SENR9888-45 (en-us)
June 2020

Systems Operation Testing and Adjusting

C11 and C13 Engines for Caterpillar Built Machines

i07966018

Important Safety Information

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

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

Do not operate or perform any lubrication, maintenance or repair on this product, until you verify that you are authorized to perform this work, and have read and understood the operation, lubrication, maintenance and repair information.

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

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

WARNING

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

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

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

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

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

NOTICE

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

Other parts may not meet certain original equipment specifications.

When replacement parts are installed, the machine owner/user should ensure that the machine remains in compliance with all applicable requirements.

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

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Systems Operation Section

i03550480

General Information

SMCS Code: 1000

The Electronic Unit Injector (EUI) provides increased control of the timing and increased control of the fuel air mixture. Engine rpm is controlled by adjusting the injection duration. Engine timing is controlled by the precise control of fuel injection timing.

The Electronic Control Module (ECM) monitors the components of the engine during operation. In the event of a component failure, the operator will be alerted to the condition by the use of a check engine light and an event code will be logged in the ECM. Caterpillar Electronic Technician (ET) can be connected to the engine in order to read any logged faults.

Starting The Engine

The engine's ECM will automatically provide the correct amount of fuel in order to start the engine. Do not hold the throttle down while the engine is cranking. If the engine fails to start in 30 seconds, release the starting switch. Allow the starting motor to cool for two minutes before the starting motor is 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 and 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.

