Table of Contents

Systems Operation Section

Engine Design 4
General Information 4
Electronic Control System Components 8
Fuel System 11
Fuel System 16
Air Inlet and Exhaust System 21
Lubrication System 23
Cooling System 25
Basic Engine 26
Air Starting System 27
Electrical System 29

Testing and Adjusting Section

Fuel System
Fuel System - Inspect 33
Air in Fuel - Test 33
Electronic Unit Injector - Adjust 34
Electronic Unit Injector - Test 35
Finding Top Center Position for No. 1 Piston 35
Fuel Quality - Test 36
Fuel System - Prime 37
Fuel System Pressure - Test 39
Gear Group (Front) - Time 41

Air Inlet and Exhaust System
Air Inlet and Exhaust System - Inspect 44
Turbocharger - Inspect 45
Inlet Manifold Pressure - Test 47
Exhaust Temperature - Test 48
Aftercooler - Test 48
Engine Crankcase Pressure (Blowby) - Test 51
Compression - Test 51
Engine Valve Lash - Inspect/Adjust 52

Lubrication System
Engine Oil Pressure - Test 54
Excessive Bearing Wear - Inspect 57
Excessive Engine Oil Consumption - Inspect 57
Increased Engine Oil Temperature - Inspect 58

Cooling System
Cooling System - Check (Overheating) 59
Cooling System - Inspect 61
Cooling System - Test 61
Water Temperature Regulator - Test 65
Water Pump - Test 65

Basic Engine
Piston Ring Groove - Inspect 67
Connecting Rod Bearings - Inspect 67
Main Bearings - Inspect 67
Cylinder Block - Inspect 67
Cylinder Liner Projection - Inspect 67
Flywheel - Inspect 70
Flywheel Housing - Inspect 71
Vibration Damper - Check 74

Electrical System
Battery - Test 75
Charging System - Test 76
Electric Starting System - Test 77
Pinion Clearance - Adjust 77
Pinion Clearance - Adjust 78

Index Section

Index 80

Systems Operation Section

i02158067

Engine Design

SMCS Code: 1000

3406E

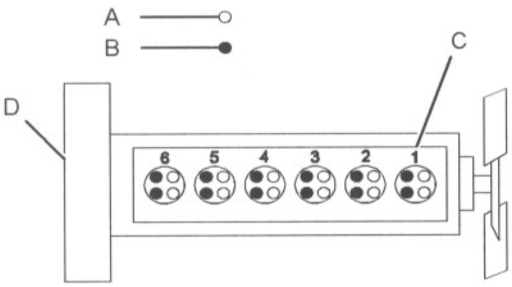

Illustration 1 g01096468

Cylinder and valve location

(A) Inlet valves
(B) Exhaust valves
(C) Cylinder number
(D) Flywheel end of the engine

Bore .... 137.2 mm (5.40 inch)

Stroke .... 165.1 mm (6.50 inch)

Displacement .... 14.6 L (890 cu in)

Cylinder arrangement .... In-line six cylinder

Valves per cylinder 4

The adjustment for the inlet valve lash is the following value. .... 0.38 mm (0.015 inch)

The adjustment for the exhaust valve lash is the following value. .... 0.76 mm (0.030 inch)

Firing order (Injection Sequence) 1, 5, 3, 6, 2, 4

Crankshaft rotation .... counterclockwise

Note: The front end of the engine is opposite the flywheel end. The left side and the right side of the engine are viewed from the flywheel end. The No. 1 cylinder is the front cylinder.

3456

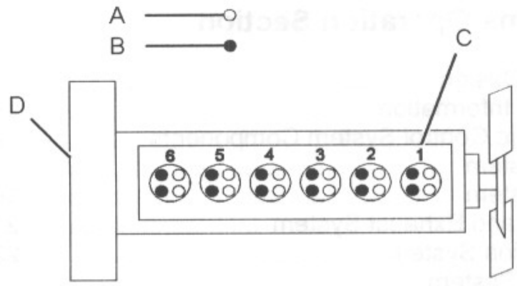

Illustration 2 g01096468

Cylinder and valve location

(A) Inlet valves
(B) Exhaust valves
(C) Cylinder number
(D) Flywheel end of the engine

Bore .... 140.0 mm (5.51 inch)

Stroke .... 171.0 mm (6.73 inch)

Displacement .... 15.8 L (964 cu in)

Cylinder arrangement .... In-line six cylinder

Valves per cylinder 4

The adjustment for the inlet valve lash is the following value. .... 0.38 mm (0.015 inch)

The adjustment for the exhaust valve lash is the following value. .... 0.76 mm (0.030 inch)

Firing order (Injection Sequence) 1, 5, 3, 6, 2, 4

Crankshaft rotation .... counterclockwise

Note: The front end of the engine is opposite the flywheel end. The left side and the right side of the engine are viewed from the flywheel end. The No. 1 cylinder is the front cylinder.

i02158307

General Information

SMCS Code: 1000

The following model views show typical 3406E and 3456 Engine features. Due to individual applications, your engine may appear different from the illustrations.

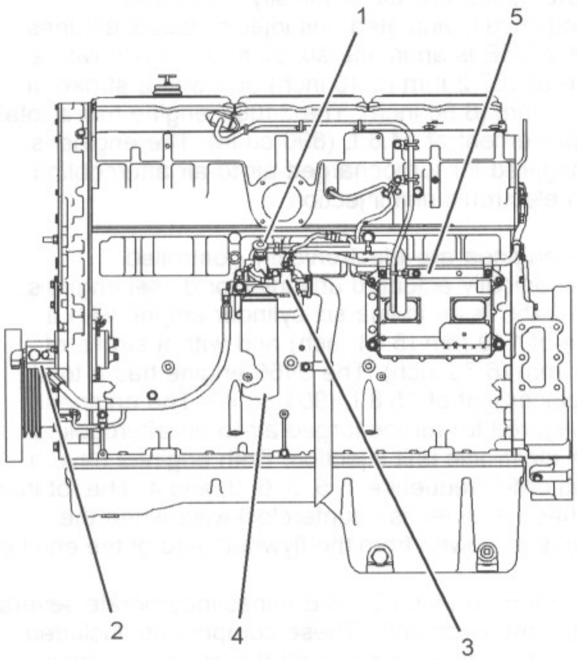

Illustration 3 g01094718

Left side view

(1) Fuel priming pump
(2) Fuel transfer pump
(3) Fuel distribution
(4) Fuel filter
(5) Electronic Control Module (ECM)

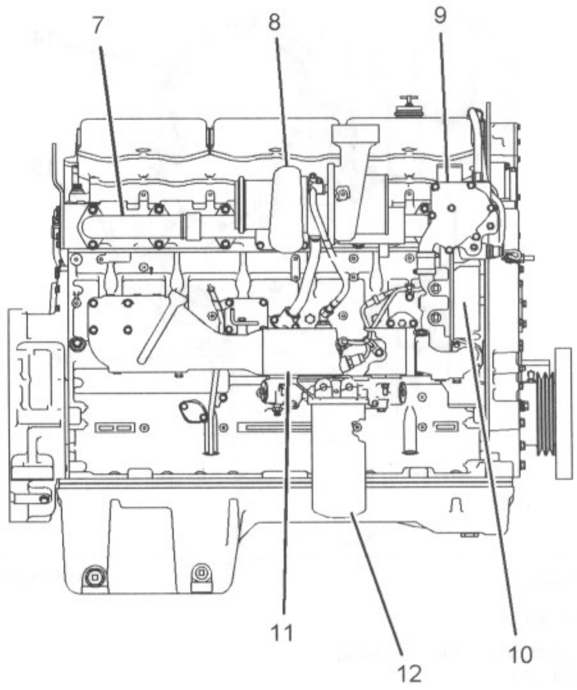

Illustration 4 g01094723

Right side view

(7) Exhaust manifold
(8) Turbocharger
(9) Temperature regulator housing
(10) Water pump
(11) Oil cooler
(12) Oil filter

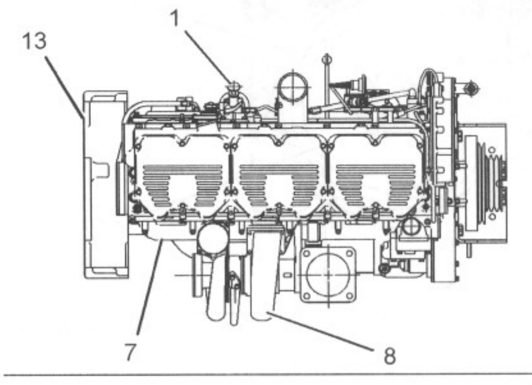

Illustration 5 g01094725

Top view

(1) Fuel priming pump
(7) Exhaust manifold
(8) Turbocharger
(13) Flywheel housing

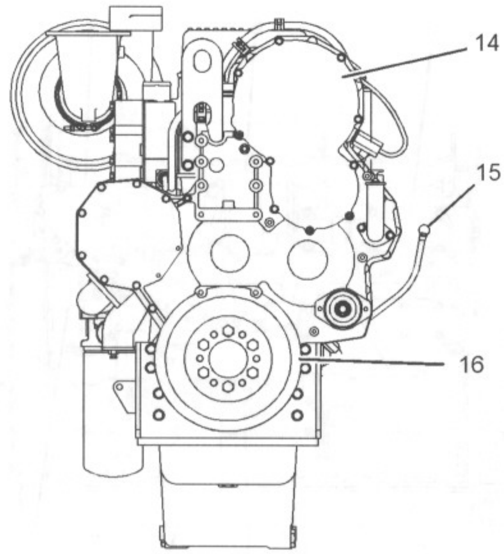

Illustration 6 g01094735

Front view

(14) Front timing gear housing
(15) Oil gauge
(16) Vibration damper

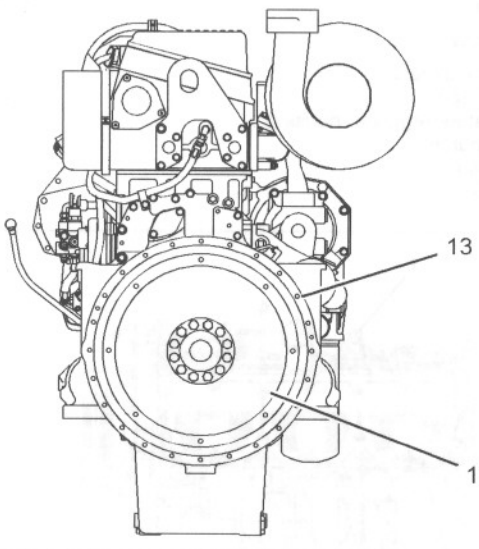

Illustration 7 g01094740

Rear view

(13) Flywheel housing
(17) Flywheel

General Information

The engines are electronically controlled mechanically actuated unit injector diesel engines. The 3406E is an in-line six cylinder engine with a bore of 137.2 mm (5.40 inch) and with a stroke of 165.1 mm (6.50 inch). The 3406E engine has a total displacement of 14.6 L (890 cu in). The engine is configured for turbocharged air-to-air aftercooling with electronic unit injection.

The engines are electronically controlled mechanically actuated unit injector diesel engines. The 3456 is an in-line six cylinder engine with a bore of 140 mm (5.51 inch) and with a stroke of 171 mm (6.73 inch). The 3456 engine has a total displacement of 15.8 L (964 cu in). The engine is configured for turbocharged air-to-air aftercooling with electronic unit injection. Both engines have a firing order sequence:1, 5, 3, 6, 2, and 4. The rotation of these engines is counterclockwise when the engine is viewed from the flywheel end of the engine.

The 3406E and the 3456 Engines incorporate several major improvements. These components included an improved electronic control system. The new features lower the smoke level for emissions under all operating conditions.

The Electronic Unit Injector system eliminates many of the mechanical components that are traditionally used in the fuel injector assembly. The Electronic Unit Injector (EUI) also provides increased control of the timing and the fuel air mixture. The timing advance is achieved by precise control of the fuel injection timing. Engine rpm is controlled by adjusting the injection duration.

The engine has built-in diagnostics in order to ensure that all of the components are operating properly. In the event of a system component failure, the operator will be alerted to the condition by a warning lamp or a diagnostic lamp. An electronic service tool can be used to read the numerical code of the faulty component or condition. Intermittent faults are logged and stored in memory.

Starting the Engine

The Electronic Control Module (ECM) will automatically provide the correct amount of fuel that is necessary to start the engine. The throttle should not be held while the engine is being cranked. If the engine fails to start in 30 seconds, the starter switch should be released. The starter motor should be allowed to cool for two minutes before being used again.

NOTICE

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

Cold Mode Operation

The ECM will set the cold start strategy when the coolant temperature is below 18 °C (64 °F).

When the cold start strategy is activated, low idle rpm will be increased to 1000 rpm and the engine's power will be limited.

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

- Coolant temperature reaches 18 °C (64 °F).
- The engine has been running for fourteen minutes.

Cold mode operation varies the fuel injection amount for white smoke cleanup. Cold mode operation also varies the timing for white smoke cleanup. The engine operating temperature is usually reached before the walk-around inspection is completed. The engine will idle at the programmed low idle rpm in order to be put in gear.

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

Programmable Parameters

The engine is capable of being programmed for several programmable parameters. For a brief explanation of each of the programmable parameters, see the Operation and Maintenance Manual.

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Electronic Control System Components

SMCS Code: 1900

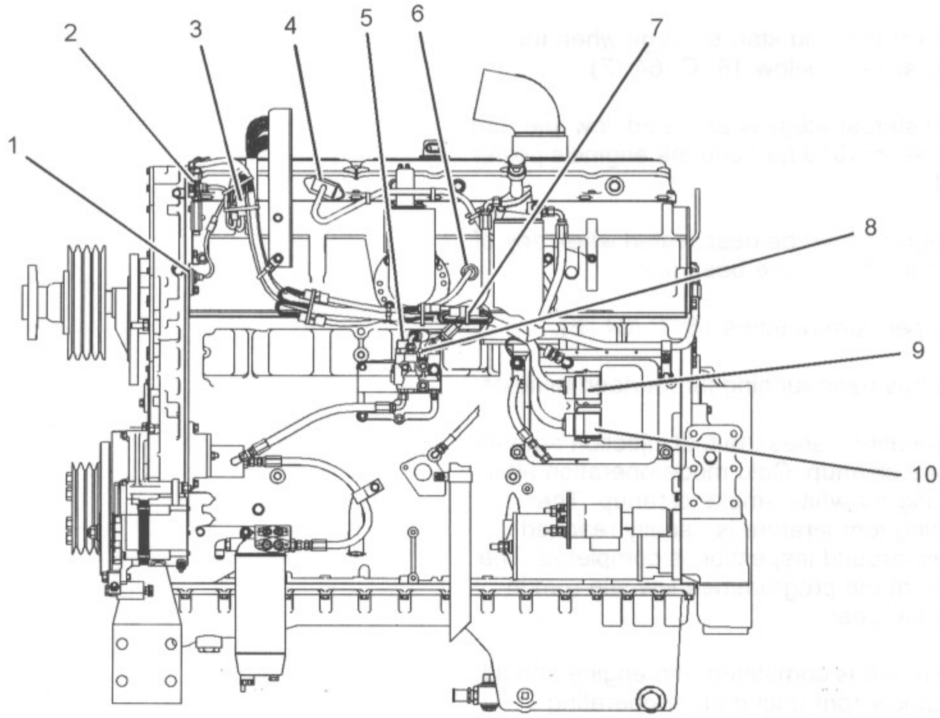

Illustration 8 g01094786

Typical example

(1) Primary engine speed/timing sensor
(2) Secondary engine speed/timing sensor
(3) Turbocharger outlet pressure sensor
(4) Unit injector connector
(5) Fuel temperature sensor
(6) Inlet air temperature sensor
(7) Timing calibration connector
(8) Atmospheric pressure sensor connector
(9) Electronic Control Module (ECM) connector
(10) ECM connector

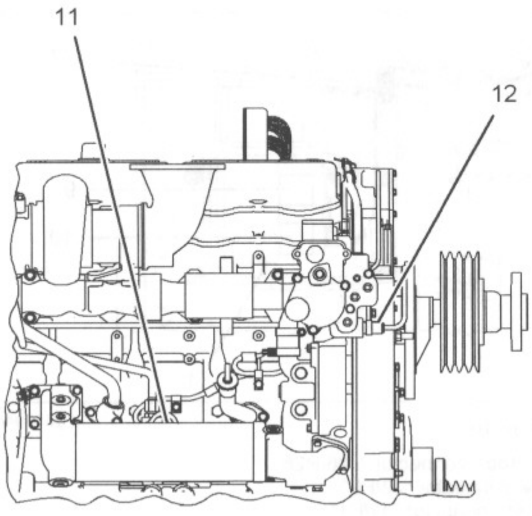

Illustration 9 g01094799

Electronic control system components (right side view)

(11) Oil pressure sensor connector
(12) Coolant temperature sensor connector

Engine Monitoring

An engine monitoring function is included in the electronic control system. The engine monitoring function monitors the following items:

- Engine oil pressure
- Coolant temperature
- Inlet manifold air temperature
- Coolant level

All engines are shipped with the following sensors:

- Oil pressure sensor
- Coolant temperature sensor
- Inlet air temperature sensor
- Coolant level sensor

The coolant level sensor is the only sensor that can be individually selected for engine monitoring. The Electronic Control Module (ECM) programmable parameter enables the coolant level sensor. The default factory setting is "NO". The programmable parameters for the ECM have four levels that are for engine monitoring:

- Off
- Warning (Factory Default)
- Derate
- Shutdown

Engine Monitoring is Programmed to "Off"

The ECM will ignore the oil pressure sensor and the coolant level sensor. Coolant Temperature is still used for Cold Mode. Inlet Manifold Air Temperature is used for operation in cold air regardless of the engine monitoring mode.

Engine Monitoring is Programmed to "Warning "

Warning mode uses the following sensors: Oil Pressure, Coolant Temperature, Inlet Manifold Temperature, and Coolant Level Sensor.

Electronic Control System Operation

The fuel delivery and injection timing are electronically controlled. In comparison to engines that are controlled mechanically, the electronic control system provides increased control of timing and increased control to the fuel to air ratio. Injection timing is achieved by precise control of injector firing time, and engine power is controlled by adjusting the firing duration. The ECM energizes the fuel injection solenoid in order to start the injection of fuel. The ECM will de-energize the fuel injection solenoid in order to stop the injection of fuel. Refer to the Systems Operation, "Fuel System" for a complete explanation of the fuel injection process.

The engine uses the following types of electronic components: input, control, and output.

An input component is one that sends an electrical signal to the ECM. The signal that is sent varies in either voltage or in frequency when there is a change in some specific system. An example would be the engine speed/timing sensor or the coolant temperature sensor. The electronic control module interprets the input sensor signal as information about the condition, environment, or operation of the engine.

An electronic control system component receives the input signals. Electronic circuits that are inside the ECM evaluate the signals. The ECM then supplies electrical energy to the output components of the system, which are in response to predetermined combinations of input signal values.

An output component is one that is operated by the ECM. An output component receives electrical energy from the ECM. The electrical energy is used to perform one of the following functions:

- Perform work. An example would be moving a solenoid plunger. An output component takes an active part in regulating or operating the engine.

- An output component can give information or a warning. An example would be a light or an alarm to the operator of the engine or other person.

Output components provide the ability to electronically control the engine operation in order to improve the following items: performance, fuel consumption rate, and reduced emissions levels.

Check Engine Lamp (Diagnostic Lamp)

The Check Engine Lamp is sometimes referred to as the Diagnostic Lamp. The Check Engine Lamp can be used as a diagnostic lamp in order to communicate any problems with the operation of the electronic control system.

Note: The Check Engine Lamp and the Warning Lamp are different.

When a diagnostic fault is detected by the ECM, the Check Engine Lamp will turn ON. When a diagnostic fault is detected by the ECM, the Check Engine Lamp will flash at five second intervals. The Check Engine Lamp should be ON and the Check Engine Lamp should be flashing Diagnostic Code 55 whenever the START switch is turned ON but the engine is not running. This condition will test whether the lamp is operating correctly.

If the Check Engine Lamp comes on and the Check Engine Lamp stays on after the initial start-up, the system has detected a fault. The Check Engine Lamp or Caterpillar Electronic Technician (ET) can be used to identify the diagnostic code.

The Check Engine Lamp will begin to flash in order to indicate a two digit diagnostic code while the SET/RESUME switch is held in the RESUME position. The sequence of flashes represents the system diagnostic message. The first sequence of flashes adds up to the first digit of the diagnostic code. After a one second pause, a second sequence of flashes will occur. The second sequence of flashes represent the second digit of the diagnostic code. If necessary, additional diagnostic codes will follow after a three second pause. Additional diagnostic codes will be displayed in the same manner.

Electronic Control Module

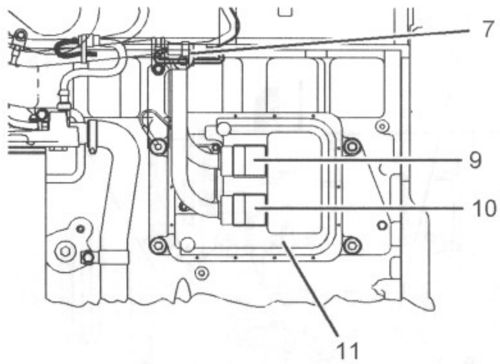

Illustration 10 g01094817

(7) TC Probe connector "J26/P26"
(9) ECM connector "J2/P2"
(10) ECM connector "J1/P1"
(11) Electronic Control Module

The 3406E and 3456 Engines use an ECM microprocessor. The ECM is mounted on the rear left side of the engine.

The ECM power supply provides electrical power to all engine mounted sensors and actuators. Reverse voltage polarity protection and resistance to voltage swings or surges have been designed into the ECM. The ECM also monitors all input from the sensors. The ECM also provides the correct outputs in order to ensure desired engine operation.

The electronic engine control system has the following features that are designed into the system.

- Resistance to radio frequency

- Resistance to electromagnetic interference

The ECM contains memory in order to store customer specified parameters. The ECM also identifies a selected factory engine rating. The memory also contains a personality module identification code in order to prevent unauthorized tampering. The memory also contains an identification code in order to prevent switching of engine ratings and other pertinent manufacturing information.

