ground. Activate the starting solenoid and look at the multimeter. A reading of the battery voltage shows that the problem is in the motor. The motor must be removed for further testing. A zero reading on the multimeter shows that the solenoid contacts do not close. Repair the solenoid if the contacts do not close. The clearance for the starter motor pinion gear may also need adjusting.

Perform a test. Fasten one multimeter lead to the connecting (terminal) for the small wire to the solenoid and fasten the other lead to the ground. Look at the multimeter and activate the starting solenoid. A voltage reading shows that the problem is in the solenoid. A zero reading indicates that the problem is in the start switch or in the wires for the start switch.

Fasten one multimeter lead to the start switch at the connection (terminal) for the wire from the battery. Fasten the other lead to a good ground. A zero reading indicates a broken circuit from the battery. Check the circuit breaker and wiring. If there is a voltage reading, the problem is in the start switch or in the wires for the start switch.

Starting motors that operate too slowly can have an overload because of too much friction in the engine that is being started. Slow operation of the starting motors can also be caused by the following conditions:

- A short circuit
- Loose connections
- Dirt in the motors

i02388967

Pinion Clearance Adjustment

SMCS Code: 1454-025

When the solenoid is installed, make an adjustment of the pinion clearance. The adjustment can be made with the starting motor removed.

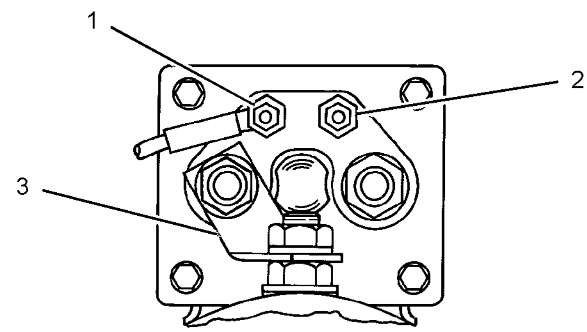


Illustration 92 g01192756

Connection for checking pinion clearance

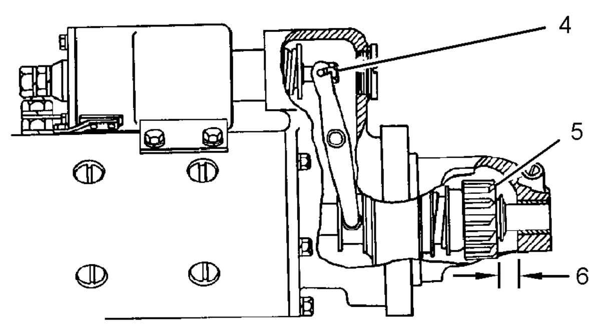
(1) Ground terminal
(2) SW terminal
(3) Connector

1. Install the solenoid without connector (3) from the MOTOR connections (terminal) on the solenoid to the motor.

2. Connect a battery, that has the same voltage as the solenoid, to “SW” terminal (2).

3. Connect the other side of the battery to connector (3).

4. For a moment, connect a wire from the solenoid connection (terminal), which is marked “MOTOR”, to the ground connection (terminal). The pinion will shift to the crank position and the pinion will stay there until the battery is disconnected.



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Pinion clearance adjustment

(4) Shaft nut
(5) Pinion
(6) Pinion Clearance

5. Push the pinion toward the end with the commutator in order to remove free movement.

6. Pinion clearance (6) must be 9.1 mm (0.36 inch).

7. In order to adjust the pinion clearance, remove the plug and turn shaft nut (4).

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