Customer Specified Parameters

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

i02518130

Electronic Control System Components

SMCS Code: 1900

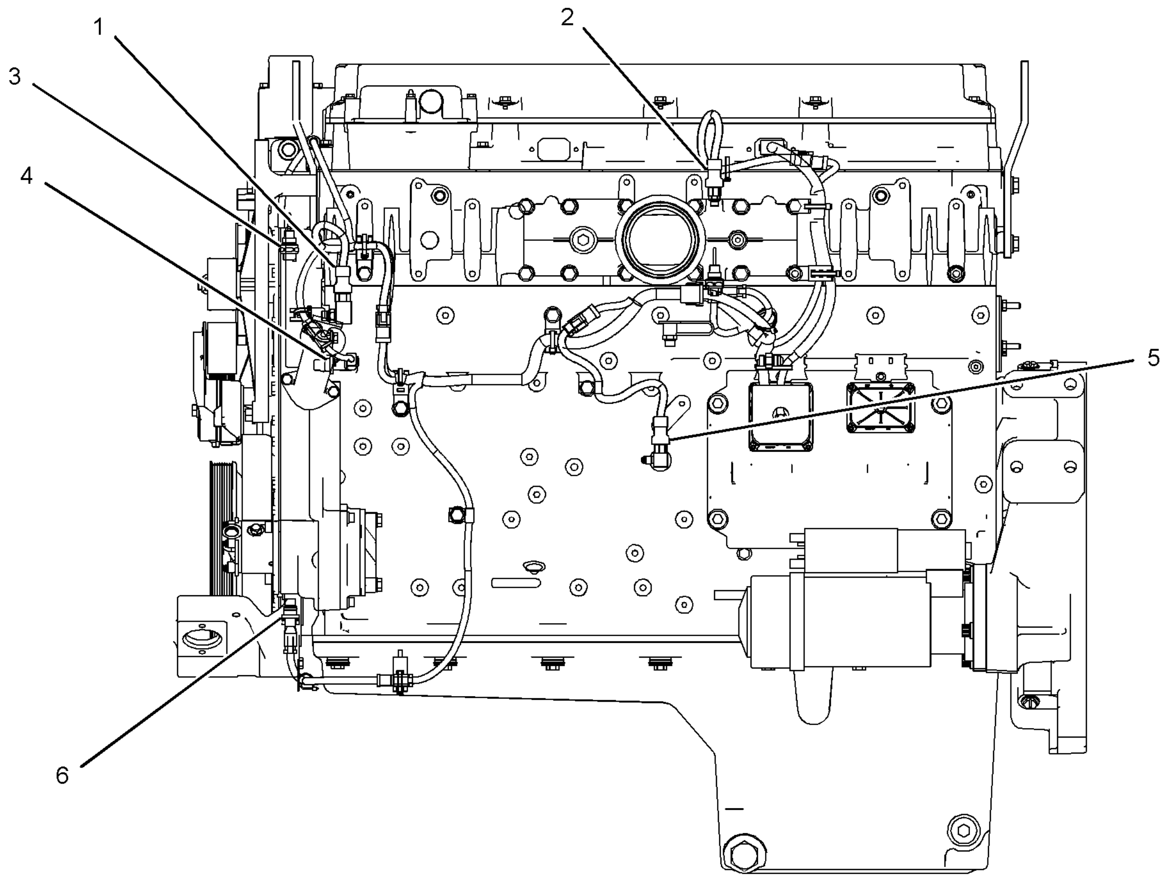

Illustration 1 g01259874

(1) Atmospheric pressure sensor
(2) Inlet manifold pressure sensor
(3) Coolant temperature sensor
(4) Secondary speed/timing sensor
(5) Engine oil pressure sensor
(6) Primary speed/timing sensor

The electronic control system has the following components:

- Electronic Control Module (ECM)
- Pressure sensors
- Temperature sensors
- Speed/Timing sensors
- Solenoids

The ECM functions as the governor for the engine. The ECM modulates the quantity of fuel and injection timing in order to govern the engine.

The ECM can activate the following starting aids:

- Ether injection
- Cycling of injector solenoids

The ECM will provide the operator with an illuminated warning light if the engine senses an engine problem. The operator may also experience an engine derate. The warning light or the engine derate could turn off during engine operation. The diagnostic code will be logged in the ECM. The diagnostic code can then be diagnosed at a later time.

The ECM is password protected in order to secure calibration of the ECM and customer programmed information. The calibration can be adjusted with flash files by authorized dealers. The flash file is programmed into the personality module.