The wiring harness provides communications to the following areas:

- Various sensors

- Data link connector

- Engine connectors

The ECM is programmed to perform the following functions:

- Diagnostic tests on all inputs
- Diagnostic tests on all outputs
- Separate faults to a specific circuit

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

i02162946

Fuel System

SMCS Code: 1250

S/N: BGA1-Up

S/N: CCB1-Up

S/N: EPE1-Up

S/N: C1G1-Up

S/N: C3G1-Up

S/N: C4G1-Up

S/N: CAH1-Up

S/N: GHJ1-Up

S/N: CBX1-Up

S/N: 8AZ1-Up

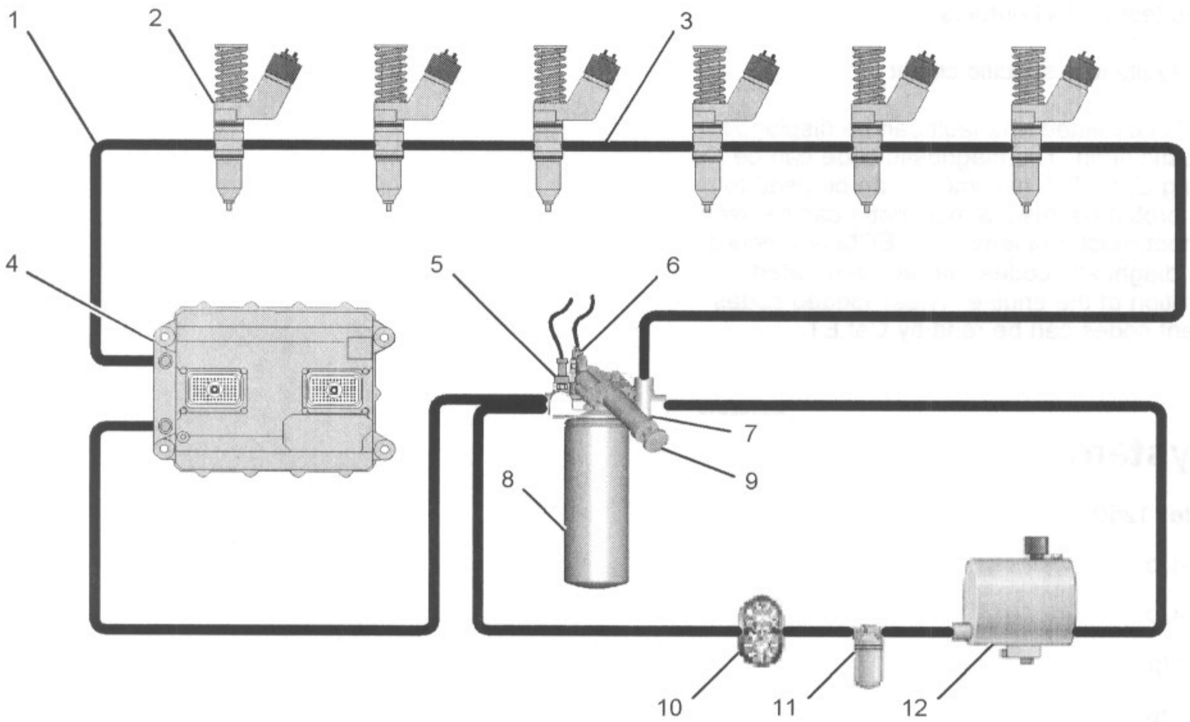

Illustration 11 g01061346

Fuel system schematic

(1) Fuel supply line
(2) Electronic unit injectors
(3) Fuel gallery
(4) Electronic Control Module (ECM)
(5) Fuel pressure sensor
(6) Fuel temperature sensor
(7) Pressure regulating valve
(8) Secondary fuel filter
(9) Fuel priming pump
(10) Fuel transfer pump
(11) Primary fuel filter
(12) Fuel tank

The fuel supply circuit is a conventional design for engines with electronic unit injection. A fuel tank (12) is used to store the fuel prior to use by the engine. A primary fuel filter/water separator (11) is placed into the fuel supply circuit in order to remove large debris from the fuel. This debris may have entered the fuel tank during fueling. The debris may have also entered the fuel tank through the vent for the fuel tank. The primary filter element also separates water from the fuel. The water is collected in the bowl at the bottom of the primary fuel filter/water separator.

Fuel is drawn from the fuel tank by the fuel transfer pump (10). The fuel transfer pump is a gear type pump with fixed clearances. The fuel transfer pump incorporates an internal relief valve that protects the fuel system from extreme pressure. In the case of extreme pressure, fuel is redirected back to the inlet of the fuel transfer pump. There are internal check valves that are also incorporated into the fuel transfer pump. An inlet check valve prevents fuel from draining back to the fuel tank while the fuel transfer pump is not in operation. An outlet check valve is used in order to prevent pressurized fuel leakage back through the pump. The fuel transfer pump is located in the front of the engine. The fuel transfer pump is driven by the front gear train.

Note: The inlet fuel temperature to the fuel transfer pump must not exceed 79 °C (175 °F) when the engine has reached normal operating temperature. Fuel temperatures above 79 °C (175 °F) will reduce the life of the fuel transfer pump check valves. The fuel efficiency and the engine power output are reduced when the fuel temperature increases from 30 °C (86 °F) to 70 °C (158 °F). The fuel heaters should be turned "OFF" during warm weather operating conditions.

Fuel from the fuel transfer pump flows to the fuel filter base. The fuel flows through cored passages in the fuel filter base. The fuel priming pump (9) is mounted on the fuel filter base. The fuel priming pump is used in order to manually pump the fuel into the fuel system after the system, or parts of the system have been drained. The fuel priming pump is used in order to refill the fuel system after air has been introduced into the system. For more information on priming the fuel system, refer to Testing and Adjusting, "Fuel System - Prime".

As the fuel flows through cored passages in the fuel filter base, the fuel is directed into a 2 micron fuel filter (8). The fuel is filtered in order to remove small abrasive particles that will cause premature wear to fuel system components. Fuel flows out of the fuel filter and returns to the passages in the fuel filter base. Prior to exiting the fuel filter base, the fuel pressure and the fuel temperature is sampled by the fuel pressure sensor (5) and by the fuel temperature sensor (6). The signals that are generated by the sensors are used by the engine control in order to monitor the condition of the engine's components. This information is also used to adjust the fuel delivery of the engine in order to optimize efficiency.

The fuel flows from the fuel filter base to the Electronic Control Module (ECM) (4). The pressurized fuel is used in order to cool the electronic components that are in the ECM. Excessive heat will damage the electronic components in the ECM. The electronics are used to control engine operation.

The fuel is then directed through the fuel supply line (1) to fuel manifold (3) that runs the length of the cylinder head. The fuel enters the cylinder head at the front of the engine. A continuous flow of fuel is supplied to the electronic unit injectors (2) in order to perform the following tasks:

- Supply fuel for injection
- Remove excessive heat from the injectors.
- Remove air that may accumulate in the fuel system.

The excess fuel flow that pumped through the system exits the cylinder head near the rear of the engine.

The fuel exits the fuel gallery and returns to the fuel filter base. A pressure regulating valve (7) that is located in the fuel filter base regulates the pressure for the fuel system. A sufficient amount of back pressure is maintained in the system in order to ensure a continuous availability of fuel to the electrònic unit injectors.

Fuel Heaters

Fuel heaters prevent the waxing of the fuel in cold weather. The engine does not dissipate enough heat in order to prevent waxing during cold weather conditions. Heaters that are not thermostatically controlled can heat the fuel in excess of 65 °C (149 °F). High fuel temperatures can have the following effects:

- Reduced engine efficiency
- Fuel pump damage
- Premature wear

Note: Fuel heaters without thermostatic controls must never be used.

The two types of fuel heaters that can be used: thermostatically controlled and self-adjusting.

Electronic Controls

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

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

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

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

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

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

Fuel Injection

The ECM controls the amount of fuel that is injected by varying the signal to each of the unit injectors. The unit injectors will inject fuel only while the unit injector solenoid is energized. The ECM sends a 105 volt signal to the solenoid in order to energize the injector solenoid. By controlling the timing of the 105 volt signal, the ECM controls injection timing. By controlling the duration of the 105 volt signal, the ECM controls the amount of fuel that is injected.

The ECM sets certain limits on the amount of fuel that can be injected. The FRC fuel position is a limit that is based on boost pressure in order to control the fuel air mixture for the emission control. When the ECM senses an increase in the boost pressure, the ECM increases the FRC fuel position. The rated fuel position is a limit that is based on the horsepower rating of the engine. The rated fuel position is similar to the rack stops and the torque spring on a mechanically governed engine. The rated fuel position provides the horsepower and the torque curves for a specific engine family. The rated fuel position provides the horsepower and the torque curves for a specific horsepower rating. The limits are programmed by the factory into the personality module. The limits are not programmable in the field.

The injection timing relies on the following engine parameters: engine speed, engine load, and other engine data. The ECM senses the top center position of number one cylinder from the signal that is provided by the engine speed/timing sensors. The ECM decides when the injection should occur relative to this top center position. The ECM provides the signal to the unit injector at the desired time.

Unit Injector Mechanism

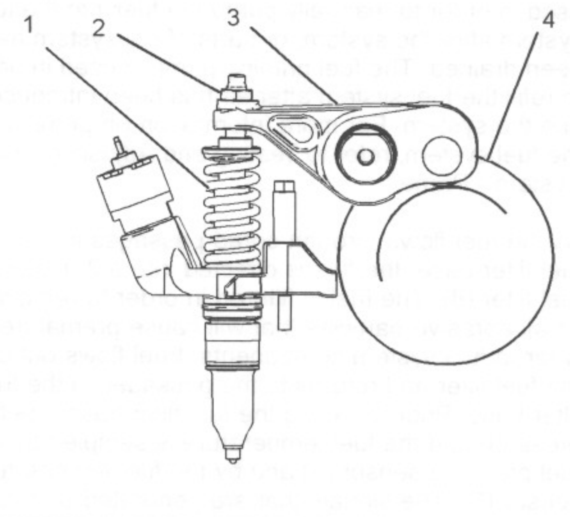

Illustration 12 g01033483

Typical unit injector mechanism

(1) Unit injector
(2) Adjusting nut
(3) Rocker arm assembly
(4) Camshaft

The unit injector mechanism provides the downward force that is required to pressurize the fuel in the unit injector. When a signal is received from the ECM, the unit injector (1) injects the pressurized fuel into the combustion chamber. The camshaft gear is driven by an idler gear which is driven through the front gear train by the crankshaft gear. The gears of the front gear train that are timed must be aligned in order to provide the correct relationship between the piston and valve movement. During assembly of the front gear train, care must be taken in order to correctly align the timing marks of the gears. The camshaft has three camshaft lobes for each cylinder. Two lobes operate the inlet and exhaust valves, and one operates the unit injector mechanism. Force is transferred from the unit injector lobe on camshaft (4) through rocker arm assembly (3) to the top of the unit injector. The adjusting nut (2) allows setting of the unit injector adjustment. Refer to the section on adjustment of the injector in Testing and Adjusting for the proper setting of the unit injector.

Electronic Unit Injector

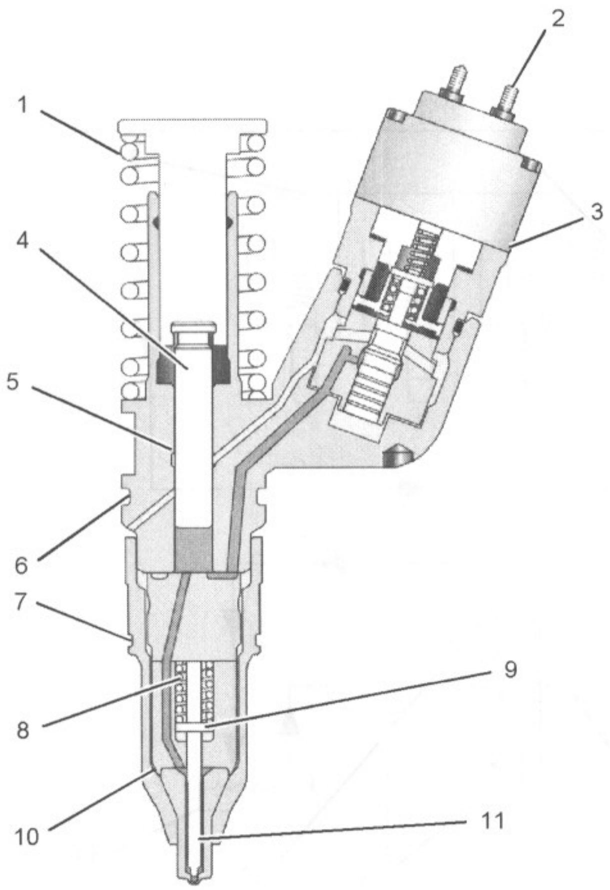

Illustration 13 g01096757

Electronic unit injector

(1) Spring
(2) Solenoid connection to the Electronic Control Module (ECM)
(3) Solenoid valve assembly
(4) Plunger assembly
(5) Barrel
(6) Seal
(7) Seal
(8) Spring
(9) Spacer
(10) Body
(11) Check valve

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

As the electronic unit injector mechanism transfers the force to the top of the electronic unit injector, spring (1) is compressed and plunger (4) is driven downward. This action displaces fuel through the valve in solenoid valve assembly (3), and into the return manifold to the fuel tank. As the plunger travels downward, the passage in barrel (5) is closed by the outside diameter of the plunger. The passages within body (10) and along check valve (11) to the injector tip already contain fuel for injection. After the passage in the plunger barrel is closed, the injector is ready for injection at any time. The start of injection relies on the software in the Electronic Control Module (ECM).

When the solenoid valve assembly is energized from a signal across solenoid connection (2), the valve closes and fuel pressure is elevated in the injector tip. Injection begins at 34500 ± 1900 kPa (5000 ± 275 psi) as the force of spring (8) above spacer (9) is overcome. The check valve begins to lift from the valve seat. The pressure continues to rise as the plunger cycles through a full stroke. After the correct amount of fuel has been discharged into the cylinder, the ECM removes the signal to the solenoid connection. The solenoid valve assembly is de-energized and the valve in the solenoid valve assembly is opened. The high pressure fuel is then dumped through the spill port and into the fuel return manifold. The fuel is then returned to the fuel tank. The check valve in the injector tip seats as the pressure in the tip decreases.

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

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

i02158633

Fuel System

SMCS Code: 1250

S/N: 9NN1-Up

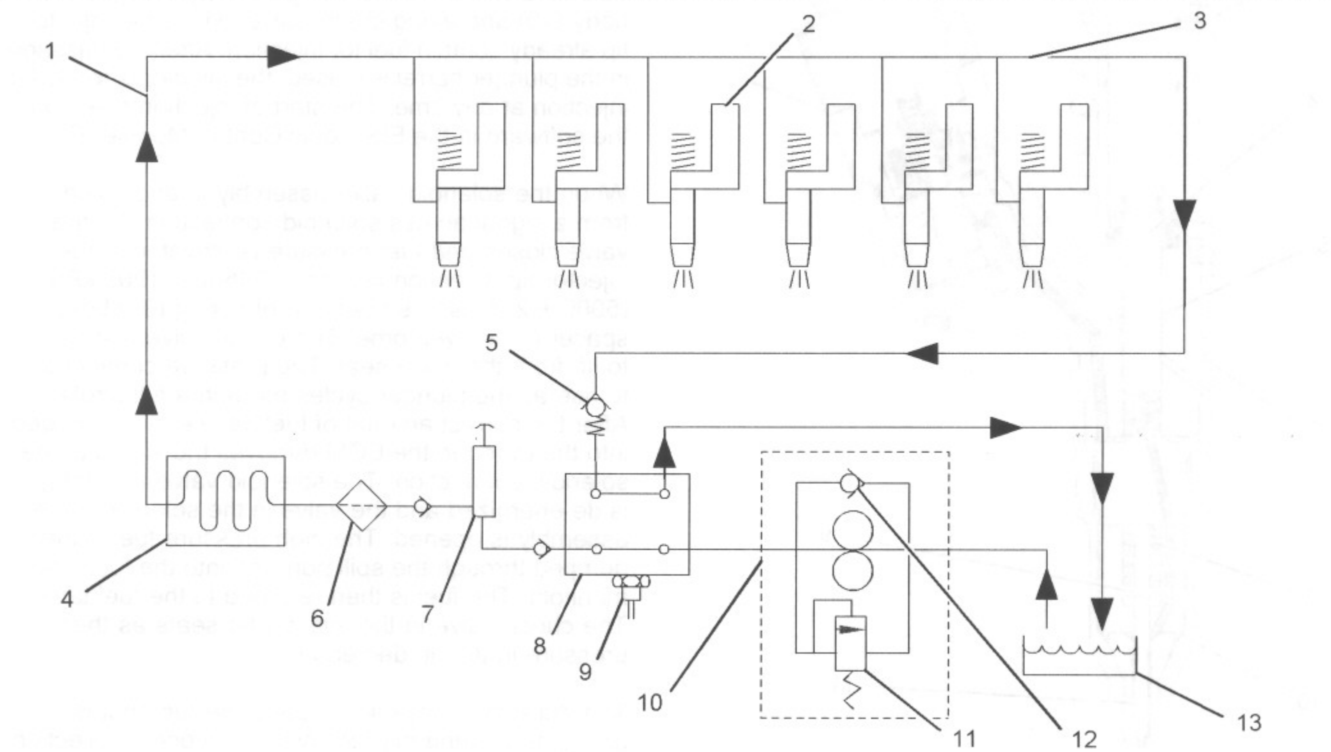

Illustration 14 g01094959

Typical fuel system schematic

(1) Fuel supply line
(2) Unit injectors
(3) Fuel gallery (fuel manifold)
(4) Electronic Control Module (ECM)
(5) Pressure regulating valve
(6) Secondary fuel filter
(7) Fuel priming pump
(8) Distribution block
(9) Fuel temperature sensor
(10) Fuel transfer pump
(11) Pressure relief valve
(12) Check valve
(13) Fuel tank

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

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

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

Fuel filter – The fuel filter is used to remove abrasive material and contamination from the fuel system.

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

The purpose of the low pressure fuel supply circuit is to supply fuel that has been filtered to the fuel injectors at a rate that is constant and a pressure that is constant. The fuel system is also utilized to cool components such as the electronic control module and the fuel injectors.

Once the injectors receive the low pressure fuel, the fuel is pressurized again before the fuel is injected into the cylinder.

The unit injector uses mechanical energy that is provided by the camshaft to achieve pressures that can be in excess of 200,000 kPa (30,000 psi).

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

- Injection timing
- Fuel injection timing advance
- Injection duration
- Engine cold mode status

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

Low Pressure Fuel Supply Circuit

The flow of fuel through the system begins at fuel tank (13). Fuel is pulled from the tank by fuel transfer pump (10). The fuel transfer pump incorporates a check valve (12) that will allow fuel to flow around the gears of the pump during hand priming of the fuel system. The fuel transfer pump also incorporates a pressure relief valve (11). The pressure relief valve is used in order to protect the fuel system from extreme pressure.

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

The fuel travels from the fuel transfer pump to distribution block (8). A fuel temperature sensor (9) that is installed in the distribution block is used to sample the fuel temperature. A signal that represents the fuel temperature is sent to the electronic control module (ECM) for processing.

The fuel is then pumped into the fuel filter base. In most applications, fuel priming pump (7) is located on the fuel filter base. The fuel filter base also incorporates a siphon break that prevents fuel from draining from the fuel system when the engine is not in operation. The priming pump utilizes a series of check valves in order to direct the flow of fuel during the priming pump's operation. The check valves work with the fuel priming pump in order to produce a pumping action. The check valves also prevent fuel from being forced back into the fuel transfer pump. The fuel flows through a two micron fuel filter (6). The filtered fuel then flows out of the fuel filter base.

If a fuel cooled ECM is installed on the engine, the fuel is pumped into the ECM. The fuel travels through the cored passages of the electronic control module housing in order to cool the control module's electronics.

The fuel is transfered by fuel supply lines (1) to fuel gallery (3) in the cylinder head or to fuel manifold (3). Only a portion of the fuel that is supplied to the fuel injectors is used for engine operation.

The fuel that is unused by the engine is provided for cooling purposes. This unused fuel is discharged into the return passages of the fuel gallery. The fuel is returned to the fuel tank by the fuel return lines. A continuous flow of fuel is experienced within the low pressure fuel system.

During engine operation, fuel injectors (2) receive fuel from the low pressure fuel system. The injector pressurizes the fuel to high pressure. The fuel is then injected into the cylinder. The excess fuel is returned to the tank. Refer to Systems Operation, "Unit Injector" for a complete explanation of the injection process.

A pressure regulating valve (5) is located in the fuel return. The pressure regulating valve allows the low pressure fuel system to maintain a constant pressure. A flow control orifice is also located in the fuel return. The flow control orifice maintains a system back pressure that is constant. The orifice allows the flow of fuel through the system to be constant. This prevents excessive heating of the fuel.

Fuel Heaters

Fuel heaters help to prevent the plugging of the fuel filters in cold weather. This plugging is called waxing. In cold ambient conditions, the cold engine does not dissipate enough heat into the fuel system in order to prevent waxing. Heaters that are not thermostatically controlled can heat the fuel in excess of 65° C (149° F). Excessive temperatures in the fuel system will drastically reduce the efficiency of the engine. The fuel system's reliability is also affected by high fuel temperatures.

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

Fuel System Electronic Control Circuit

The fuel system's electronic control circuit can be viewed as two distinct control circuits: engine control logic and electronic governor control.

Refer to Illustration 15 for a typical example of the engine control logic. Refer to Illustration 16 for a typical example of the electronic governor control.

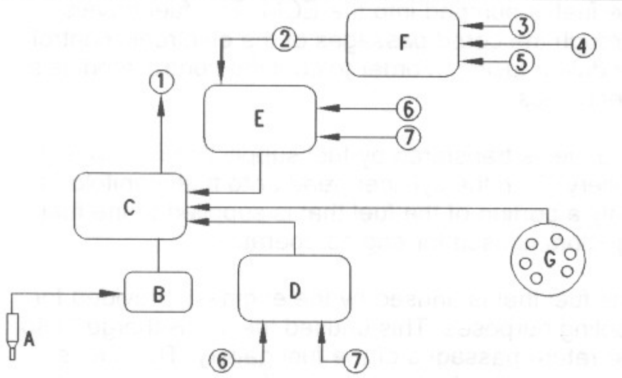

Illustration 15 g00418418

Typical logic for engine speed control

(A) Coolant temperature sensor
(B) Cold mode operation
(C) Logic for engine control (Desired RPM)
(D) Customer parameters
(E) Control for PTO
(F) Logic for PTO
(G) Throttle position sensor
(1) Retarder enable signal (signal to the retarder controls)
(2) PTO set speed
(3) PTO enable
(4) PTO ramp up/down switch
(5) Remote shutdown
(6) PTO interrupt
(7) Engine speed in rpm

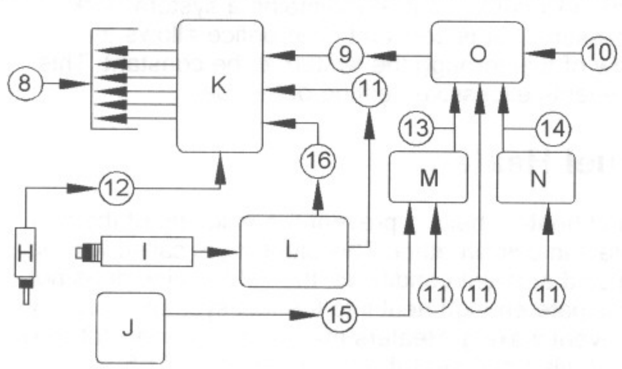

Illustration 16 g01095023

Typical control for electronic governor

(H) Coolant temperature sensor
(I) Engine speed/timing sensor
(J) Boost pressure sensor
(K) Fuel injection control
(L) Engine speed signal interpreter
(M) Fuel ratio control maps
(N) Torque maps
(O) Electronic governor
(8) Signals to unit injectors
(9) Fuel position
(10) Desired engine speed (rpm)
(11) Engine speed (rpm)
(12) Coolant temperature
(13) FRC fuel position
(14) Rated fuel position
(15) Turbocharger outlet pressure
(16) Top center for number one cylinder

Electronic Controls

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

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

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

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

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

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

Fuel Injection

The ECM controls the amount of fuel that is injected by varying the signal to each of the unit injectors. The unit injectors will inject fuel only while the unit injector solenoid is energized. The ECM sends a 105 volt signal to the solenoid in order to energize the injector solenoid. By controlling the timing of the 105 volt signal, the ECM controls injection timing. By controlling the duration of the 105 volt signal, the ECM controls the amount of fuel that is injected.

The ECM sets certain limits on the amount of fuel that can be injected. The FRC fuel position is a limit that is based on boost pressure in order to control the fuel air mixture for the emission control. When the ECM senses an increase in the boost pressure, the ECM increases the FRC fuel position. The rated fuel position is a limit that is based on the horsepower rating of the engine. The rated fuel position is similar to the rack stops and the torque spring on a mechanically governed engine. The rated fuel position provides the horsepower and the torque curves for a specific engine family. The rated fuel position provides the horsepower and the torque curves for a specific horsepower rating. The limits are programmed by the factory into the personality module. The limits are not programmable in the field.

The injection timing relies on the following engine parameters: engine speed, engine load, and other engine data. The ECM senses the top center position of number one cylinder from the signal that is provided by the engine speed/timing sensors. The ECM decides when the injection should occur relative to this top center position. The ECM provides the signal to the unit injector at the desired time.

Unit Injector Mechanism

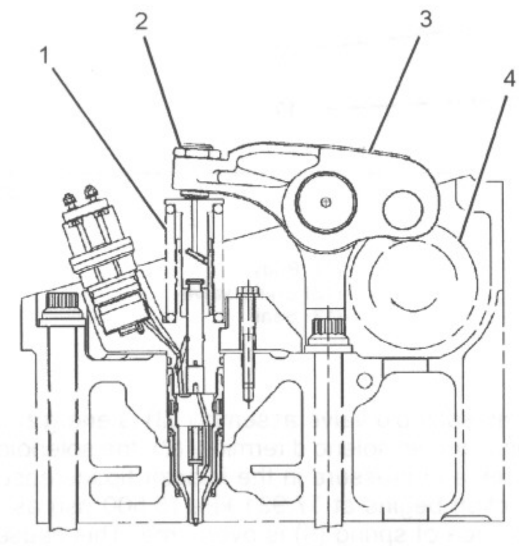

Illustration 17 g01095057

Typical unit injector mechanism

(1) Unit injector
(2) Adjusting nut
(3) Rocker arm assembly
(4) Camshaft

The unit injector mechanism provides the downward force that is required to pressurize the fuel in the unit injector. When a signal is received from the ECM, the unit injector (1) injects the pressurized fuel into the combustion chamber. The camshaft gear is driven by an idler gear which is driven through the front gear train by the crankshaft gear. The gears of the front gear train that are timed must be aligned in order to provide the correct relationship between the piston and valve movement. During assembly of the front gear train, care must be taken in order to correctly align the timing marks of the gears. The camshaft (4) has three camshaft lobes for each cylinder. Two lobes operate the inlet and exhaust valves, and one operates the unit injector mechanism. Force is transferred from the unit injector lobe on camshaft (4) through rocker arm assembly (3) to the top of the unit injector. The adjusting nut (2) allows setting of the unit injector adjustment. Refer to the section on adjustment of the injector in Testing and Adjusting for the proper setting of the unit injector.

Unit Injector

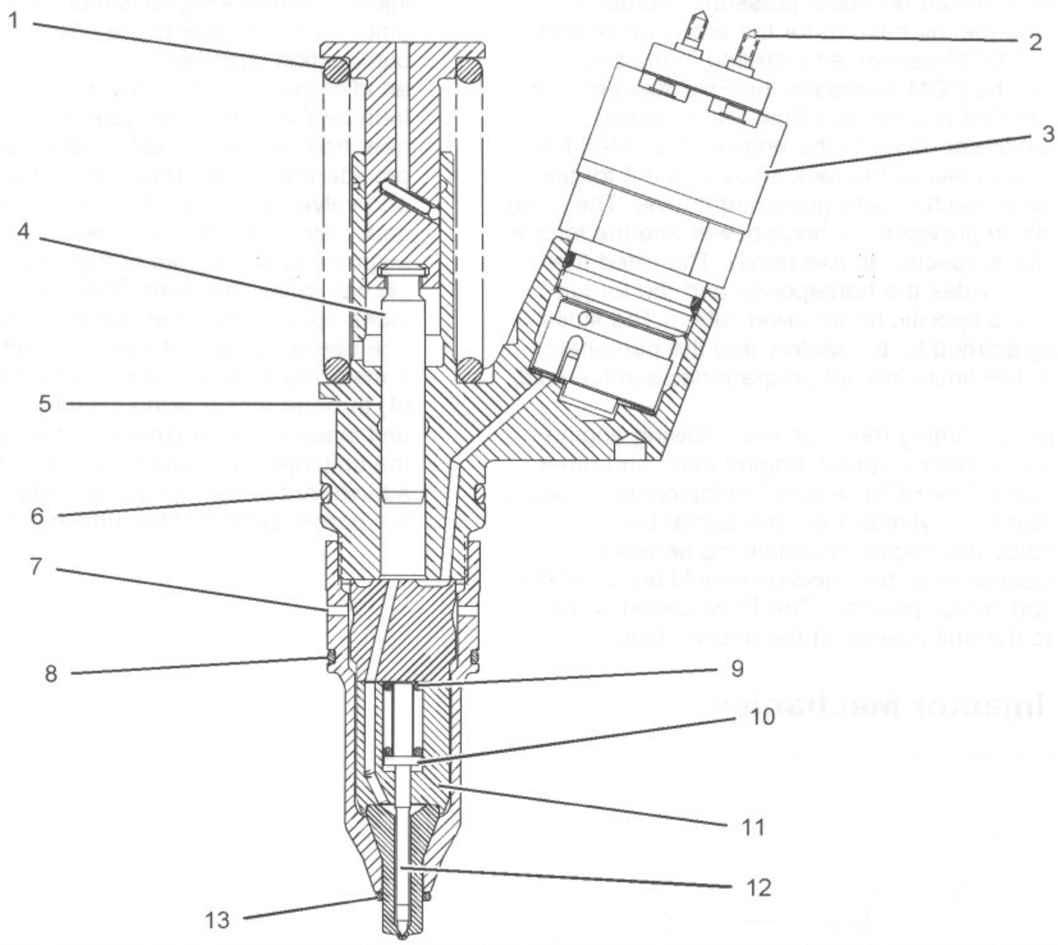

Illustration 18 g01095086

Typical mechanical electronic unit injector

(1) Spring
(2) Solenoid terminal
(3) Solenoid valve assembly
(4) Plunger
(5) Barrel
(6) Seal
(7) Fill port
(8) Seal
(9) Spring
(10) Spacer
(11) Body
(12) Check valve
(13) Seal

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

As the unit injector mechanism transfers the force to the top of the unit injector, the spring (1) is compressed and the plunger (4) is driven downward. This causes fuel to be displaced through the valve, in solenoid valve assembly (3), and into the fuel return port of the cylinder head. As the plunger continues to be driven downward, the fuel passage in the barrel (5) is closed by the outside diameter of the plunger. The passages to the injector tip within body (11) and along check valve (12) are filled with the fuel that is displaced by the plunger. After the fuel passage in the plunger barrel is closed, fuel can be injected at any time. The characteristics of the injection cycle relies on the software in the ECM.

When solenoid valve assembly (3) is energized by a signal across solenoid terminal (2), the solenoid valve closes and pressure in the injector tip increases. Injection begins at 37,931 kPa (5,500 psi) as the force of spring (9) is overcome. This causes the check valve to rise from the valve seat. The pressure continues to increase as the plunger cycles through the full stroke. After the correct amount of fuel has been discharged into the cylinder, the ECM discontinues the 105 volt signal. The solenoid valve assembly is de-energized and the solenoid valve is opened. The high pressure fuel is dumped through the spill port and into the fuel return port of the cylinder head. The check valve in the injector tip seats. Injection has ended as the fuel pressure decreases to 25,517 kPa (3,700 psi).

The duration of injection determines the quantity of fuel that is injected into the cylinder. Injection duration is controlled by the governor logic that is programmed into the ECM.

As the unit injector mechanism begins to retract, the force to the top of the unit injector is removed as spring (1) expands. The plunger returns to the original position. As the plunger retracts, a vacuum is created in barrel (5) of the injector. This pulls fuel into the barrel which fills the cavity in preparation of the next injection cycle.

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Air Inlet and Exhaust System

SMCS Code: 1050

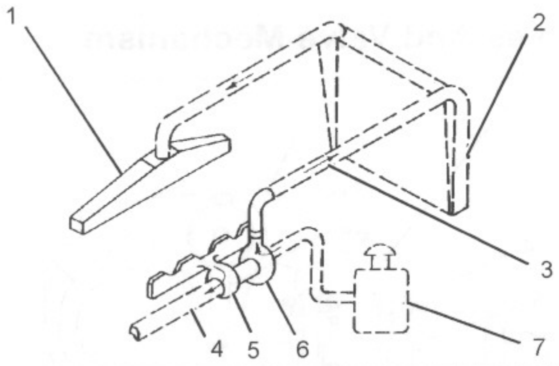

Illustration 19 g01115457

Air inlet and exhaust system schematic

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

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

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

The turbocharger compressor wheel pulls inlet air through the air cleaner and into the air inlet. The air is compressed and heated to about 150 °C (300 °F) before the air is forced to the aftercooler. The air flows through the aftercooler core (2) and the temperature of the compressed air lowers to about 43 °C (110 °F). The combustion efficiency increases because of the cooler inlet air. This helps to provide lowered fuel consumption and increased horsepower output. The aftercooler core (2) is a separate cooler core that is mounted in front of the engine radiator. The engine fan moves ambient air across both cores. This cools the turbocharged inlet air and the engine coolant.

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

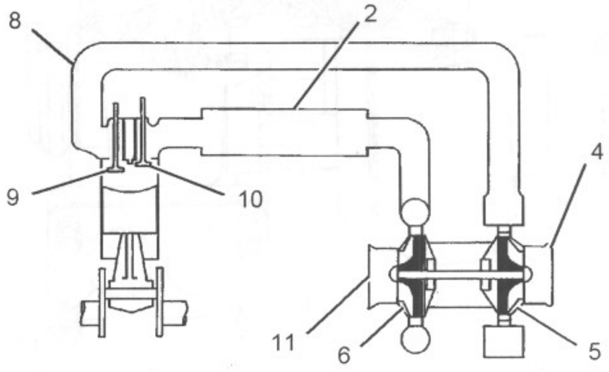

Illustration 20 g01115461

Air inlet and exhaust system

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

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

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

Turbocharger

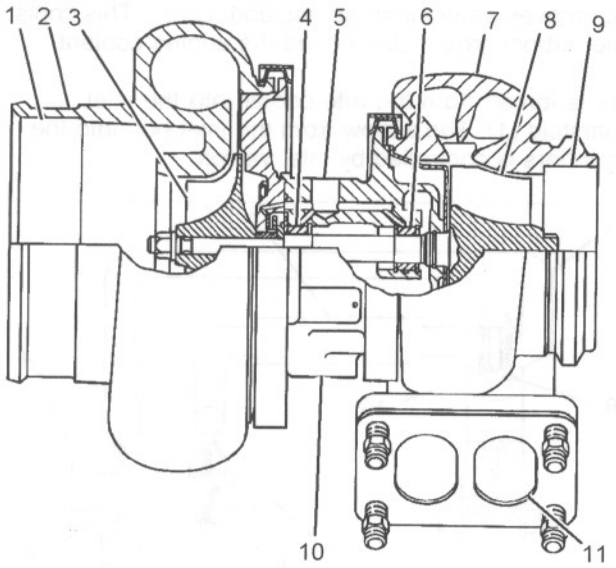

Illustration 21 g01115466

Turbocharger (typical example)

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

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

The exhaust gases enter the turbocharger and the blades of the turbocharger turbine wheel are turned. Because the turbocharger turbine wheel is connected by a shaft to the turbocharger compressor wheel, the turbine wheel and the compressor wheel turn at very high speeds. The rotation of the compressor wheel pulls clean air through the compressor housing air inlet. The action of the compressor wheel blades causes a compression of the inlet air. This compression gives the engine more power. The engine gets more power because the engine is able to burn more air and more fuel during combustion.

When the load on the engine increases or when a greater engine speed is desired, additional fuel is injected into the cylinders. This creates more exhaust gases, which cause the turbine wheel and the compressor wheel to turn faster. Additional air is forced into the engine as the compressor wheel turns faster. The increased flow of air provides more power to the engine. The engine gets more power because the engine is able to burn additional fuel with greater efficiency.

The bearings (4) and (6) in the turbocharger use engine oil that is under pressure for lubrication. The lubrication oil for the bearings flows through an oil inlet port (5) and into the inlet port in the center section of the cartridge. The oil exits the turbocharger through an oil outlet port (10) and through an oil drain line. The oil then returns to the engine lubrication system.

Valves And Valve Mechanism

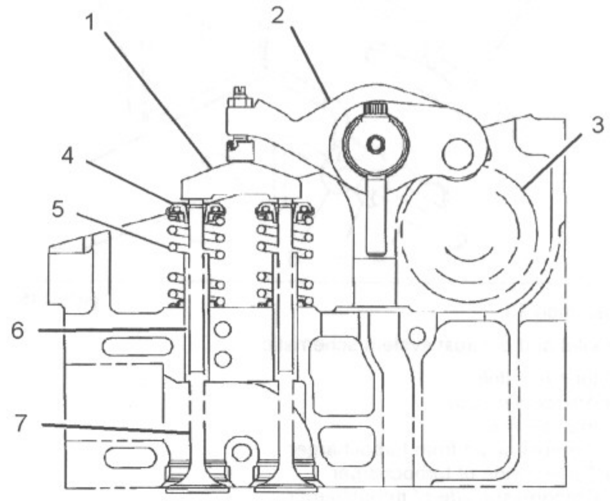

Illustration 22 g01115472

Valve system components

(1) Valve bridge
(2) Rocker arm
(3) Camshaft
(4) Rotocoil
(5) Valve spring
(6) Valve guide
(7) Valve

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

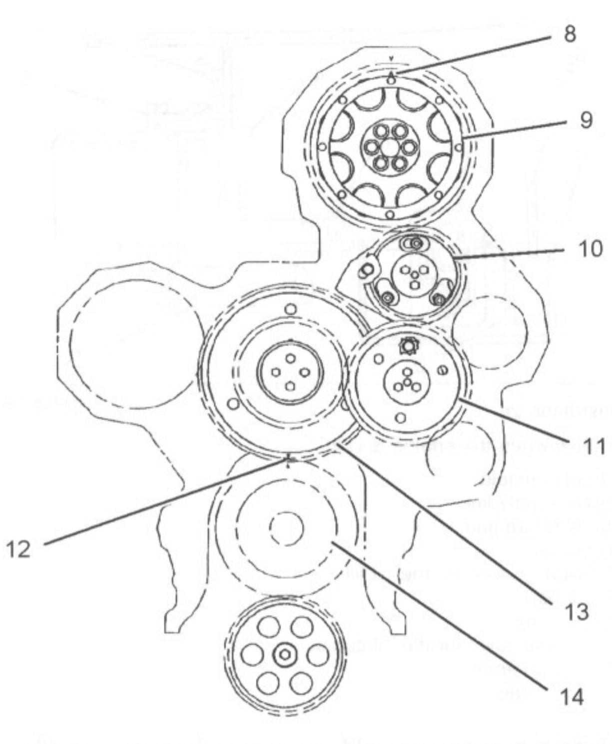

Illustration 23 g01115484

Components of the timing gear

(8) Timing mark
(9) Camshaft gear
(10) Adjustable idler gear
(11) Idler gear
(12) Timing mark
(13) Cluster gear
(14) Crankshaft gear

The inlet valves and the exhaust valves are opened by the valve mechanism. The inlet valves and the exhaust valves are also closed by the valve mechanism. This occurs as the rotation of the crankshaft causes camshaft (3) to rotate. Camshaft gear (9) is driven by a series of two idler gears (10) and (11). Idler gear (11) is driven by cluster gear (13). Cluster gear (13) is driven by crankshaft gear (14). Timing mark (12) and Timing mark (8) are aligned in order to provide the correct relationship between the piston and the valve movement.

The camshaft has three lobes for each cylinder. One lobe operates the inlet valves. A second lobe operates the exhaust valves. The third lobe operates the unit injector mechanism. The camshaft lobes turn and the rocker arms move up and down. Movement of the rocker arms will make the inlet and exhaust valve bridges move up and down. These bridges allow one rocker arm to either open or either close two valves at the same time. Each cylinder has two inlet valves and two exhaust valves. Each valve has one valve spring (5). The spring closes the valve when the camshaft lobe is rotated past the rocker arm.

Rotocoils (4) cause the valves to rotate while the engine is running. Valve rotation provides a longer service life. Valve rotation also minimizes carbon deposits on the valves.

Adjustable idler gear (10) is designed to provide the required gear backlash between nonadjustable idler gear (11) and camshaft gear (9). If the cylinder head is removed, tolerances of the components will change. The components that change are the cylinder head and the head gasket. The adjustable idler gear must be relocated. For information on setting the correct backlash, refer to Testing and Adjusting, "Gear Group (Front) - Time".

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

i02209653

Lubrication System

SMCS Code: 1300

Lubrication System Components

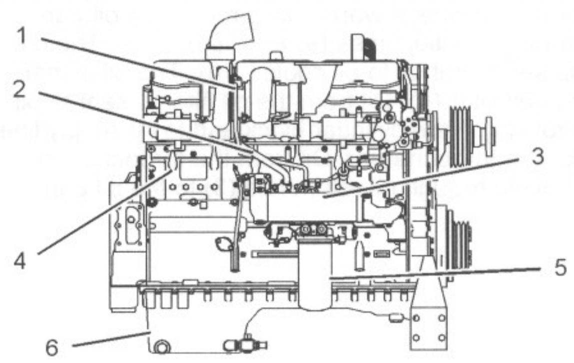

Illustration 24 g01115529

(1) Oil supply line
(2) Oil return line
(3) Oil cooler
(4) Oil manifold
(5) Oil filter
(6) Oil pan

The lubrication system has the following components:

- Oil pan
- Oil pump
- Oil cooler
- Oil filter
- Turbocharger oil lines

- Oil passages for the cylinder block

Oil Flow Through The Oil Filter And Oil Cooler

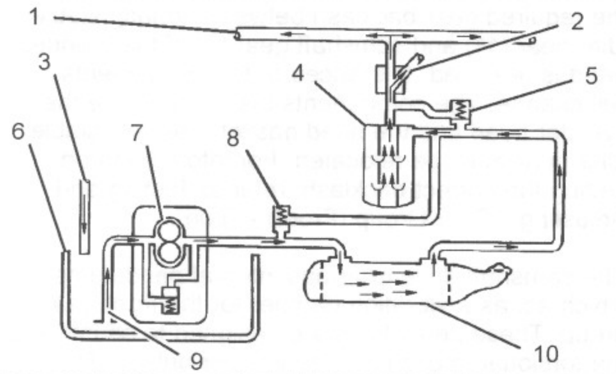

Illustration 25 g01115540

Oil flow when the engine is warm.

(1) Oil manifold
(2) Oil supply line
(3) Oil return line
(4) Oil filter
(5) Bypass valve for the oil filter
(6) Oil pan
(7) Oil pump
(8) Bypass valve for the oil cooler
(9) Suction lines
(10) Oil cooler

When the engine is warm, oil comes from oil pan (6) through suction lines (9) to oil pump (7). The oil pump sends hot oil to oil cooler (10). The oil is then sent to oil filter (4). Oil from the oil filter is sent to oil manifold (1) in the cylinder block and to oil supply line (2) for the turbocharger. Oil from the turbocharger goes back through oil return line (3) to the oil pan.

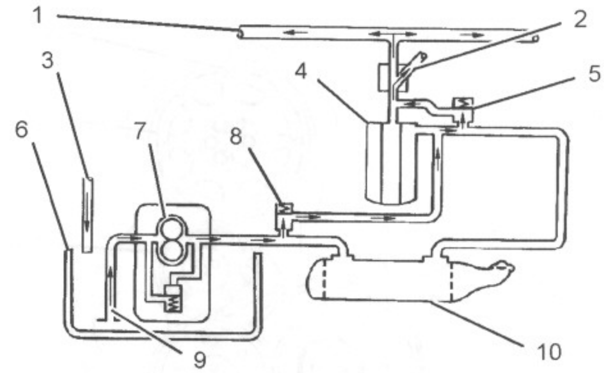

Illustration 26 g01115568

Oil flow when the engine is cold.