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Fuel System

SMCS Code: 1250

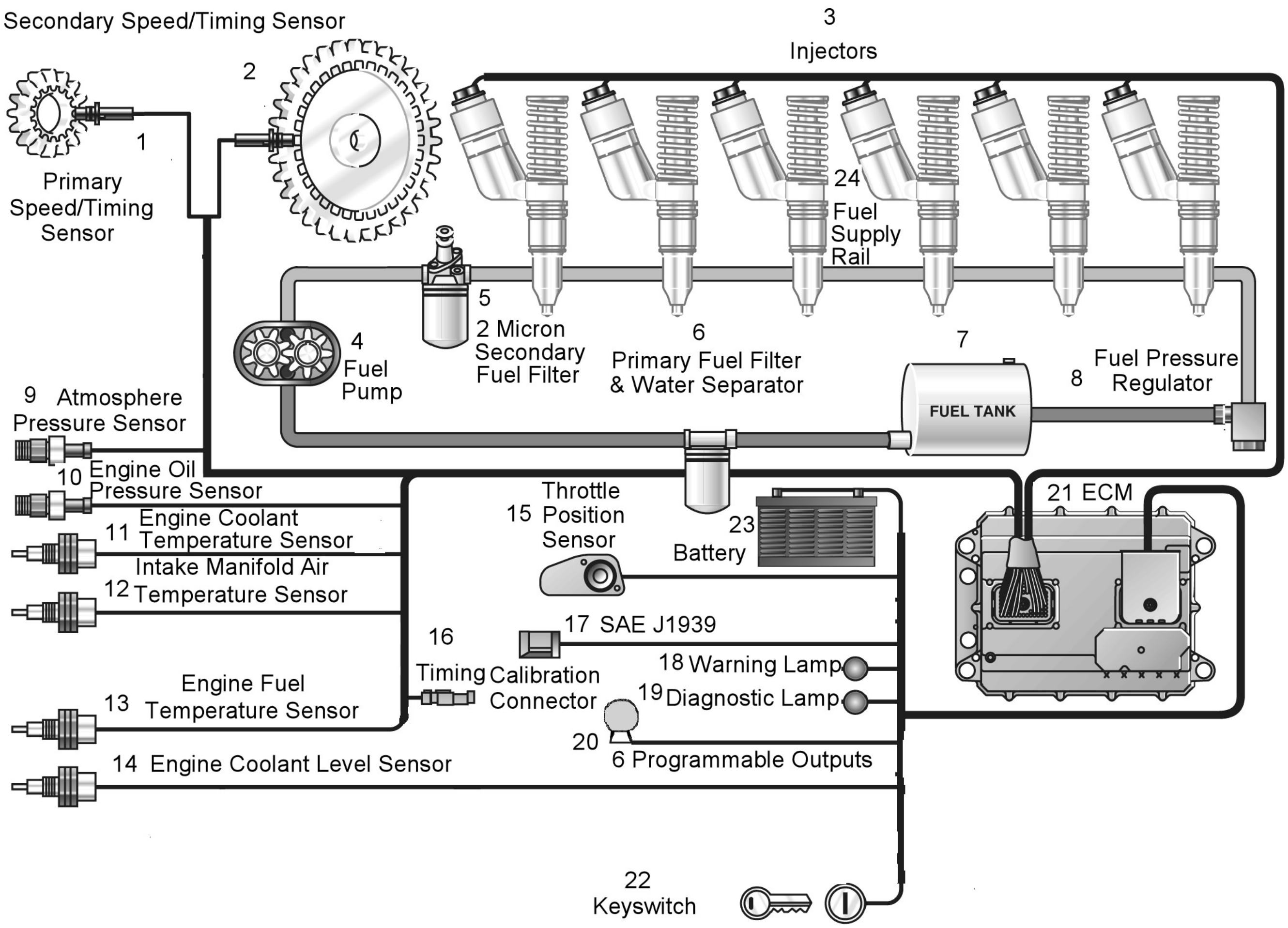

Illustration 2 g01105705

(1) Primary speed/timing sensor
(2) Secondary speed/timing sensor
(3) Injectors
(4) Fuel pump
(5) 2 Micron secondary fuel filter
(6) Primary fuel filter and water separator
(7) Fuel tank
(8) Fuel pressure regulator
(9) Atmospheric pressure sensor
(10) Engine oil pressure sensor
(11) Engine coolant temperature sensor
(12) Inlet air temperature sensor
(13) Fuel temperature sensor
(14) Engine coolant level sensor
(15) Throttle position sensor
(16) Timing calibration connector
(17) SAE J1939 Data Link
(18) Warning lamp
(19) Diagnostic lamp
(20) Programmable outputs
(21) Electronic Control Module (ECM)
(22) Keyswitch
(23) Battery
(24) Fuel supply rail

The electronic unit injector system consists of the following systems: the mechanical system and the electronic system. The mechanical system is made up of the low-pressure fuel supply system and the electronic unit injectors. The electronic system provides complete electronic control of all engine functions. The electronic control system consists of the following three types of components: input, control, and output.

There are five major components of the electronic unit injector fuel system:

- Electronic unit injectors
- Fuel transfer pump
- ECM
- Sensors
- Solenoids

The electronic unit injectors produce fuel injection pressures up to 207000 kPa (30000 psi). The electronic unit injectors also fire up to 19 times per second at rated speed. The fuel transfer pump supplies the injectors by drawing fuel from the tank and by pressurizing the system between 60 and 125 PSI. The ECM is a powerful computer which controls all major engine functions. Sensors are electronic devices which monitor engine performance parameters. Engine performance parameters measure pressure, temperature, and speed. This information is sent to the ECM via a signal. Solenoids are electronic devices which use electronic currents from the ECM to change engine performance. An example of a solenoid is the injector solenoid.

Electronic Controls

The electronic control system provides complete electronic control of all engine functions. The electronic control system consists of the following three types of components: input, control, and output. Sensors monitor engine operating conditions. This information is sent to the ECM. The ECM has three main functions. The ECM provides power for the engine electronics and monitors input signals from the engine sensors. The ECM also acts as a governor to control engine rpm. The ECM stores active faults, logged faults, and logged events. The personality module is the software in the ECM which contains the specific maps that define power, torque, and RPM of the engine. The ECM sends electrical current to the output components to control engine operation. The vehicle harness connects the ECM to the engine control portion of the vehicle harness. The engine control portion includes the following components.