(1) Oil manifold
(2) Oil supply line
(3) Oil return line
(4) Oil filter
(5) Bypass valve for the oil filter
(6) Oil pan
(7) Oil pump
(8) Bypass valve for the oil cooler
(9) Suction lines
(10) Oil cooler

When the engine is cold, oil comes from oil pan (6) through suction lines (9) to oil pump (7). When the oil is cold, an oil pressure difference in the bypass valves also causes the bypass valves to open. These bypass valves then provide immediate lubrication to all of the engine components when cold oil with high viscosity causes a restriction to the oil flow through oil cooler (10) and oil filter (4). The oil pump then sends the cold oil through bypass valve (8) for the oil cooler and through bypass valve (5) for the oil filter. The oil then goes to oil manifold (1) in the cylinder block and to supply line (2) for the turbocharger. Oil from the turbocharger goes back through oil return line (3) to the oil pan.

When the oil is hot, an oil pressure difference in the bypass valves also causes the bypass valves to close. There is normal oil flow through the oil cooler and the oil filter.

The bypass valves will also open when there is a restriction in the oil cooler or the oil filter. This prevents a restricted oil filter or a restricted oil cooler from stopping the lubrication of the engine.

Oil Flow In The Engine

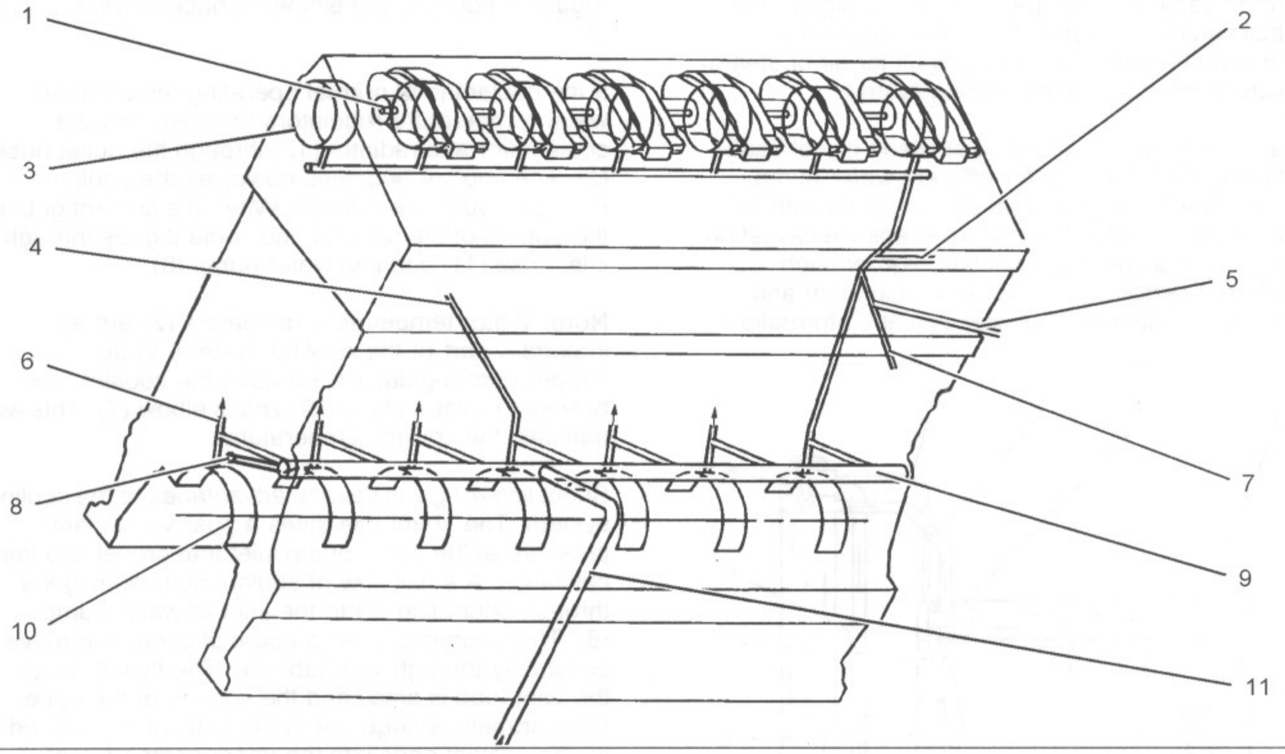

Illustration 27 g01115577

Engine oil flow schematic

(1) Rocker arm shaft
(2) Oil passage to the adjustable idler gear
(3) Camshaft bearing journals
(4) Oil passage to the air compressor
(5) Oil passage to the fixed idler stub shaft
(6) Piston cooling jets
(7) Oil passage to cluster idler gear
(8) Oil passage to the rear crankshaft seal
(9) Oil manifold
(10) Crankshaft main bearings
(11) Oil passage from filter

The oil from oil manifold (9) is sent under pressure through drilled passages to crankshaft main bearings (10). The oil flows through drilled holes in the crankshaft. This oil lubricates the connecting rod bearings. A small amount of oil is sent through piston cooling jets (6). The piston cooling jets cool the pistons.

Oil flows through passages in the timing gear housing and the accessory drive gear. This oil flows to the air compressor through oil passage (4).

Oil passage (2) provides oil to the adjustable idler gear. Oil passage (5) provides oil to the fixed idler gear. Oil passage (7) provides oil to the cluster gear. The oil flows through a passage in the shafts of the gears. This lubrication helps to ensure a long life for the front gear group.

Oil passage (8) provides lubrication to the rear crankshaft seal. This ensures a long service life for the rear crankshaft seal.

Oil flows into the cylinder head via a hollow locating dowel in the top deck of the cylinder block. Oil travels to camshaft bearing journals (3) and the three center rocker arm shaft supports through drilled passages in the cylinder head. The supports supply oil to each rocker shaft. Oil flows to the bushings of the electronic unit injector rocker arm through holes in rocker arm shaft (1). This same oil lubricates the valve and the rollers. Oil flows through drilled passages in the rocker arms. This oil lubricates the roller, the valve bridge and the contact surfaces of the actuator of the unit injector. Splash oil lubrication is used to lubricate other components of the valve system.

When all the components are lubricated the excess oil returns to the engine oil pan.

i02162740

Cooling System

SMCS Code: 1350

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

A pressure type cooling system gives two advantages. First, the cooling system can be operated safely at a temperature that is higher than the boiling point of water. Also, cavitation in the water pump is prevented. It is more difficult for air or steam pockets to be made in the cooling system.

Note: A 30 percent mixture of ethylene glycol base antifreeze must be used for efficient water pump performance on engines that are equipped with an air-to-air aftercooler. This mixture keeps the cavitation temperature range of the coolant high enough for efficient performance. Refer to Operation and Maintenance Manual, "General Coolant Information".

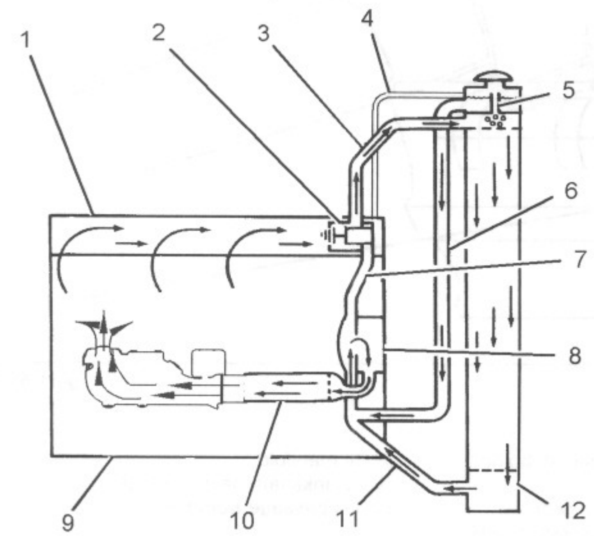

Illustration 28 g01096647

Cooling system for a warm engine

(1) Cylinder head
(2) Water temperature regulators
(3) Outlet hose
(4) Vent line
(5) Vent tube
(6) Shunt line
(7) Elbow
(8) Water pump
(9) Cylinder block
(10) Oil cooler
(11) Inlet hose
(12) Radiator

During operation, water pump (8) sends most of the coolant from radiator (12) to oil cooler (10).

The coolant from oil cooler (10) goes into cylinder block (9) through a bonnet and an elbow. The coolant flows around the cylinder liners into the cylinder head.

The flow of coolant goes around the valves and the passages for exhaust gases in the cylinder head. The coolant then goes to the front of the cylinder head. At this point, two water temperature regulators (2) control the direction of coolant flow.

Water temperature regulators (2) are closed when the engine is cold. The coolant flows through the regulator housing and elbow (7) back to water pump (8).

If the coolant is at normal operating temperature, water temperature regulators (2) open and the coolant flows to radiator (12) through the outlet hose (3). The coolant becomes cooler as the coolant moves through the radiator. When the coolant gets to the bottom of the radiator, the coolant goes through inlet hose (11) and into water pump (8).

Note: Water temperature regulators (2) are an important part of the cooling system. Water temperature regulator (2) divides the coolant flow between radiator (12) and bypass elbow (7). This will maintain the correct temperature.

Shunt line (6) gives several advantages to the cooling system. The shunt line gives a positive coolant pressure at the water pump inlet that prevents pump cavitation. A small flow of coolant constantly goes through shunt line (6) to the inlet of water pump (8). This causes a small amount of coolant to move constantly through vent tube (5). The flow through the vent tube is small and the volume of the upper compartment is large. Air in the coolant is removed as the coolant goes into the upper compartment.

The vent line is used to fill the cooling system with coolant for the first time. This will purge any air out of the top of a bottom filled system.

A surge tank may be installed into the system. The tank can be mounted on the radiator or the tank can be mounted on a remote location. The coolant that expands past the radiator cap is retained in the surge tank. The coolant contracts as the temperature drops and the coolant is drawn back into the radiator.

i01192915

Basic Engine

SMCS Code: 1200

Cylinder Block Assembly

Passages supply the lubrication for the crankshaft bearings and the piston crowns. These passages are drilled passages in the oil manifolds. Cooling passages for the top piston ring are located in the top deck of the block. This configuration provides improved rigidity. This configuration will resist the deflection that is caused by combustion.

The cylinder liner is an induction hardened liner. A steel spacer plate provides improved reusability and durability.

Cylinder Head Assembly

The cylinder head is a one-piece cast iron head. The camshaft is contained within the cylinder head. This improves the rigidity of the valve train. Steel reinforced aluminum bearings are pressed into each journal. The bearings are lubricated under pressure. Bridge dowels have been eliminated as the valve train uses floating valve bridges.

Thermal efficiency is enhanced by the use of stainless steel thermal sleeves in each exhaust port. The sleeves reduce the amount of heat rejection to the cooling system. The sleeves then transfer the thermal energy to the turbocharger.

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

Pistons, Rings And Connecting Rods

Two-Piece Pistons

The piston is a two-piece articulated design that consists of a forged steel crown and a cast aluminum skirt. Both parts are retained by the piston pin to the small end of the connecting rod. An oil cooling chamber is formed by the lip that is cast at the top of the piston skirt and the cavity that is behind the ring grooves in the crown. The oil flow then returns to the sump through the clearance gap between the crown and the skirt. The pistons have three rings that are located in grooves in the steel crown. The rings seal the combustion gas and the rings provide control of the oil. The top ring has a barrel face. This ring is a KEYSTONE ring with a plasma face coating. The second ring has a tapered face and the ring has a coating of chrome finish for the face. The third ring is the oil ring. The ring is double railed and the ring is profile ground. This ring has a coating of chrome finish for the face. The oil ring has a coil spring expander. There are four holes that are drilled from the piston oil ring groove to the interior of the piston. These holes drain excess oil from the oil ring.

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

Crankshaft

The crankshaft converts the combustion force in the cylinder into rotating torque. The rotating torque powers the equipment. On this engine, a vibration damper is used at the front of the crankshaft in order to reduce the torsional vibrations. The torsional vibrations can cause damage to the engine.

The crankshaft drives a group of gears (front gear train) on the front of the engine. The front gear train provides power for the following components: camshaft, water pump, oil pump, air compressor, and other accessories.

The crankcase has seven main bearings that support the crankshaft. The crankcase also has two bolts which hold each bearing cap to the block. The oil holes in the shell for the upper bearing are located at all of the main bearing journals. The grooves in the shell for the upper bearing are also located at all of the main bearing journals. The holes and the grooves supply oil to the connecting rod bearings. The crankshaft has eight counterweights which are forged integrally. The eight counterweights are located at cheeks 1, 2, 5, 6, 7, 8, 11 and 12.

To seal the crankcase, crankshaft seals are installed in the front timing gear housing and the flywheel housing.

Camshaft

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

i02111768

Air Starting System

SMCS Code: 1450

S/N: 8AZ1-Up

To start the engine, an optional air starting motor may be used to turn the engine flywheel at the appropriate speed for starting.

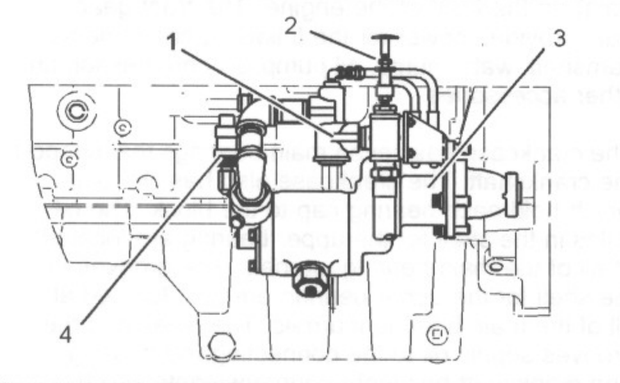

Illustration 29 g01098687

Typical Air Starting System

(1) Relay valve
(2) Air start control valve
(3) Air starting motor
(4) Oiler

The air starting motor (2) can be mounted on either side of the engine. Air is normally contained in a storage tank. The storage tank must hold this volume of air at 1720 kPa (250 psi) when the storage tank is filled.

The regulator setting is approximately 690 kPa (100 psi) for engines which do not have heavy loads when the engine is started. This setting is a favorable compromise between the following conditions:

- The engine cranking speeds that are needed to start the engine
- Volume of air in the storage tank

If the engine has a heavy load which can not be disconnected during starting, the setting of the air pressure regulating valve needs to be higher in order to get high enough speed for easy starting.

This system is designed to operate between 640 kPa (93 psi) and 1034 kPa (150 psi). A pressure regulator must be used for pressures above 1034 kPa (150 psi).

The air consumption is directly related to speed. Also, the air pressure is related to the force that is needed to turn the engine flywheel. If necessary, the air pressure regulator can be adjusted to 1034 kPa (150 psi) in order to produce the correct cranking speed for a heavily loaded engine. With the correct setting, the air starting motor can turn the excessively loaded engine as fast as an engine that does not have an excessive load.

Other air supplies can be used with the correct pressure and volume. For good life of the air starting motor, the supply should be free of dirt and water. The maximum pressure for use in the air starting motor is 1030 kPa (150 psi).

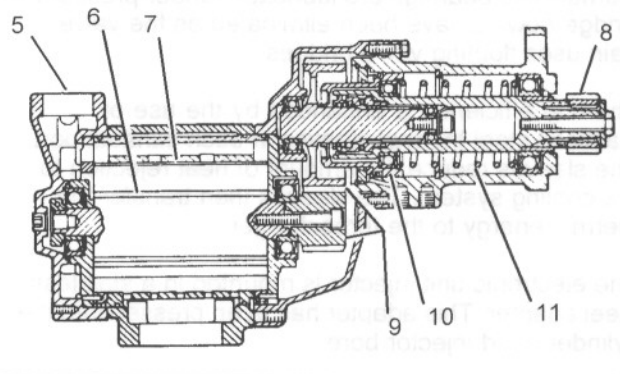

Illustration 30 g01098688

Air Starting Motor

(5) Air inlet
(6) Vanes
(7) Rotor
(8) Pinion
(9) Gears
(10) Piston
(11) Piston spring

The air from the supply goes to relay valve (3). The air start control valve (1) is connected to the line before the relay valve. The flow of air is stopped by the relay valve until air start control valve (1) is activated. Then, air from the control valve goes to piston (10) and behind pinion (8) for the air starting motor. The air pressure on piston (10) compresses piston spring (11). Also, the air pressure on piston (10) engages pinion (8) with the flywheel gear. When the pinion is in engagement, air can go out through another line to the relay valve. The air activates the relay valve which opens the supply line to the air starting motor.

The flow of air goes through the oiler (4) in order to pick up lubrication oil for the air starting motor.

The air with lubrication goes into the air starting motor through air inlet (5). The pressure of the air pushes vanes (6) in rotor (7). This turns the rotor which is connected by gears (9) and a drive shaft to starter pinion (8) which turns the engine flywheel.

When the engine starts running, the flywheel will start to turn faster than pinion (8). The pinion (8) retracts under this condition. This prevents damage to the motor, to pinion (8) or to the flywheel gear.

When air start control valve (1) is released, the air pressure and flow to piston (10) behind pinion (8) is stopped. Piston spring (11) retracts pinion (8). Relay valve (3) stops the flow of air to the air starting motor.

i02210064

Electrical System

SMCS Code: 1400; 1550; 1900

Reference

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

Grounding Practices

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

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

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

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

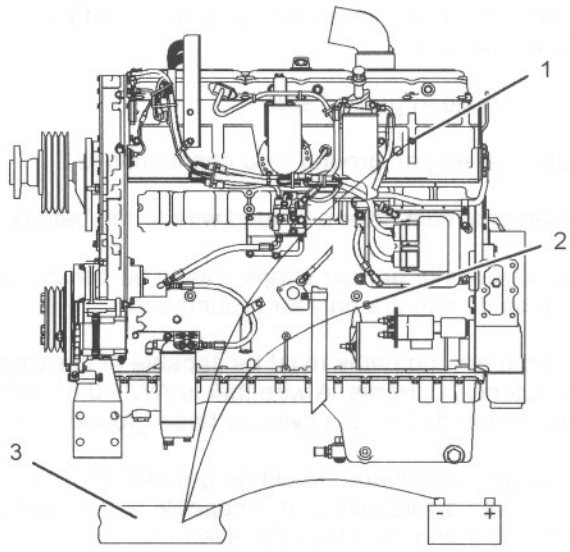

Illustration 31 g01096922

Typical example of grounding the battery and the cylinder head to the frame rail

(1) Cylinder head ground stud
(2) Optional engine ground stud
(3) Frame rail

Connect the battery negative post to frame rail (3). From the frame rail, connect the ground wire to one of the following locations:

- Cylinder head ground stud (1)
- Optional engine ground stud connection (2)

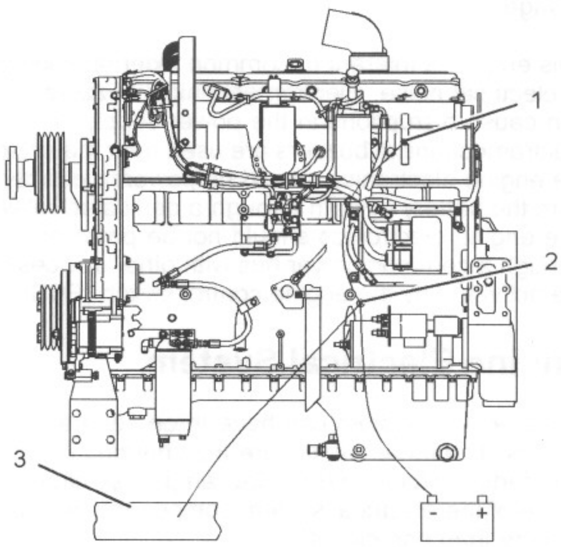

Illustration 32 g01096929

Typical example of the alternate cylinder head to the battery ground

(1) Cylinder head ground stud
(2) Optional engine ground stud
(3) Frame rail

The engine must be grounded to frame rail (3). Connect the battery negative post to one of the following locations:

- Cylinder head ground stud (1)
- Optional engine ground stud connection (2)

The engine must have a ground wire to the battery.

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

All of the ground paths must be capable of carrying any potential currents. A wire that is AWG 0 or more is recommended for the cylinder head ground strap.

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

NOTICE

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

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

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

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

Engine Electrical System

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

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

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

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

Charging System Components

Alternator

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

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

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

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

NOTICE

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

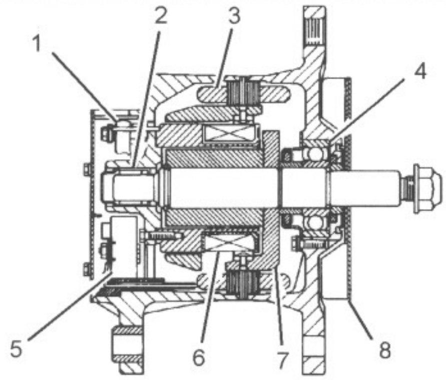

Illustration 33 g01096944

Typical cross section of an alternator

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

Starting System Components

Solenoid

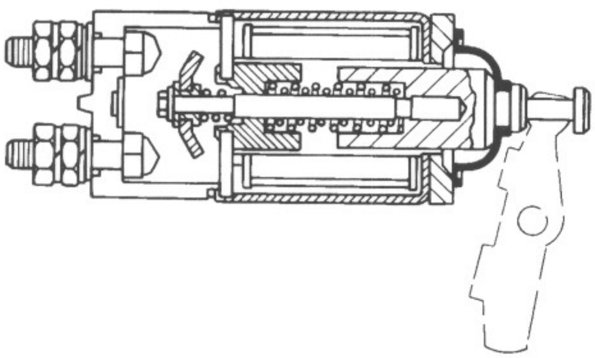

Illustration 34 g00292316

Typical cross section of a solenoid

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

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

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

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

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

Starter Motor

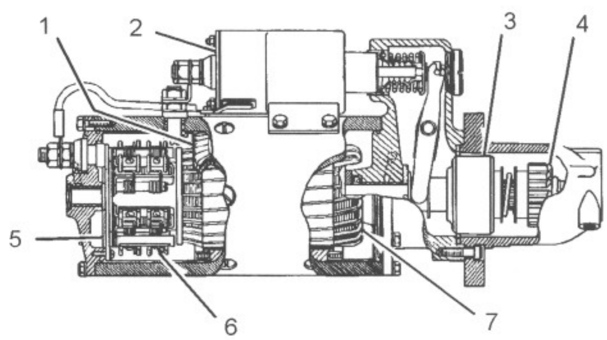

Illustration 35 g01096954

Typical cross section of a starter motor

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

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

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

Testing and Adjusting Section

Fuel System

i02209792

Fuel System - Inspect

SMCS Code: 1250-040

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

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

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

3. Install a new fuel filter.

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

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

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

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

i02162794

Air in Fuel - Test

SMCS Code: 1280-081

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

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

2. Install a 2P-8278 Tube As (Sight Gauge) in the fuel return line. When possible, install the sight gauge in a straight section of the fuel line that is at least 304.8 mm (12 inches) long. Do not install the sight gauge near the following devices that create turbulence:

   - Elbows
   - Relief valves
   - Check valves

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

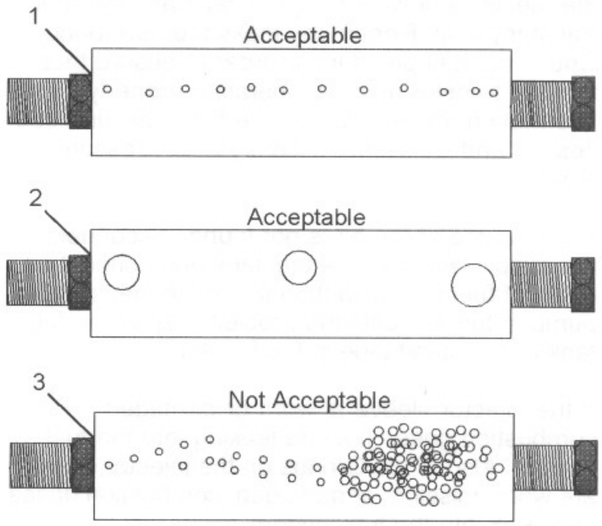

Illustration 36 g01096678

2P-8278 Tube As (Sight Gauge)

(1) A steady stream of small bubbles with a diameter of approximately 1.60 mm (0.063 inch) is an acceptable amount of air in the fuel.

(2) Bubbles with a diameter of approximately 6.35 mm (0.250 inch) are also acceptable if there is two seconds to three seconds intervals between bubbles.

(3) Excessive air bubbles in the fuel are not acceptable.

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

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

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

WARNING

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

NOTICE

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

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

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

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

i01962472

Electronic Unit Injector - Adjust

SMCS Code: 1290-025

Table 1

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

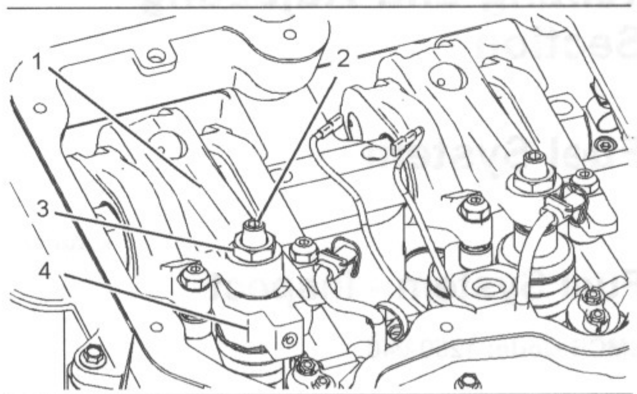

Illustration 37 g01023138

Injector Mechanism (Typical example)

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

To make an adjustment to the unit injectors on cylinders 3, 5, and 6 use the following procedure:

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

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

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

4. Hold the adjusting screw in this position and tighten locknut (3) to a torque of 100 ± 10 N·m (74 ± 7 lb ft).

5. To make an adjustment to the unit injectors on cylinders 1, 2, and 4, remove the timing bolt. Turn the flywheel by 360 degrees in the direction of engine rotation. The direction of engine rotation is counterclockwise, as the engine is viewed from the flywheel end. This will put the number 1 piston at the top center position on the exhaust stroke.

6. Repeat Steps 3 through 4.

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

i02209818

Electronic Unit Injector - Test

SMCS Code: 1290-081

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

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

WARNING

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

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

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

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

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

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

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

i02073597

Finding Top Center Position for No. 1 Piston

SMCS Code: 1105-531

Table 2

Needed Tools		
9S-9082	Engine Turning Tool	1

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

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

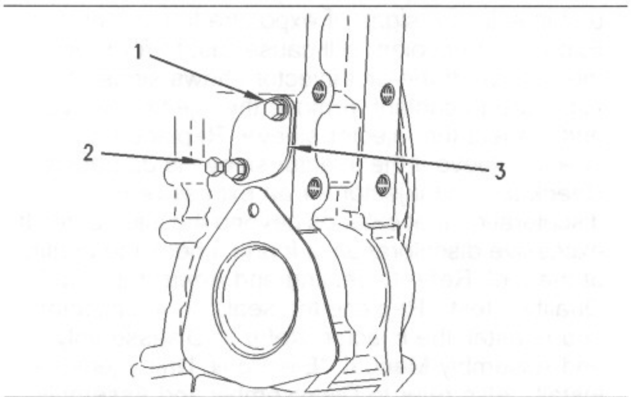

Illustration 38 g00294875

Locating Top Center (Left Side Of Engine)

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

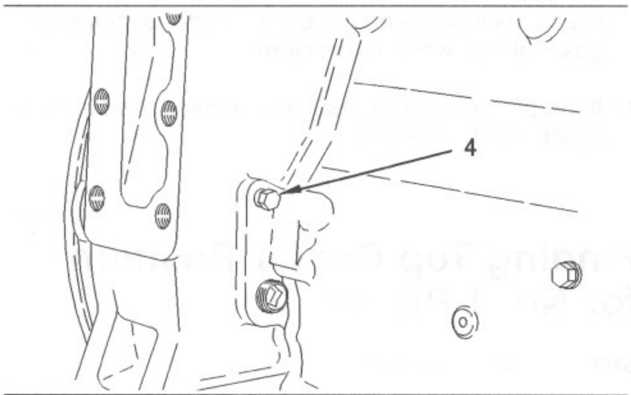

Illustration 39 g00294876

Locating Top Center (Right Side Of Engine)

(4) Timing bolt location.

1. Timing bolt (1) is a cover bolt. The timing bolt can be installed in either the left side of the engine at location (2) or in the right side of the engine at timing bolt location (4). Remove both bolts (1) and cover (3) from the flywheel housing. Remove the plug from the timing hole in the flywheel housing.

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

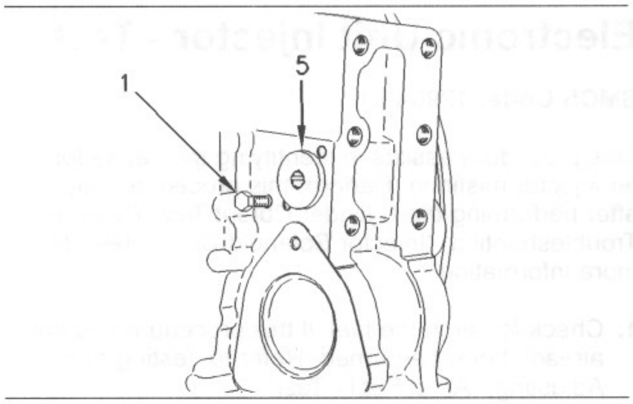

Illustration 40 g00294877

Using 9S-9082 Engine Turning Tool

(1) Timing bolt
(5) 9S-9082 Engine Turning Tool

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

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

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

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

i02209841

Fuel Quality - Test

SMCS Code: 1280-081

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

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

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

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

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

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

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

3. Check fuel API with a 5P-2712 Thermometer/Hydrometer for low power complaints. The acceptable range of the fuel API is 30 to 45 when the API is measured at 15 °C (60 °F), but there is a significant difference in energy within this range.

Table 3

Fuel Density (API)[1] Correction Factors	
API at 16 °C (60 °F)	**Correction Factor**
32.0	.987
35.0	1.000
40.0	1.031
45.0	1.077

[1] The measured fuel API rating and the corresponding temperature must be corrected to 16 °C (60 °F) before selecting a fuel correction factor. Use the chart for the fuel density correction factor in order to determine the fuel API rating at 16 °C (60 °F).

Note: A correction factor that is greater than 1.000 may be the cause of low power and/or poor fuel consumption.

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

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

i02163244

Fuel System - Prime

SMCS Code: 1258-548

The Secondary Fuel Filter Has Been Replaced

WARNING

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

NOTICE

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

NOTICE

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

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

1. Turn the engine control switch (ECS) to the "OFF" position.

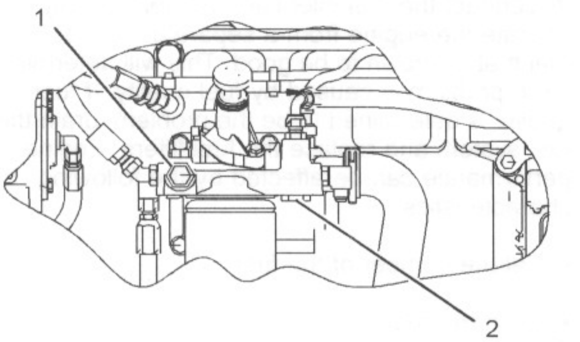

Illustration 41 g01096972

Hand priming pump

(1) Air purge screw
(2) Fuel pressure regulating valve

2. Open air purge screw (1) for the fuel filter by three full turns. Do not remove the air purge screw.

NOTICE

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

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

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

4. While the engine is running, observe air purge screw (1). When a small drop of fuel appears at the threads of the air purge screw, close and tighten air purge screw (1).

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

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

5. Clean any residual fuel from the engine components.

The Engine Has Been Run Out of Fuel

NOTICE

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

NOTICE

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

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

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

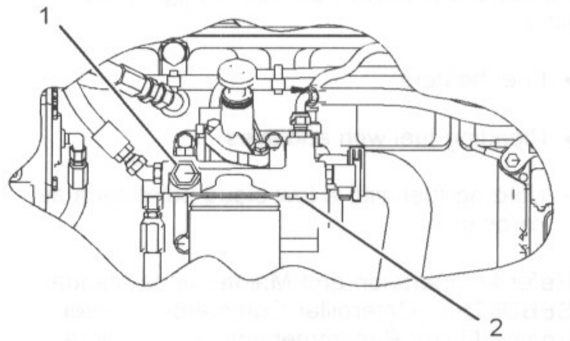

Illustration 42 g01096972

Hand priming pump

(1) Air purge screw
(2) Fuel pressure regulating valve

3. Open fuel pressure regulating valve (2) by two and a half turns. The regulating valve is located in the integral fuel filter base.

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

NOTICE

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

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

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

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

6. Close and tighten fuel pressure regulating valve (2).

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

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

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

9. Clean any residual fuel from the engine components.

The Engine Has Been Rebuilt

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

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

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

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

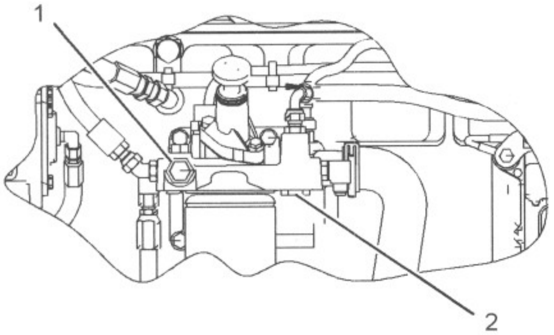

Illustration 43 g01096972

Hand priming pump

(1) Air purge screw
(2) Fuel pressure regulating valve

3. Open the air purge screw (1) for the fuel filter by three full turns. Do not remove the air purge screw.

4. Open fuel pressure regulating valve (2) by two and a half turns. The regulating valve is located in the integral fuel filter base.

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

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

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

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

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

7. Close and tighten air purge screw (1).

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

9. Close and tighten fuel pressure regulating valve (2).

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

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

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

12. Clean any residual fuel from the engine components.

i02160582

Fuel System Pressure - Test

SMCS Code: 1250-081; 1256-081

Low Fuel Pressure

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

- Plugged fuel filters
- Debris in the check valves for the fuel priming pump
- Debris in the pressure regulating valve
- Partially open check valve

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

High Fuel Pressure

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

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

Fuel Pressure Readings

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

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

Checking Fuel Pressure

Table 4

Required Tools		
Part Number	Part Name	Quantity
1U-5470 or 198-4240	Engine Pressure Group or Digital Pressure Indicator	1
3Y-2888	Connector	1
3J-1907	O-Ring Seal	1

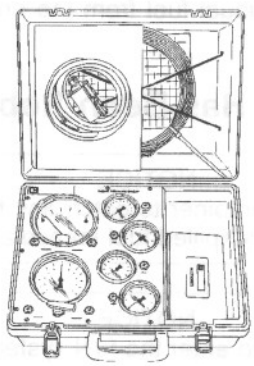

Illustration 44 g00294866

1U-5470 Engine Pressure Group

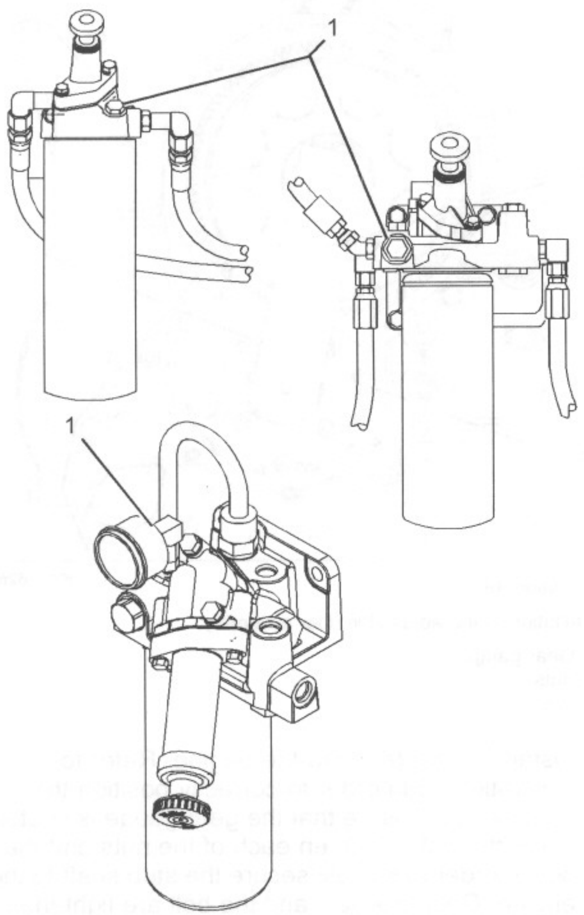

Illustration 45 g01095598

(1) Typical locations of fuel pressure taps

To check the fuel transfer pump pressure, remove the plug from the fuel filter base. Install the 3Y-2888 Connector with a 3J-1907 O-Ring Seal. Install a pressure gauge, and start the engine.

The 1U-5470 Engine Pressure Group can be used in order to check the fuel pressure of the engine. The engine pressure group includes Special Instruction, SEHS8907, "Using the 1U-5470 Engine Pressure Group". This instruction provides information about the usage of the group.

i02188003

Gear Group (Front) - Time

SMCS Code: 1206-531

Static Check of the Timing Gear Position

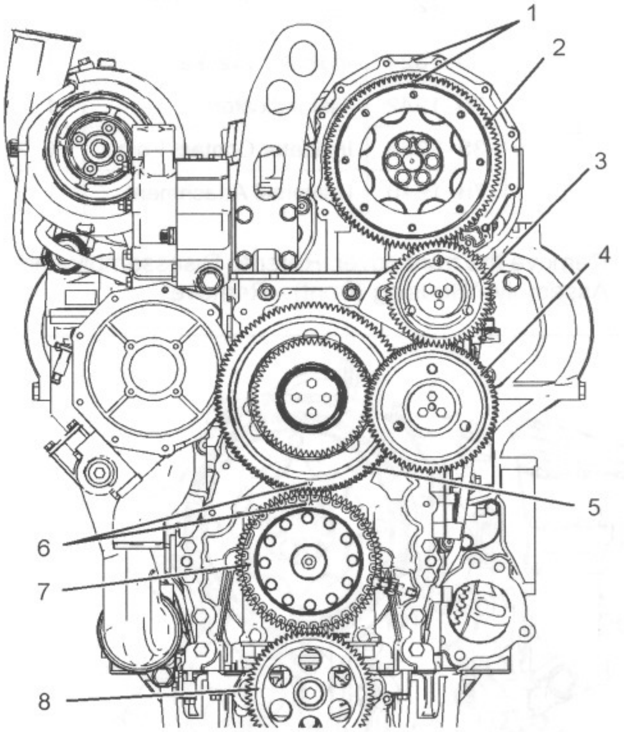

Illustration 46 g01106267

Front gear group

(1) Timing marks
(2) Camshaft gear
(3) Adjustable idler gear
(4) Idler gear
(5) Cluster gear
(6) Timing marks
(7) Crankshaft gear
(8) Oil pump gear

The basis for the correct fuel injection timing and the valve mechanism operation is determined by the alignment of the timing for the front gear group. Timing marks (1) and timing marks (6) are aligned in order to provide the correct relationship between the piston movement and the valve movement.

Setting Backlash for Camshaft and Adjustable Idler Gear

Table 5

Required Tools			
Tool	Part Number	Part Description	Qty
A	9U-7255	Gear Gauge (Adjustable Idler)	1
B	9U-7324	Indicator Bracket	1
	7H-1942	Dial Indicator	1
	3S-3268	Indicator Contact Point	1
	7H-1940	Universal Attachment	1

1. Remove the front cover. Refer to Disassembly and Assembly, "Housing (front) - Remove".

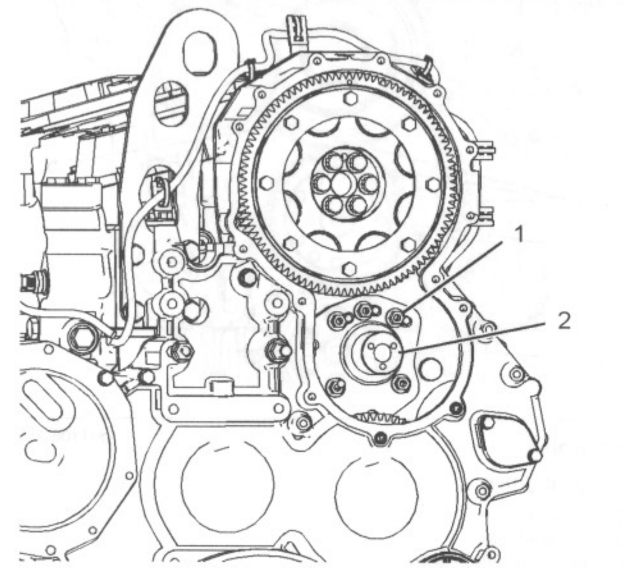

Illustration 47 g01106268

Loosen stub shaft assembly.

(1) Nuts
(2) Stub shaft

2. Remove the adjustable idler gear from stub shaft (2). The stub shaft is held in position with five nuts (1) and one bolt. Loosen each of the five nuts and loosen the one bolt.

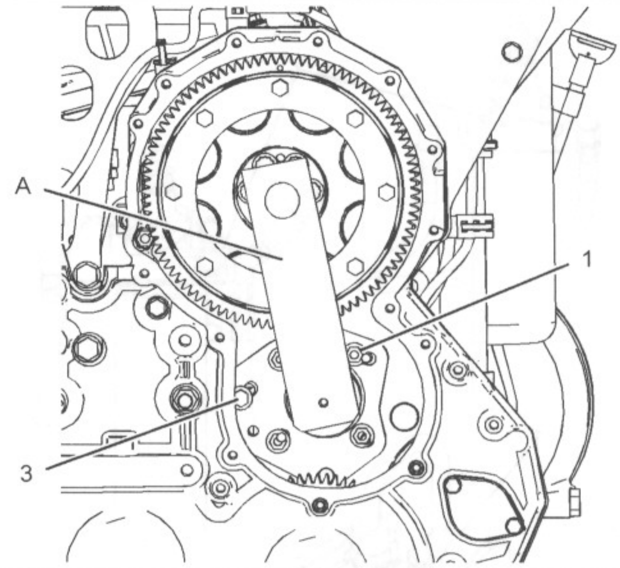

Illustration 48 g01106269

Installation of the adjustable idler assembly

(A) Gear gauge
(1) Nuts
(3) Bolt

3. Install Tooling (A) onto the engine. Refer to Illustration 48 in order to correctly position the gear gauge. Ensure that the gear gauge is seated correctly. Lightly tighten each of the nuts and the bolt in order to loosely secure the stub shaft to the engine. Once the nuts and the bolt are tightened, lightly tap the gear gauge with a rubber mallet on each side. This will ensure that the tool is properly seated. The gear gauge should be free to move in and out without any binding. Tighten the nuts and the bolt to a torque of 55 ± 10 N·m (41 ± 7 lb ft).

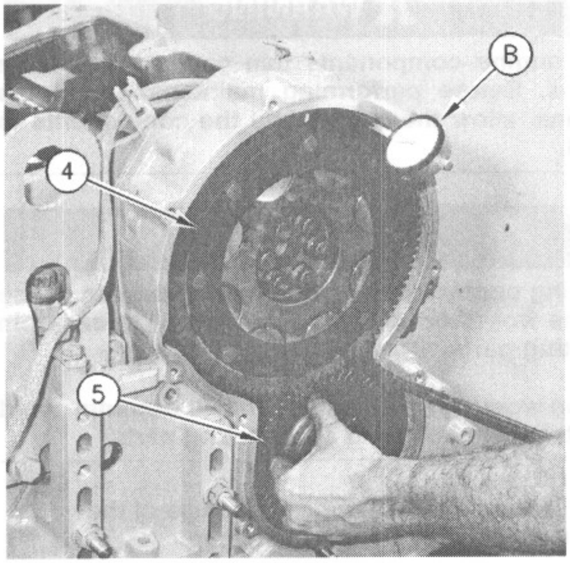

Illustration 49 g00294874

Checking backlash

(B) Indicator assembly
(4) Camshaft gear
(5) Idler gear assembly

4. Install Tooling (B) on the timing gear housing. Measure the backlash between camshaft gear (4) and idler gear (5). When the idler gear is held stationary, the backlash between the gears is 0.216 ± 0.114 mm (0.0085 ± 0.0045 inch).