- Transmission
- Brake
- Clutch switches
- PTO switch
- Data links
- Check engine light
- Warning light
- Engine retarder switch
- Speedometer
- Tachometer
- Cooling fan solenoid

The following list of features are part of the electronic control system:

- Cold start strategy
- Oil pressure
- Coolant temperature warning indicator
- Automatic altitude compensation
- Variable injection timing
- Electronic engine speed governing

These features result in the following items: precise engine speed control, little smoke, faster cold starting, and built-in engine protection.

The ECM consists of the following two main components: the ECM and the personality module.

The ECM is a computer and the personality module is the software for the computer. The personality module contains the operating maps. The operating maps define the following characteristics of the engine:

- Horsepower
- Torque curves
- Rpm
- Other characteristics

The ECM, the personality module, the sensors, and the unit injectors work together to control the engine. The ECM, the personality module, the sensors, and the unit injectors cannot control the engine alone.

The ECM determines a desired rpm that is based on the following criteria:

- Throttle signal
- Certain diagnostic codes
- Vehicle speed signal

The ECM maintains the desired engine rpm by sensing the actual engine rpm. The ECM calculates the fuel amount that needs to be injected to achieve the desired rpm.

Fuel Injection Timing and Delivery

The ECM controls the injected fuel amount by varying the signals to the unit injectors. The unit injectors will inject fuel ONLY if the unit injector solenoid is energized. The ECM sends a 105 volt signal to the solenoid for energizing the 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 injected fuel amount.

Injection timing is determined by engine rpm, and other engine data. The ECM senses the top center position of cylinder number 1 from the signal that is provided by the engine speed sensor. The ECM decides when the injection should occur relative to the top center position. The ECM provides the signal to the unit injector at the desired time.

Unit Injector Mechanism

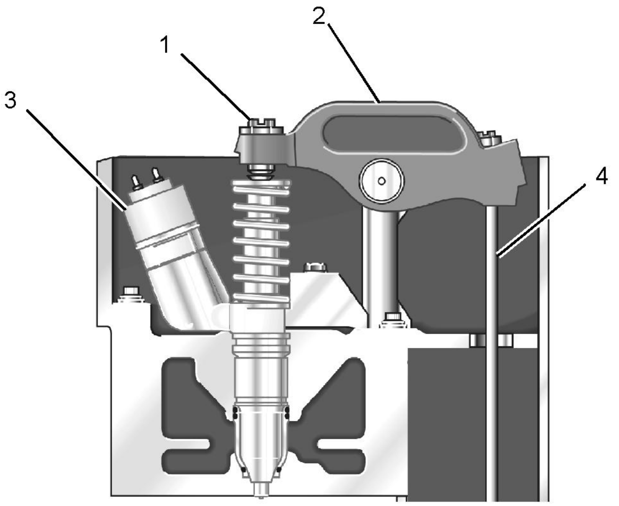

Illustration 3 g01092960

Typical examples of Electronic Unit Injector fuel systems.

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

The unit injector pressurizes the fuel. The correct amount of fuel is then injected into the cylinder block at precise times. The ECM determines the injection timing and the amount of fuel that is delivered. The unit injector is operated by a camshaft lobe and a rocker arm. The camshaft has three camshaft lobes for each cylinder. Two lobes operate the inlet and exhaust valves, and the other lobe operates the unit injector mechanism. Force is transferred from the unit injector lobe on the camshaft through the lifter to the pushrod (4). The force of the pushrod is transferred through rocker arm assembly (2) and to the top of the unit injector. The adjusting nut (1) allows setting of the unit injector adjustment. Refer to Systems Operation/Testing and Adjusting, “Electronic Unit Injector - Adjust” for the proper setting of the unit injector adjustment.