5. If necessary, repeat step 2 through step 4 until the correct backlash is obtained.

6. Install the front cover. Refer to Disassembly and Assembly, "Housing (Front) - Install".

Air Inlet and Exhaust System

i01554323

Air Inlet and Exhaust System - Inspect

SMCS Code: 1050-040

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

Table 6

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

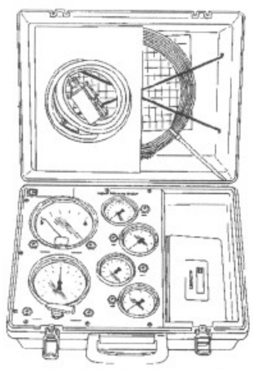

Illustration 50 g00295554

1U-5470 Engine Pressure Group

Air Inlet Restriction

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

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

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

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

WARNING

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

WARNING

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

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

4. Use the differential pressure gauge of the 1U-5470 Engine Pressure Group.

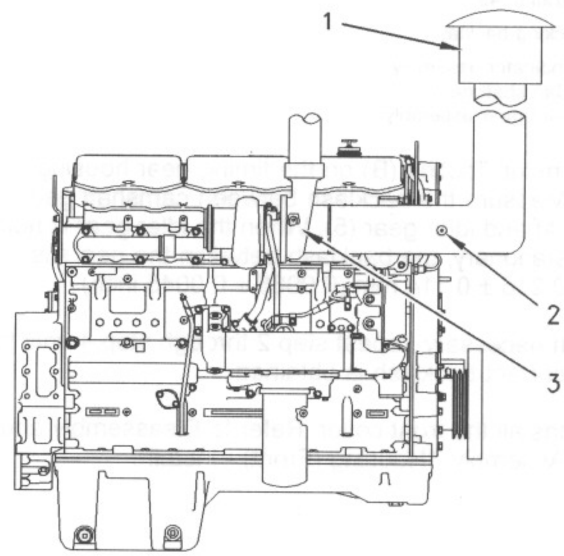

Illustration 51 g00808208

Air inlet piping

(1) Air Cleaner
(2) Test location
(3) Turbocharger

a. Connect the vacuum port of the differential pressure gauge to test location (2). Test location (2) may be located anywhere along the air inlet piping after air cleaner (1) but before turbocharger (3).

b. Leave the pressure port of the differential pressure gauge open to the atmosphere.

c. Start the engine. Run the engine in the no-load condition at high idle.

d. Record the value.

e. Multiply the value from Step 4.d by 1.8.

f. Compare the result from Step 4.e to the appropriate values that follow.

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

Maximum restriction .... 6.2 kPa (25 in of H_2O)

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

Maximum restriction .... 3.7 kPa (15 in of H_2O)

Exhaust Restriction

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

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

WARNING

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

WARNING

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

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

Use the differential pressure gauge of the 1U-5470 Engine Pressure Group in order to measure back pressure from the exhaust. Use the following procedure in order to measure back pressure from the exhaust:

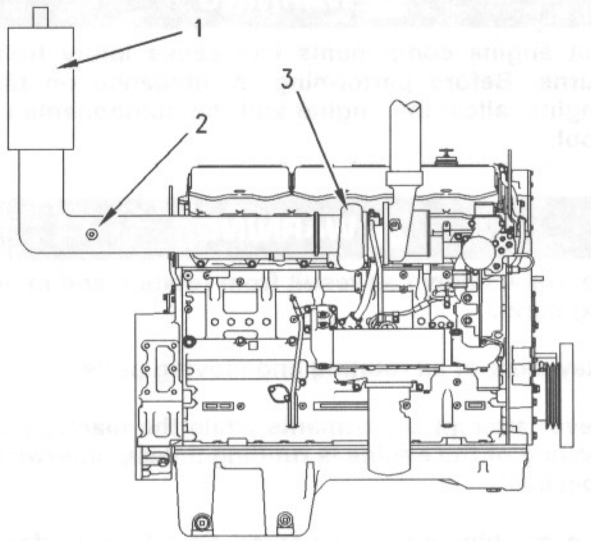

Illustration 52 g00808215

Exhaust piping

(1) Muffler
(2) Test location
(3) Turbocharger

1. Connect the pressure port of the differential pressure gauge to test location (2). Test location (2) can be located anywhere along the exhaust piping after turbocharger (3) but before muffler (1).

2. Leave the vacuum port of the differential pressure gauge open to the atmosphere.

3. Start the engine. Run the engine in the no-load condition at high idle.

4. Record the value.

5. Multiply the value from Step 4 by 1.8.

6. Compare the result from Step 5 to the value that follows.

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

Maximum back pressure .... 10.0 kPa (40 in of H_2O)

i02209847

Turbocharger - Inspect

SMCS Code: 1052-040

WARNING

Disconnect batteries before performance of any service work.

⚠ WARNING

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

⚠ WARNING

Personal injury can result from rotating and moving parts.

Stay clear of all rotating and moving parts.

Never attempt adjustments while the machine is moving or the engine is running unless otherwise specified.

The machine must be parked on a level surface and the engine stopped.

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

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

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

Dispose of all fluids according to local regulations and mandates.

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

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

- Inspection of the compressor and the compressor housing
- Inspection of the turbine wheel and the turbine housing

Inspection of the Compressor and the Compressor Housing

Remove air piping from the compressor inlet.

1. Inspect the compressor wheel for damage from a foreign object. If there is damage, determine the source of the foreign object. As required, clean the inlet system and repair the inlet system. Replace the turbocharger. If there is no damage, go to Step 3.

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

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

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

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

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

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

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

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

Inspection of the Turbine Wheel and the Turbine Housing

Remove the air piping from the turbine outlet casing.

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

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

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

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

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

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

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

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

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

NOTICE

If the high idle rpm or the engine rating is higher than given in the Technical Marketing Information (TMI) for the height above sea level at which the engine is operated, there can be damage to engine or to turbocharger parts. Damage will result when increased heat and/or friction due to the higher engine output goes beyond the engine cooling and lubrication system's abilities.

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i02209852

Inlet Manifold Pressure - Test

SMCS Code: 1058-081

Table 7

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

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

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

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

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

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

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

1. Connect the electronic service tool.

2. Operate the engine under the suspect conditions.

3. Record the value.

4. Compare the value that was recorded in Step 3 to the pressure that is given in the TMI.

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

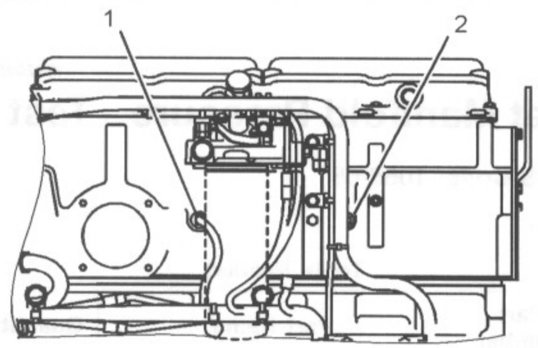

Illustration 53 g01098341

Pressure test location on the inlet manifold

(1) Inlet air temperature sensor
(2) Pipe plug

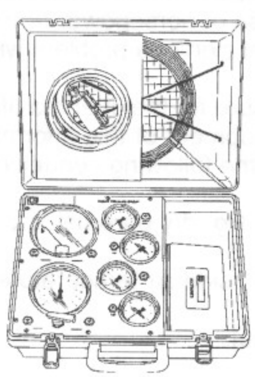

Illustration 54 g00293196

1U-5470 Engine Pressure Group

1. Remove pipe plug (2) from the inlet manifold. Inlet air temperature sensor (1) does not need to be removed.

2. Connect the 1U-5470 Engine Pressure Group to the inlet manifold at the pressure test location.

   Refer to Special Instruction, SEHS8907, "Using the 1U-5470 Engine Pressure Group" for more information on using the tool.

3. Operate the engine under the suspect conditions.

4. Record the value.

5. Compare the value that was recorded in Step 4 to the pressure that is given in the TMI.

i01582969

Exhaust Temperature - Test

SMCS Code: 1088-081

Table 8

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

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

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

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

Use the 164-3310 Infrared Thermometer to check exhaust temperature. The Operator's Manual, NEHS0630 contains the complete operating and maintenance instructions for the 164-3310 Infrared Thermometer.

i02165397

Aftercooler - Test

SMCS Code: 1063-081

Table 9

Tools Needed		
Part Number	Part Name	Quantity
1U-5470	Engine Pressure Group	1
FT-1984	Aftercooler Testing Group	1
FT-1438	Aftercooler Gp (Dynamometer Test)	1

Visual Inspection

Inspect the following parts at each oil change:

- Air lines
- Hoses
- Gasket joints

⚠ WARNING

Pressurized air can cause personal injury. When pressurized air is used for cleaning, wear a protective face shield, protective clothing, and protective shoes.

Ensure that the constant torque hose clamps are tightened to the correct torque. Refer to Specifications, SENR3130, "Torque Specifications" in order to locate the proper torque. Check the welded joints for cracks. Ensure that the brackets are tightened in the correct positions. Ensure that the brackets are in good condition. Use compressed air to clean any debris or any dust from the aftercooler core assembly. Inspect the fins in the aftercooler core for the following conditions:

- Damage
- Debris
- Corrosion

Use a stainless steel brush to remove any corrosion.

Note: When parts of the air-to-air aftercooler system are repaired or replaced, a leak test is recommended.

Inlet Manifold Pressure

Normal inlet manifold pressure with high exhaust temperature can be caused by blockage of the fins of the aftercooler core. Clean the fins of the aftercooler core. Refer to "Visual Inspection" under this topic for the cleaning procedure.

Low inlet manifold pressure and high exhaust manifold temperature can be caused by any of the following conditions:

Plugged air cleaner – Clean the air cleaner or replace the air cleaner, as required. Refer to the Operation and Maintenance Manual, "Engine Air Cleaner Element - Clean/Replace".

Blockage in the air lines – Blockage in the air lines between the air cleaner and the turbocharger must be removed.

Aftercooler core leakage – Aftercooler core leakage should be pressure tested. Refer to "Aftercooler Core Leakage" under this topic for the testing procedure.

Inlet manifold leak – An inlet manifold leak can be caused by the following conditions: loose fittings and plugs, missing fittings and plugs, damaged fittings and plugs, and leaking inlet manifold gasket.

Aftercooler Core Leakage

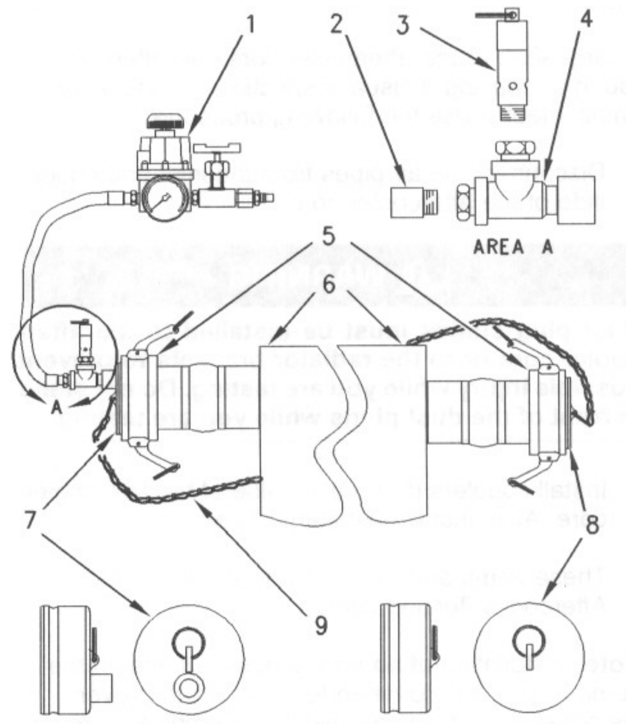

Illustration 55 g00295702

FT-1984 Aftercooler Testing Group

(1) Regulator and valve assembly
(2) Nipple
(3) Relief valve
(4) Tee
(5) Coupler
(6) Aftercooler
(7) Dust plug
(8) Dust plug
(9) Chain

A low power problem in the engine can be the result of aftercooler leakage. Aftercooler system leakage can result in the following problems:

- Low power
- Low boost pressure
- Black smoke
- High exhaust temperature

NOTICE

Remove all air leaks from the system to prevent engine damage. In some operating conditions, the engine can pull a manifold vacuum for short periods of time. A leak in the aftercooler or air lines can let dirt and other foreign material into the engine and cause rapid wear and/or damage to engine parts.

A large leak of the aftercooler core can often be found by making a visual inspection. To check for smaller leaks, use the following procedure:

1. Disconnect the air pipes from the inlet and outlet side of the aftercooler core.

WARNING

Dust plug chains must be installed to the aftercooler core or to the radiator brackets to prevent possible injury while you are testing. Do not stand in front of the dust plugs while you are testing.

2. Install couplers (5) on each side of the aftercooler core. Also, install dust plugs (7) and (8).

   These items are included with the FT-1984 Aftercooler Testing Group.

Note: Installation of additional hose clamps on the hump hoses is recommended in order to prevent the hoses from bulging while the aftercooler core is being pressurized.

NOTICE

Do not use more than 240 kPa (35 psi) of air pressure or damage to the aftercooler core can be the result.

3. Install the regulator and valve assembly (1) on the outlet side of the aftercooler core assembly. Also, attach the air supply.
4. Open the air valve and pressurize the aftercooler to 205 kPa (30 psi). Shut off the air supply.
5. Inspect all connection points for air leakage.
6. The pressure in the aftercooler system should not drop more than 35 kPa (5 psi) in 15 seconds.
7. If the pressure drop is more than the specified amount, use a solution of soap and water to check all areas for leakage. Look for air bubbles that will identify possible leaks. Replace the aftercooler core, or repair the aftercooler core, as needed.

WARNING

To help prevent personal injury when the tooling is removed, relieve all pressure in the system slowly by using an air regulator and a valve assembly.

8. After the testing, remove the FT-1984 Aftercooler Testing Group. Reconnect the air pipes on both sides of the aftercooler core assembly.

Air System Restriction

Pressure measurements should be taken at the inlet manifold and the turbocharger outlet.

Use the differential pressure gauge of the 1U-5470 Engine Pressure Group. Use the following procedure in order to measure the restriction of the aftercooler:

1. Connect the vacuum port of the differential pressure gauge to a port on the inlet manifold.
2. Connect the pressure port of the differential pressure gauge to a port on the turbocharger outlet.
3. Record the value.

The air lines and the cooler core must be inspected for internal restriction when both of the following conditions are met:

- Air flow is at a maximum level.
- Total air pressure drop of the charged system exceeds 13.5 kPa (4 in Hg) for engines with a 14.6 L (890 cu in) displacement.
- Total air pressure drop of the charged system exceeds 15.2 kPa (4.5 in Hg) for engines with a 15.8 L (964 cu in) displacement.

If a restriction is discovered, proceed with the following tasks, as required:

- Clean
- Repair
- Replacement

Turbocharger Failure

⚠ WARNING

Personal injury can result from air pressure.

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

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

If a turbocharger failure occurs, remove the air-to-air aftercooler core. Internally flush the air-to-air aftercooler core with a solvent that removes oil and other foreign substances. Shake the air-to-air aftercooler core in order to eliminate any trapped debris. Wash the aftercooler with hot, soapy water. Thoroughly rinse the aftercooler with clean water and blow dry the aftercooler with compressed air. Blow dry the assembly in the reverse direction of normal air flow. To make sure that the whole system is clean, carefully inspect the system.

NOTICE

Do not use caustic cleaners to clean the air-to-air aftercooler core.

Caustic cleaners will attack the internal metals of the core and cause leakage.

Dynamometer Test

In hot ambient temperatures, dynamometer tests for models with an air-to-air aftercooler can add a greater heat load to the jacket water cooling system. Therefore, the jacket water cooling system's temperature must be monitored. The following measurements may also need a power correction factor:

- Inlet air temperature
- Fuel API rating
- Fuel temperature
- Barometric pressure

With dynamometer tests for engines, use the FT-1438 Aftercooler Gp (Dynamometer Test). This tool provides a water cooled aftercooler in order to control the inlet air temperature to 43 °C (110 °F).

i01096015

Engine Crankcase Pressure (Blowby) - Test

SMCS Code: 1215; 1317

Table 10

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

Damaged pistons or rings can cause 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 (blowby) rising from the crankcase breather. The breather can then become restricted in a very short time, causing oil leakage at gaskets and seals that would not normally have leakage. Blowby can also be caused by worn valve guides or by a failed turbocharger seal.

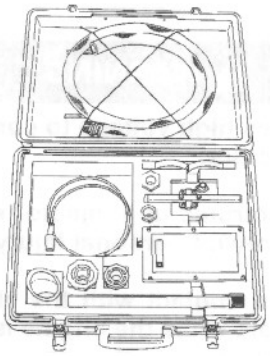

Illustration 56 g00286269

8T-2700 Blowby/Air Flow Indicator

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

i01398573

Compression - Test

SMCS Code: 1215

Cylinder compression may be affected by intake valves and exhaust valves that are not properly adjusted. Ensure that the intake valves and the exhaust valves are correctly adjusted.

This Caterpillar engine uses Keystone piston rings. Keystone piston rings are designed to expand during the compression stroke of the engine. At engine cranking speed, the Keystone piston rings do not fully expand. This results in unstable readings for cylinder compression. As a result Caterpillar does not recommend performing compression tests on engines that use Keystone piston rings.

i01215531

Engine Valve Lash - Inspect/Adjust

SMCS Code: 1102-025

WARNING

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

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

WARNING

This engine uses high voltage to control the electronic unit injectors.

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

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

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

Valve Lash Check

An adjustment is NOT NECESSARY if the measurement of the valve lash is in the acceptable range. Check the valve lash while the engine is stopped. The range is specified in Table 11.

Table 11

Valve Lash	
Valves	Acceptable Range for Valve Lash
Inlet	0.38 ± 0.08 mm (0.015 ± 0.003 inch)
Exhaust	0.76 ± .08 mm (0.030 ± 0.003 inch)

If the measurement is not within this range adjustment is necessary. Refer to Testing And Adjusting, "Valve Lash Adjustment".

Valve Lash Adjustment

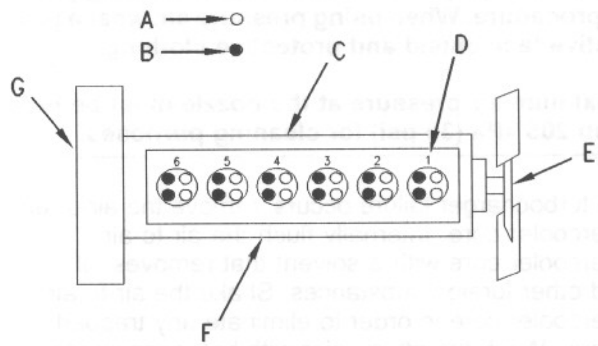

Illustration 57 g00561261

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

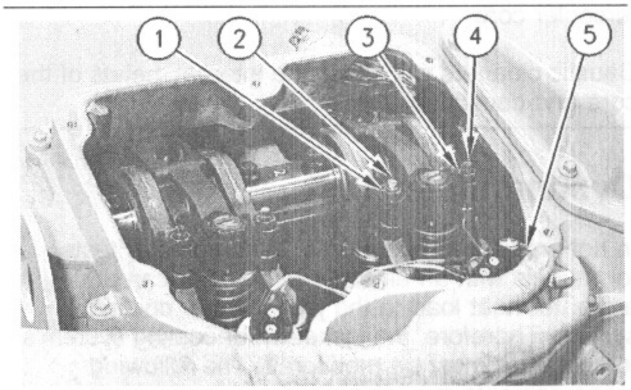

Illustration 58 g00506544

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

Table 12

Valve Lash	
Valves	Gauge Dimension
Inlet	0.38 mm (0.015 inch)
Exhaust	0.76 mm (0.030 inch)

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

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

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

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

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

3. Make an adjustment to the valve lash on the inlet valves for cylinders 1, 2, and 4.

a. Loosen valve adjustment locknut (3).

b. Place the appropriate feeler gauge (5) between the inlet rocker arm and the inlet valve bridge. Turn inlet adjustment screw (4) while valve adjustment locknut (3) is being held from turning. Adjust the valve lash until the correct specification is achieved. Refer to Table 12.

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

4. Make an adjustment to the valve lash on the exhaust valves for cylinders 1, 3, and 5.

a. Loosen valve adjustment locknut (1).

b. Place the appropriate feeler gauge (5) between the exhaust rocker arm and the exhaust valve bridge. Turn exhaust adjustment screw (2) while valve adjustment locknut (1) is being held from turning. Adjust the valve lash until the correct specification is achieved. Refer to Table 12.

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

5. Remove the timing bolt, and turn the flywheel by 360 degrees in the direction of engine rotation. This will position the No. 6 piston at the top center on the compression stroke. Install the timing bolt in the flywheel.

6. Make an adjustment to the valve lash on the inlet valves 3, 5, and 6.

a. Loosen valve adjustment locknut (3).

b. Place the appropriate feeler gauge (5) between the inlet rocker arm and the inlet valve bridge. Turn inlet adjustment screw (4) while valve adjustment locknut (3) is being held from turning. Adjust the valve lash until the correct specification is achieved. Refer to Table 12.

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

7. Make an adjustment to the valve lash on the exhaust valves 2, 4, and 6.

a. Loosen valve adjustment locknut (1).

b. Place the appropriate feeler gauge (5) between the exhaust rocker arm and the exhaust valve bridge. Turn exhaust adjustment screw (2) while valve adjustment locknut (1) is being held from turning. Adjust the valve lash until the correct specification is achieved. Refer to Table 12.

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

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

The lash must also be adjusted on the electronic unit injector. Refer to Testing and Adjusting, "Electronic Unit Injector - Adjust" for more information.

Lubrication System

i02087228

Engine Oil Pressure - Test

SMCS Code: 1304-081

Measuring Engine Oil Pressure

⚠ WARNING

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

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

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

Refer to Special Publication, NENG2500, "Caterpillar 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 13

Required Tools		
Part Number	Part Description	Qty
1U-5470	Engine Pressure Group	1

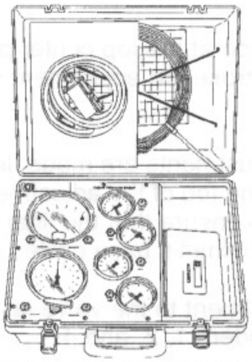

Illustration 59 g00296486

1U-5470 Engine Pressure Group

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

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

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

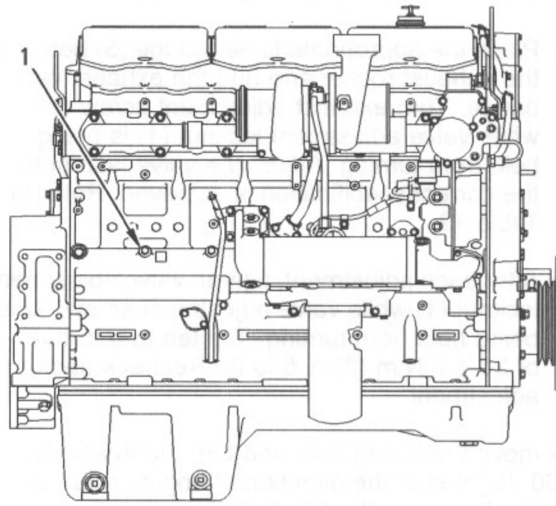

Illustration 60 g00293197

Location of the oil gallery plug

(1) Oil gallery 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.

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

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

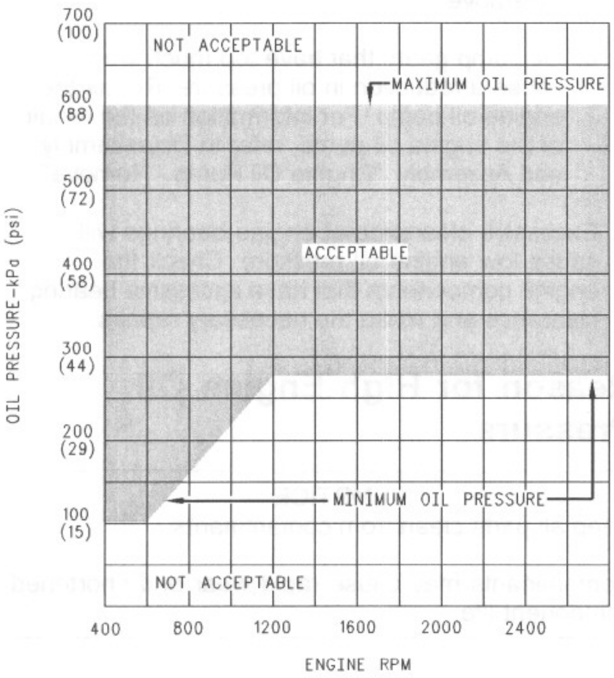

Illustration 61 g00293198

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. This problem needs to be corrected. Engine failure or a reduction in engine life can be the result if engine operation is continued with oil manifold pressure outside this range.

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

6. Compare the engine oil pressure from Step 3 with the other oil pressure indicators that are for the engine.

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

8. If a low engine oil pressure condition is confirmed, refer to "Reasons for Low Engine Oil Pressure".

9. If engine oil pressure is above the specification, refer to "Reason for High Engine Oil Pressure".

Reasons for Low Engine Oil Pressure

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

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

Refer to Special Publication, NENG2500, "Caterpillar 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.

- Oil level is low. Refer to Step 1.
- Oil is contaminated. Refer to Step 2.
- Engine oil bypass valves are open. Refer to Step 3.
- The lubrication system is open. Refer to Step 4.
- The oil suction tube has a leak or a restricted inlet screen. Refer to Step 5.

- The engine oil pump is faulty. Refer to Step 6.
- Engine bearings have excessive clearance. Refer to Step 7.

1. Check the engine oil level in the crankcase. If the oil level is below the oil pump's supply tube, the oil pump will not have the ability to supply enough lubrication to the engine components. If the engine oil level is low, add engine oil in order to obtain the correct engine oil level. Refer to Operation and Maintenance Manual, "Engine Oil Level - Check" for information that is related to checking the engine oil.

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

NOTICE

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

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3. If the engine oil bypass valves are held in the open position, a reduction in the oil pressure can be the result. This may be due to debris in the engine oil. If the engine oil bypass valves are stuck in the open position, remove each engine oil bypass valve and clean each bypass valve in order to correct this problem. You must also clean each bypass valve bore. Install new engine oil filters. For information on the repair of the engine oil bypass valves, refer to Disassembly and Assembly, "Engine Oil Filter Base - Disassemble".

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

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

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

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

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

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

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

Reason for High Engine Oil Pressure

NOTICE

Keep all parts clean from contaminants.

Contaminants may cause rapid wear and shortened component life.

NOTICE

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

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Dispose of all fluids according to local regulations and mandates.

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

NOTICE

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

i01126690

Excessive Bearing Wear - Inspect

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

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

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

i01794028

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.

i01366050

Increased Engine Oil Temperature - Inspect

SMCS Code: 1348-040

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

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

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

Cooling System

i02142687

Cooling System - Check (Overheating)

SMCS Code: 1350-535

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

⚠ WARNING

Personal injury can result from escaping fluid under pressure.

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

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

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

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

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

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

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

7. Check the radiator.

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

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

   c. Ensure that the radiator size is adequate for the application. An undersized radiator does not have enough area for the effective release of heat. This may cause the engine to run at a temperature that is higher than normal. The normal temperature is dependent on the ambient temperature.

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

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

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

   b. The fan shroud must be the proper size and the fan shroud must be positioned correctly. Ensure that the size of the fan shroud and the position of the fan shroud are adequate for the application.

10. If the fan is belt driven, check for loose drive belts. A loose fan drive belt will cause a reduction in the air flow across the radiator. Check the fan drive belt for proper belt tension. Adjust the tension of the fan drive belt, if necessary. Refer to Operation and Maintenance Manual, "Belt - Inspect".

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

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

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

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

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

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

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

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

14. Check the shunt line, if the shunt system is used. The shunt line must be submerged in the expansion tank. A restriction of the shunt line from the radiator top tank to the engine water pump inlet will cause a reduction in water pump efficiency. A reduction in water pump efficiency will result in low coolant flow and overheating.

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

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

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

18. Check the aftercooler. A restriction of air flow through the air to air aftercooler (if equipped) can cause overheating. Check for debris or deposits which would prevent the free flow of air through the aftercooler. Refer to Testing and Adjusting, "Aftercooler - Test".

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

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

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

i02209912

Cooling System - Inspect

SMCS Code: 1350-040

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

⚠ WARNING

Personal injury can result from escaping fluid under pressure.

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

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

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

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

   If the coolant does not have these properties, drain the system and flush the system. Refill the cooling system with the correct mixture of water, antifreeze, and coolant conditioner. Refer to the Operation and Maintenance Manual for your engine in order to obtain coolant recommendations.

3. Look for leaks in the system.

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

4. Ensure that the airflow through the radiator does not have a restriction. Look for bent core fins between the folded cores of the radiator. Also, look for debris between the folded cores of the radiator.

5. Inspect the drive belts for the fan.

6. Check for damage to the fan blades.

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

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

i02188278

Cooling System - Test

SMCS Code: 1350-040; 1350-081

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

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

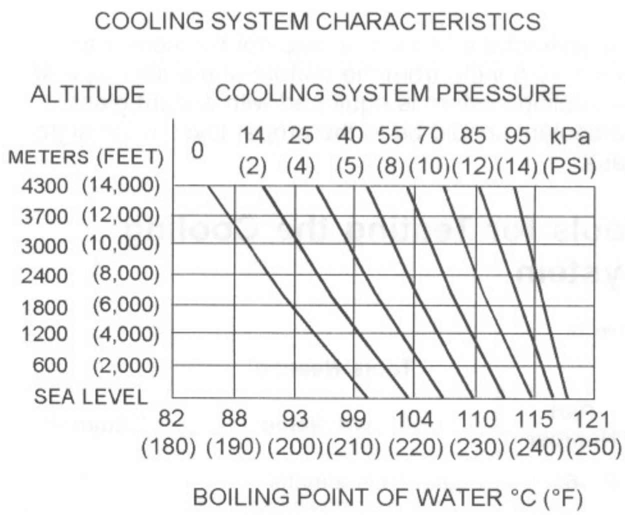


Illustration 62 g01106438

Effects of pressure on boiling point of a cooling system

Temperature and pressure work together. When a diagnosis is made of a cooling system problem, both temperature and pressure must be checked. Cooling system pressure will have an effect on the cooling system temperature. For an example, refer to Illustration 62. This will show the effect of pressure on the boiling point (steam) of water. This will also show the effect of height above sea level.

⚠ WARNING

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

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

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

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

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

Slowly loosen the pressure cap in order to relieve the pressure out of the cooling system. Then remove the pressure cap.

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

Tools for Testing the Cooling System

Table 14

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

⚠ WARNING

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

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

Illustration 63 g00876179

4C-6500 Digital Thermometer

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

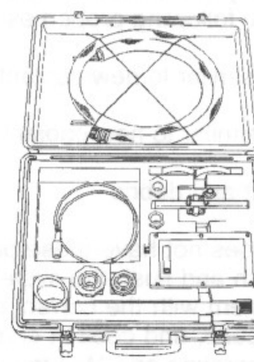


Illustration 64 g00286269

8T-2700 Blowby/Air Flow Indicator

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

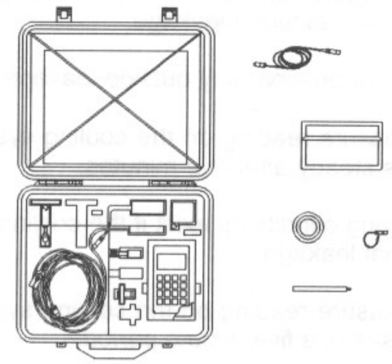


Illustration 65 g00286276

9U-7400 Multitach

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

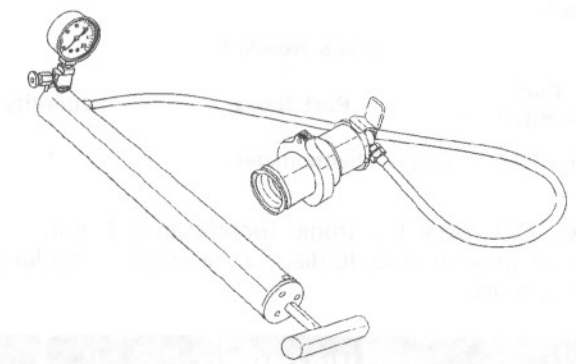


Illustration 66 g00286369

9S-8140 Pressurizing Pump

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

Check the coolant frequently in cold weather for the proper glycol concentration. Use the 245-5829 Coolant/Battery Tester Gp in order to ensure adequate freeze protection. The testers are identical except for the temperature scale. The testers give immediate, accurate readings. The testers can be used for antifreeze/coolants that contain ethylene or propylene glycol.

Test and Inspect the Filler Cap

Table 15

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

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

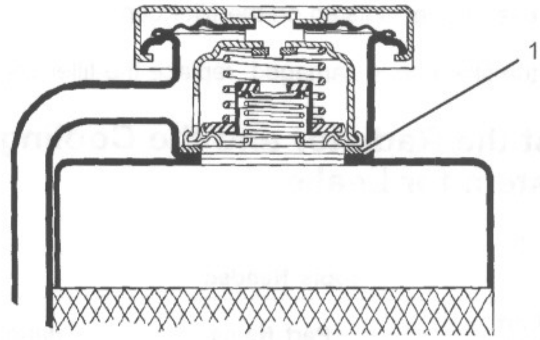


Illustration 67 g01096114

Cutaway view of a filler cap and radiator

(1) Sealing surface of both filler cap and radiator

WARNING

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

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

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

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

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

1. After the engine cools, carefully loosen the filler cap. Slowly release the pressure from the cooling system. Then, remove the filler cap.

   Carefully inspect the filler cap. Look for any damage to the seals and to the sealing surface. Inspect the following components for any foreign substances:

   - Filler cap
   - Seal
   - Surface for seal

   Remove any deposits that are found on these items, and remove any material that is found on these items.

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

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

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

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

Test the Radiator and the Cooling System for Leaks

Table 16

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

Use the following procedure in order to check the cooling system for leaks:

WARNING

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

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

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

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

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

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

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

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

5. Check the radiator for leakage on the outside.

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

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

- You do not observe any outside leakage.
- The pressure reading on the cooling system remains steady after five minutes.

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

- The pressure reading on the cooling system decreases in a five minute period.
- You do not observe any outside leakage.

Repair the cooling system, as required.

Test for the Water Temperature Gauge

Table 17

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

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

WARNING

Personal injury can result from escaping fluid under pressure.

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

WARNING

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

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

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

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

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

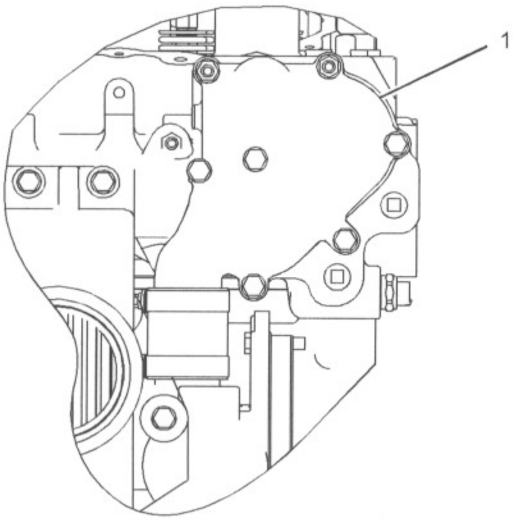


Illustration 68 g01096115

Typical example

(1) Water manifold assembly

Remove a plug from water manifold assembly (1). Install the thermometer into the open port:

- The 4C-6500 Digital Thermometer

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

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

i01666401

Water Temperature Regulator - Test

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

WARNING

Personal injury can result from escaping fluid under pressure.

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

1. Remove the water temperature regulator from the engine.
2. Heat water in a pan until the temperature of the water is equal to the fully open temperature of the water temperature regulator. Refer to Specifications, "Water Temperature Regulator" for the fully open temperature of the water temperature regulator. Stir the water in the pan. This will distribute the temperature throughout the pan.
3. Hang the water temperature regulator in the pan of water. The water temperature regulator must be below the surface of the water. The water temperature regulator must be away from the sides and the bottom of the pan.
4. Keep the water at the correct temperature for ten minutes.
5. After ten minutes, remove the water temperature regulator. Immediately measure the opening of the water temperature regulator. Refer to Specifications, "Water Temperature Regulator" for the minimum opening distance of the water temperature regulator at the fully open temperature.

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

i01964355

Water Pump - Test

SMCS Code: 1361-081

Table 18

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

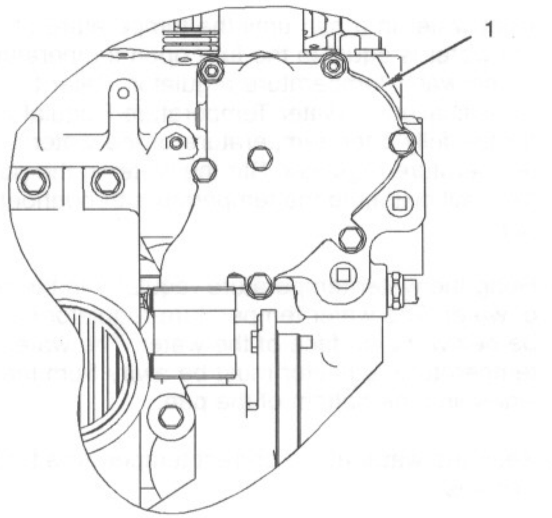


Illustration 69 g01020552

Typical example

(1) Water manifold assembly

⚠ WARNING

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

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

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

1. Remove a plug from water manifold assembly (1).
2. Install the 6V-7775 Air Pressure Gauge in the port.
3. Start the engine. Run the engine until the coolant is at operating temperature.
4. Note the water pump pressure. The water pump pressure should be at least 100 kPa (15 psi).

Basic Engine

i02209920

Piston Ring Groove - Inspect

SMCS Code: 1214-040

The 132-4389 Piston Ring Groove Gauge Gp is available to check the top ring groove in the piston. Refer to the instruction card with the tool for the correct use of the 132-4389 Piston Ring Groove Gauge Gp.

Refer to Guideline for Reusable Parts, SEBF8049, "Pistons" and Guideline for Reusable Parts, SEBF8051, "Piston Pins and Retaining Rings".

i02088908

Connecting Rod Bearings - Inspect

SMCS Code: 1219-040

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

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

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

i02142592

Main Bearings - Inspect

SMCS Code: 1203-040

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

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

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

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

i02142597

Cylinder Block - Inspect

SMCS Code: 1201-040

Table 19

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

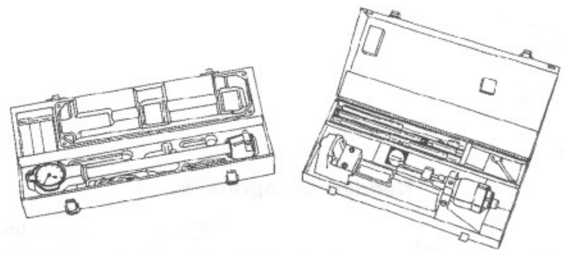


Illustration 70 g00285686

1P-3537 Dial Bore Gauge Group

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

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

i02162317

Cylinder Liner Projection - Inspect

SMCS Code: 1216-040

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

The 8T-0455 Liner Projection Tool Group can be used to check the liner projection. Refer to Special Instruction, SMHS7727, "Use of 8T-0455 Cylinder Liner Projection Indicator Group" for more information on the use of the tool.

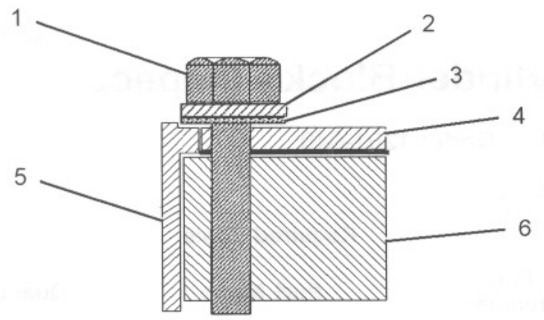


Illustration 71 g01096458

Liner Projection Components

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

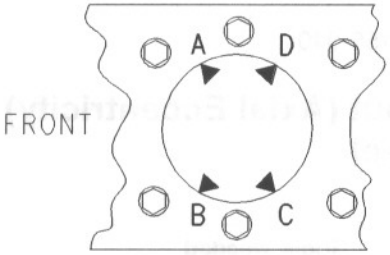
Table 20

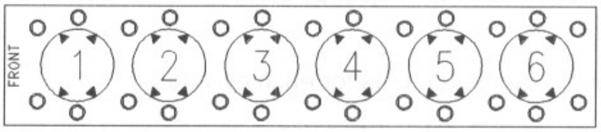
Needed Components				
Item	Part Number	Description	Quantity For One Cylinder	Quantity For Six Cylinders
1	7H-3598	Track Bolt	6	26
2	8F-1484	Washer	6	26
3	7K-1977	Washer	6	26

Note: The 7K-1977 Washer is made of a cotton fabric that is impregnated with resin. The washers will not damage the sealing surface of the cylinder block. These washers are a disposable item. You may wish to order more washers than the amount that is indicated.

Liner Projection Measurements

Date ____________ Miles, Km / Hours ____________ Engine Serial Number ____________ Vehicle Serial Number ____________





Liner Projection

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

1A	
1B	
1C	
1D	
SUM 1	
AVG 1	
2A	
2B	
2C	
2D	
SUM 2	
AVG 2	
3A	
3B	
3C	
3D	
SUM 3	
AVG 3	
4A	
4B	
4C	
14D	
SUM 4	
AVG 4	
5A	
5B	
5C	
5D	
SUM 5	
AVG 5	
6A	
6B	
6C	
6D	
SUM 6	
AVG 6	

Max Variation Each Cylinder

Max 0.051 mm (.002 in)

Max 1A-1D	
Min 1A-1D	
Variation	
Max 2A-2D	
Min 2A-2D	
Variation	
Max 3A-3D	
Min 3A-3D	
Variation	
Max 4A-4D	
Min 4A-4D	
Variation	
Max 5A-5D	
Min 5A-5D	
Variation	
Max 6A-6D	
Min 6A-6D	
Variation	

Max Variation of AVG Between Adjacent Liners

Max 0.051 mm (.002 in)

AVG 1	
AVG 2	
Variation	
AVG 2	
AVG 3	
Variation	
AVG 3	
AVG 4	
Variation	
AVG 4	
AVG 5	
Variation	
AVG 5	
AVG 6	
Variation	

Max Variation of AVG Under One Cylinder Head

Max 0.102 mm (.004 in)

Max AVG 1-6	
Min AVG 1-6	
Variation	

Illustration 72 g00443044

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

2. Install the washers. Install all bolts or the six bolts around the liner.

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

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

4. Record measurements for each cylinder.

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

Table 21

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

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

The 138-9381 Spacer Plate should be installed, if all of the liner projection measurements are below the specifications. The 138-9381 Spacer Plate should also be installed if the liner projection measurements are low within a range. This spacer plate is 0.076 mm (0.003 inch) thinner than the regular spacer plate. This spacer plate will increase the liner projection. Use this spacer plate in order to compensate for low liner projections that are less than 0.076 mm (0.003 inch). Use this spacer plate if the inspection of the top deck reveals no measurable damage directly under the liner flanges but the average liner projection is less than 0.076 mm (0.003 inch).

Do not exceed the maximum liner projection of 0.152 mm (0.006 inch). The excessive liner projection will contribute to cracking of the liner flange.

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

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

i02209931

Flywheel - Inspect

SMCS Code: 1156-040

Face Runout (Axial Eccentricity) of the Flywheel

Table 22

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

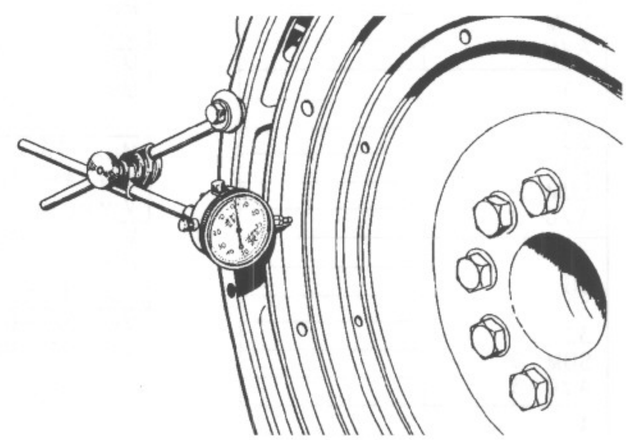


Illustration 73 g00286049

Checking face runout of the flywheel

1. Refer to Illustration 73 and install the dial indicator. Always put a force on the crankshaft in the same direction before the dial indicator is read. This will remove any crankshaft end clearance.