Unit Injector

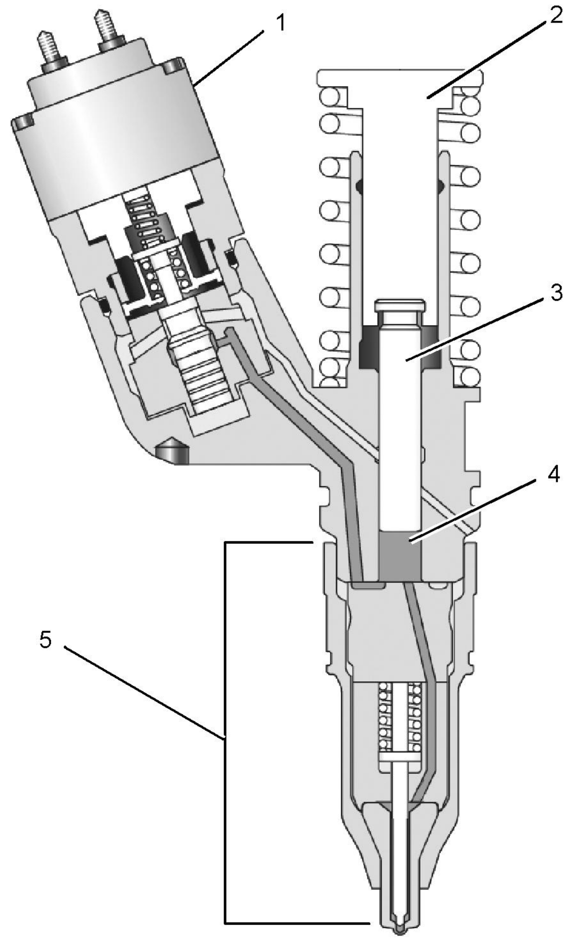

Illustration 4 g01092963

(1) Solenoid
(2) Tappet
(3) Plunger
(4) Barrel
(5) Nozzle assembly

Operation of the Electronic Unit Injector

The operation of the Electronic Control Unit (EUI) consists of the following four stages: Pre-injection, Injection, End of injection and Fill. Unit injectors use a plunger and barrel to pump high-pressure fuel into the combustion chamber. Components of the injector include the tappet, the plunger, the barrel, and nozzle assembly. Components of the nozzle assembly include the spring, the nozzle check, and a nozzle tip. The cartridge valve is made up of the following components: solenoid, armature, poppet valve, and poppet spring.

The injector is mounted in an injector bore in the cylinder head which has an integral fuel supply passage. The injector sleeve separates the injector from the engine coolant in the water jacket. Some engines use a stainless steel sleeve. The stainless steel sleeve fits into the cylinder head with a light press fit.