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

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

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

Bore Runout (Radial Eccentricity) of the Flywheel

Table 23

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

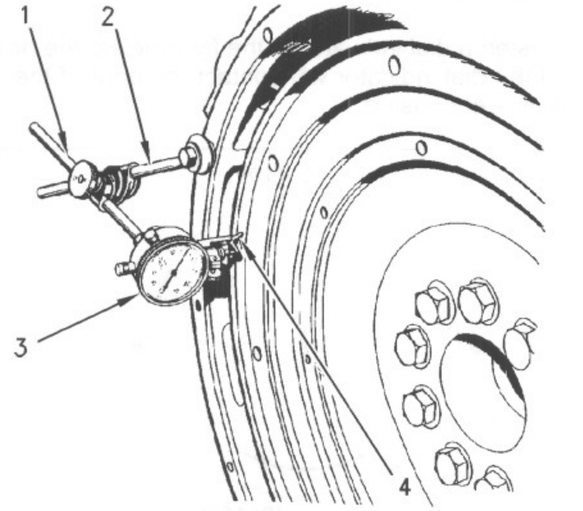


Illustration 74 g00286054

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 7H-1942 Dial Indicator (3). Make an adjustment of 7H-1940 Universal Attachment (4) so the dial indicator makes contact on the flywheel.

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

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

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

Flywheel without brakesaver .... 0.15 mm (0.006 inch)

Flywheel with brakesaver ... 0.25 mm (0.010 inch)

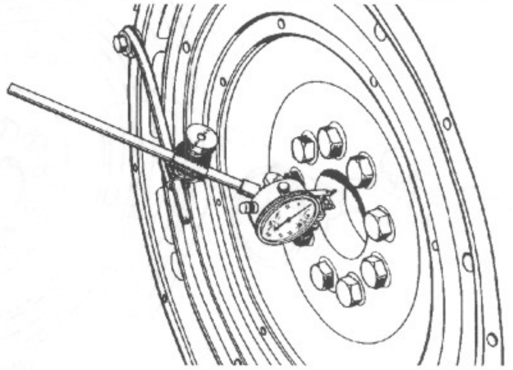


Illustration 75 g00286058

Flywheel clutch pilot bearing bore

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

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

Flywheel without brakesaver .... 0.13 mm (0.005 inch)

Flywheel with brakesaver ... 0.25 mm (0.010 inch)

i02209945

Flywheel Housing - Inspect

SMCS Code: 1157-040

Table 24

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

Face Runout (Axial Eccentricity) of the Flywheel Housing

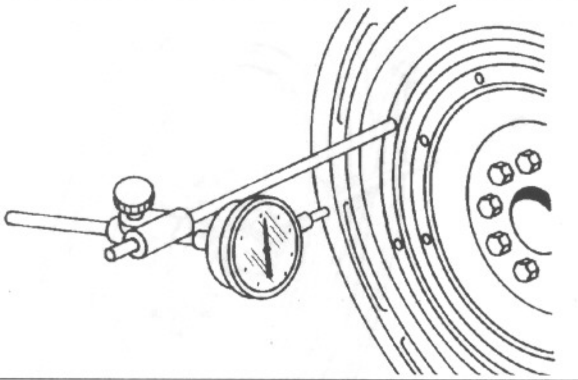


Illustration 76 g00285931

8T-5096 Dial Indicator Gp

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

1. Fasten a dial indicator to the flywheel so the anvil of the dial indicator will contact the face of the flywheel housing.
2. Use a rubber mallet and tap the crankshaft toward the rear before the dial indicator is read at each point.

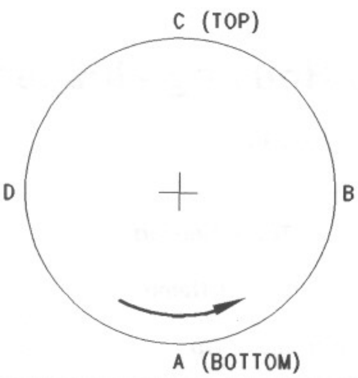


Illustration 77 g00285932

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

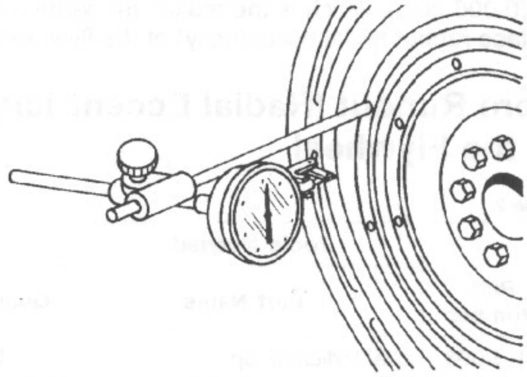


Illustration 78 g00285934

8T-5096 Dial Indicator Gp

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

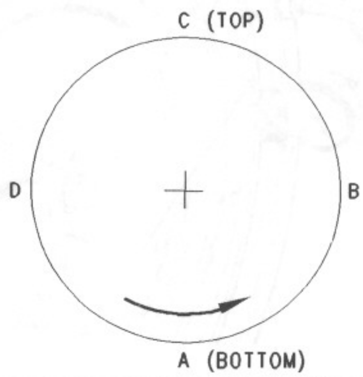


Illustration 79 g00285932

Checking bore runout of the flywheel housing

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

Illustration 80 g00763974

2. While the dial indicator is in the position at location (C) adjust the dial indicator to 0.0 mm (0.00 inch). Push the crankshaft upward against the top of the bearing. Refer to Illustration 80. Write the measurement for bearing clearance on line 1 in column (C).

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

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

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

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

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

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

8. Add the lines together in each column.

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

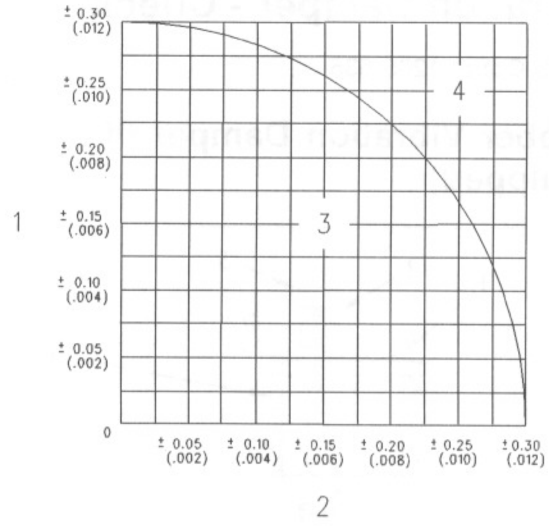


Illustration 81 g00286046

Graph for total eccentricity

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

10. Find the intersection of the eccentricity lines (vertical and horizontal) in Illustration 81.

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

i02101921

Vibration Damper - Check

SMCS Code: 1205-535

Rubber Vibration Damper (If Equipped)

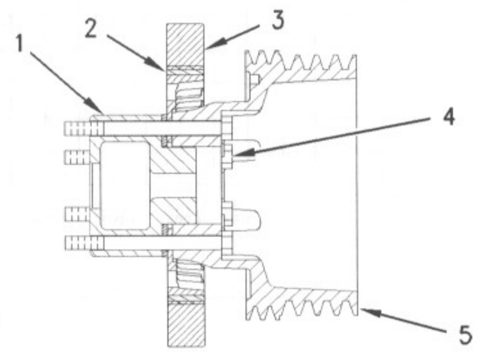


Illustration 82 g00681808

Vibration damper and pulley

(1) Adapter
(2) Rubber
(3) Damper assembly
(4) Bolt
(5) Crankshaft pulley

The vibration damper is installed on the front of crankshaft. The space in the damper assembly (3) is filled with rubber (2). The vibration damper limits the torsional vibration.

Replace the damper if any of the following conditions exist:

- The damper is dented or cracked.
- The paint on the damper is discolored from heat.
- There is a large amount of gear train wear that is not caused by lack of oil.
- Analysis of the oil has revealed that the front main bearing is badly worn.
- The engine has had a failure because of a broken crankshaft.

Viscous Vibration Damper (If Equipped)

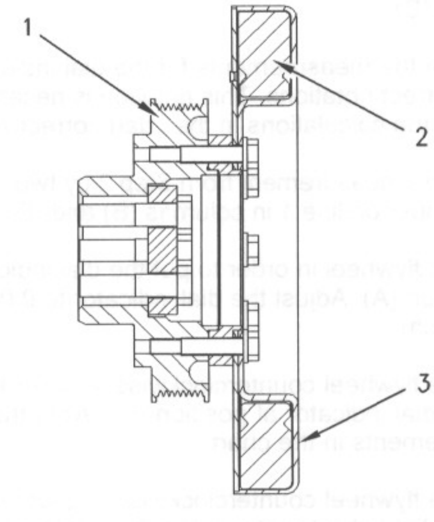


Illustration 83 g00750399

Viscous vibration damper

(1) Crankshaft pulley
(2) Weight
(3) Case

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

Replace the damper if any of the following conditions exist:

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

NOTICE

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

Electrical System

i02210035

Battery - Test

SMCS Code: 1401-081

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

WARNING

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

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

NOTICE

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

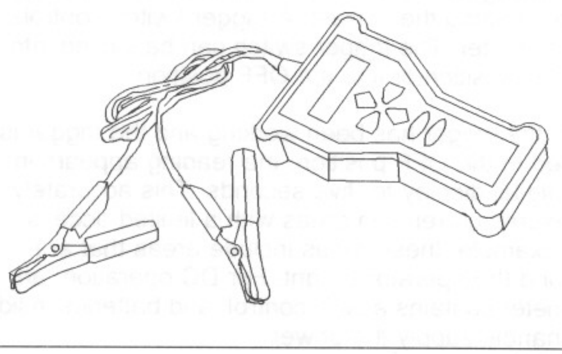


Illustration 84 g00859857

177-2330 Battery Analyzer

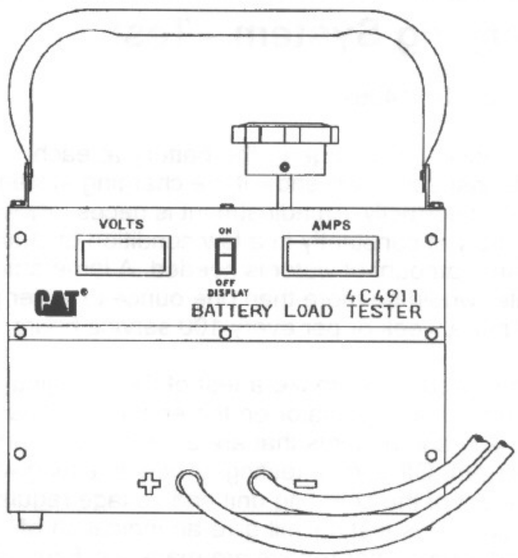


Illustration 85 g00283565

4C-4911 Battery Load Tester

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

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

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

i02204683

Charging System - Test

SMCS Code: 1406-081

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

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

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

Test Tools For The Charging System

Table 25

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

225-8266 Ammeter Tool Gp

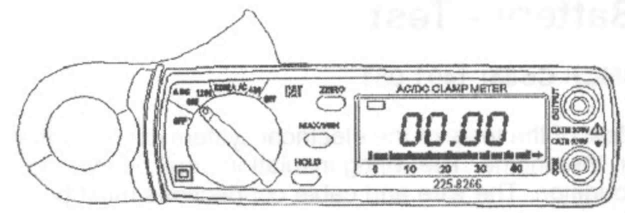


Illustration 86 g01012117

225-8266 Ammeter Tool Gp

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

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

- the readings are less than 1 ampere.

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

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

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

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

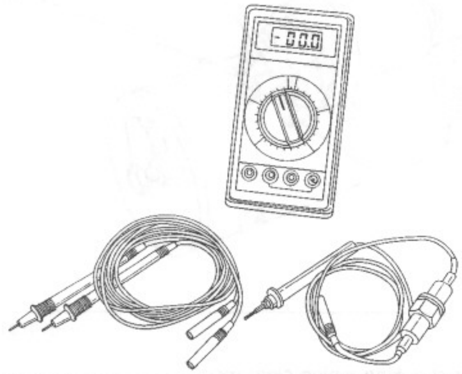


Illustration 87 g00283566

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

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

i02163258

Electric Starting System - Test

SMCS Code: 1450-081

Most of the tests of the electrical system can be done on the engine. The wiring insulation must be in good condition. The wire and cable connections must be clean, and both components must be tight. The battery must be fully charged. If the on-engine test shows a defect in a component, remove the component for more testing.

The starting system consists of the following four components:

- Engine Control Switch (ECS)
- Start relay
- Starting motor solenoid
- Starting motor

Trouble with the starting system could be caused by the battery or by charging system problems. If the starting system is suspect, refer to Service Manual, SENR3581, "37-MT, 41-MT & 42-MT Series Starting Motors". This publication contains troubleshooting for the starting system, test procedures, and specifications.

i02113366

Pinion Clearance - Adjust

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.

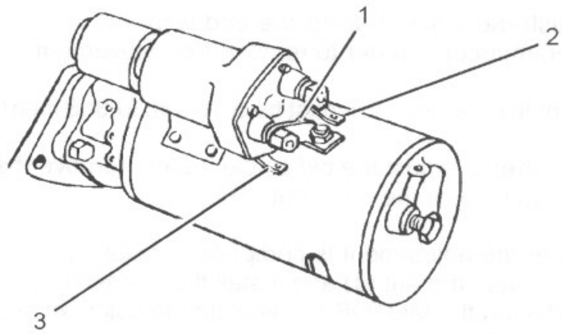


Illustration 88 g01097807

Connection for checking pinion clearance

(1) Connector to the motor
(2) Switch terminal
(3) Ground terminal

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

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

3. Connect the other side of the battery to ground terminal (3).

4. Temporarily, 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.

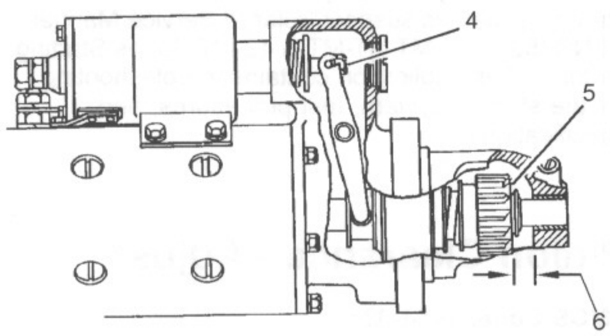


Illustration 89 g01097827

(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 9.10 mm (0.358 inch).

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

8. After the adjustment is completed, install the plug over the nut (4) and install the connector (1) between the MOTOR terminal on the solenoid and the starter motor.

i01220779

Pinion Clearance - Adjust

SMCS Code: 1454-025

Type 1

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

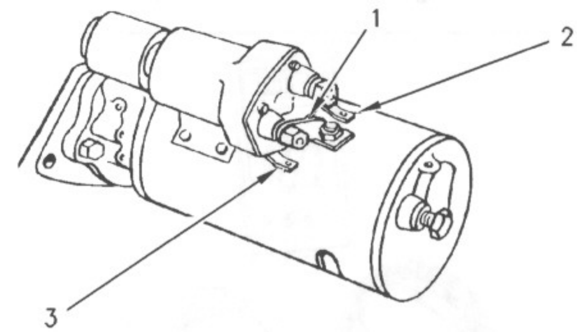


Illustration 90 g00301360

Connection for checking pinion clearance

Typical example

(1) Connector to the motor
(2) Switch terminal
(3) Ground terminal

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

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

3. Connect the other side of the battery to ground terminal (3).

4. Temporarily, 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.

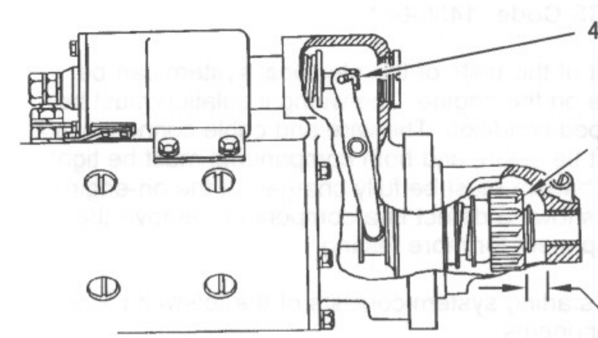


Illustration 91 g00283574

Typical example

(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 9.10 mm (0.358 inch).

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

8. After the adjustment is completed, install the plug over the nut (4) and install the connector (1) between the MOTOR terminal on the solenoid and the starter motor.

Type 2

The solenoid position on the starting motor controls the pinion clearance. If the solenoid position is correct, the pinion clearance is correct. Do the following procedure to adjust the solenoid position.

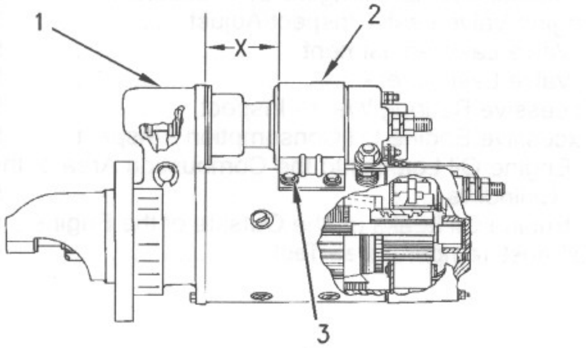


Illustration 92 g00301238

Solenoid Assembly

Typical example

(1) Intermediate housing
(2) Solenoid mounting bracket
(3) Bolts
(X) Distance for adjustment

1. Check the distance (X) between the intermediate housing (1) and the solenoid mounting bracket (2). Use calipers to check distance (X).

   (X) Distance .... 62.05 ± 0.35 mm (2.443 ± 0.014 inch)

2. If the distance (X) is not correct, loosen bolts (3) and move the solenoid until distance (X) is correct. The solenoid mounting bracket (2) has elongated holes.

3. Tighten the bolts (3) to 12 ± 3 N·m (9 ± 2 lb ft) after the adjustment is correct.

Index

A

Aftercooler - Test 48
  Aftercooler Core Leakage 49
  Air System Restriction 50
  Dynamometer Test 51
  Turbocharger Failure 51
  Visual Inspection 48
Air in Fuel - Test 33
Air Inlet and Exhaust System 21, 44
  Turbocharger 22
  Valves And Valve Mechanism 22
Air Inlet and Exhaust System - Inspect 44
  Air Inlet Restriction 44
  Exhaust Restriction 45
Air Starting System 27

B

Basic Engine 26, 67
  Camshaft 27
  Crankshaft 27
  Cylinder Block Assembly 26
  Cylinder Head Assembly 27
  Pistons, Rings And Connecting Rods 27
Battery - Test 75

C

Charging System - Test 76
  Test Tools For The Charging System 76
Compression - Test 51
Connecting Rod Bearings - Inspect 67
Cooling System 25, 59
Cooling System - Check (Overheating) 59
Cooling System - Inspect 61
Cooling System - Test 61
  Test and Inspect the Filler Cap 63
  Test for the Water Temperature Gauge 64
  Test the Radiator and the Cooling System for Leaks 64
  Tools for Testing the Cooling System 62
Cylinder Block - Inspect 67
Cylinder Liner Projection - Inspect 67

E

Electric Starting System - Test 77
Electrical System 29, 75
  Charging System Components 30
  Engine Electrical System 30
  Grounding Practices 29
  Reference 29
  Starting System Components 31
Electronic Control System Components 8
  Check Engine Lamp (Diagnostic Lamp) 10
  Electronic Control Module 10
  Electronic Control System Operation 9
  Engine Monitoring 9
Electronic Unit Injector - Adjust 34
Electronic Unit Injector - Test 35
Engine Crankcase Pressure (Blowby) - Test 51
Engine Design 4
  3406E 4
  3456 4
Engine Oil Pressure - Test 54
  Measuring Engine Oil Pressure 54
  Reason for High Engine Oil Pressure 56
  Reasons for Low Engine Oil Pressure 55
Engine Valve Lash - Inspect/Adjust 52
  Valve Lash Adjustment 52
  Valve Lash Check 52
Excessive Bearing Wear - Inspect 57
Excessive Engine Oil Consumption - Inspect 57
  Engine Oil Leaks into the Combustion Area of the Cylinders 57
  Engine Oil Leaks on the Outside of the Engine .. 57
Exhaust Temperature - Test 48

F

Finding Top Center Position for No. 1 Piston 35
Flywheel - Inspect 70
  Bore Runout (Radial Eccentricity) of the Flywheel 71
  Face Runout (Axial Eccentricity) of the Flywheel 70
Flywheel Housing - Inspect 71
  Bore Runout (Radial Eccentricity) of the Flywheel Housing 72
  Face Runout (Axial Eccentricity) of the Flywheel Housing 72
Fuel Quality - Test 36
Fuel System 11, 16, 33
  Electronic Controls 13
  Electronic Unit Injector 15
  Fuel Heaters 13, 17
  Fuel Injection 14
  Fuel System Electronic Control Circuit 17
  Low Pressure Fuel Supply Circuit 17
  Unit Injector 20
  Unit Injector Mechanism 14, 19
Fuel System - Inspect 33
Fuel System - Prime 37
  The Engine Has Been Rebuilt 39
  The Engine Has Been Run Out of Fuel 38
  The Secondary Fuel Filter Has Been Replaced .. 37

Fuel System Pressure - Test 39
  Checking Fuel Pressure................................... 40
  Fuel Pressure Readings 40
  High Fuel Pressure 40
  Low Fuel Pressure 39

G

Gear Group (Front) - Time.................................. 41
  Setting Backlash for Camshaft and Adjustable Idler Gear 42
  Static Check of the Timing Gear Position 41
General Information 4
  Cold Mode Operation 7
  General Information 6
  Programmable Parameters................................ 7
  Starting the Engine 6

I

Important Safety Information 2
Increased Engine Oil Temperature - Inspect 58
Inlet Manifold Pressure - Test.............................. 47

L

Lubrication System 23, 54
  Lubrication System Components 23
  Oil Flow In The Engine..................................... 25

M

Main Bearings - Inspect...................................... 67

P

Pinion Clearance - Adjust 77–78
  Type 1 78
  Type 2 79
Piston Ring Groove - Inspect.............................. 67

S

Systems Operation Section 4

T

Table of Contents... 3
Testing and Adjusting Section 33
Turbocharger - Inspect 45
  Inspection of the Compressor and the Compressor Housing 46
  Inspection of the Turbine Wheel and the Turbine Housing 47

V

Vibration Damper - Check 74
  Rubber Vibration Damper (If Equipped)............ 74
  Viscous Vibration Damper (If Equipped) 74

W

Water Pump - Test.. 65
Water Temperature Regulator - Test 65