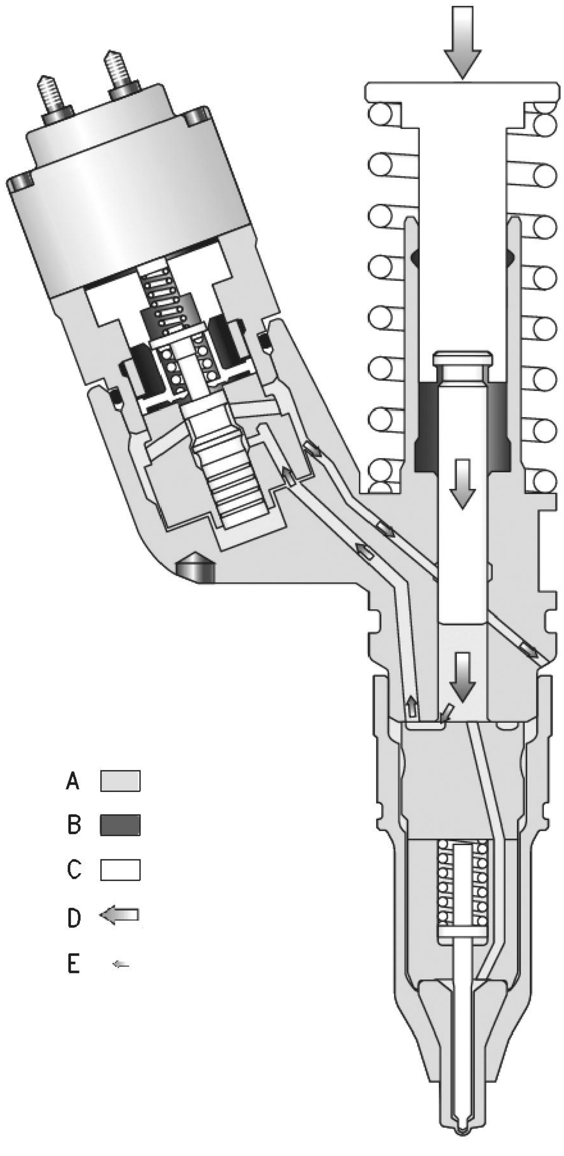

Illustration 5 g00942799

Pre-injection

(A) Fuel supply pressure
(B) Injection pressure
(C) Moving parts
(D) Mechanical movement
(E) Fuel movement.

Pre-injection metering starts with the injector plunger and the injector tappet at the top of the fuel injection stroke. When the plunger cavity is full of fuel, the poppet valve is in the open position and the nozzle check is in the open position. Fuel leaves the plunger cavity when the rocker arm pushes down on the tappet and the plunger. Fuel flow that is blocked by the closed nozzle check valve flows past the open poppet valve to the fuel supply passage in the cylinder head. If the solenoid is energized, the poppet valve remains open and the fuel from the plunger cavity continues flowing into the fuel supply passage.

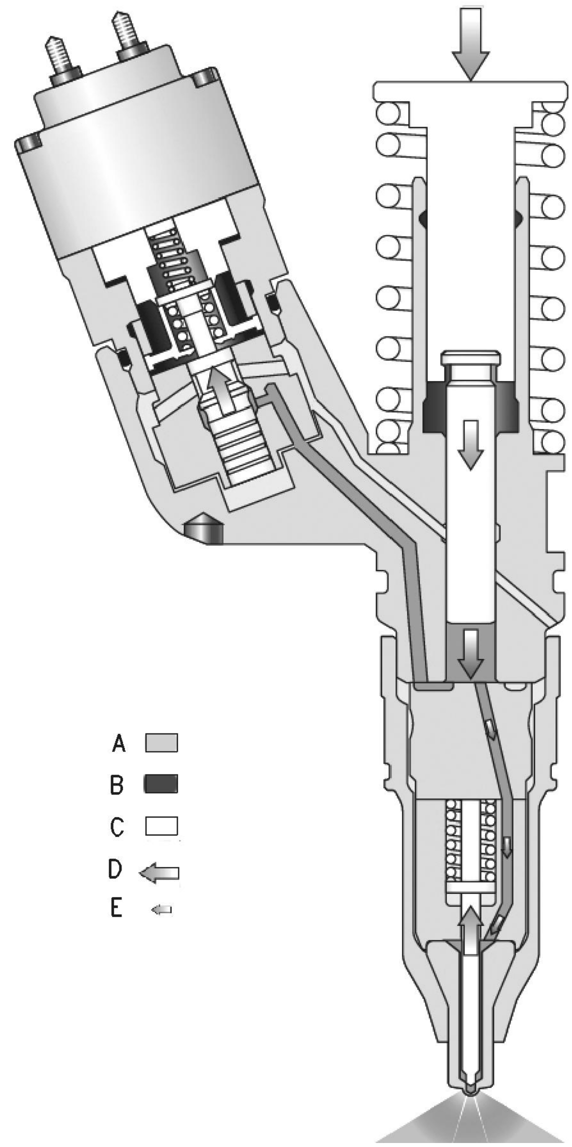

Illustration 6 g00942798

Injection

(A) Fuel supply pressure.
(B) Injection pressure
(C) Moving parts
(D) Mechanical movement
(E) Fuel movement.

To start injection, the ECM sends a current to the solenoid on the cartridge valve. The solenoid creates a magnetic field which attracts the armature. When the solenoid is energized, the armature assembly will lift the poppet valve so the poppet valve contacts the poppet seat. This is the closed position. Once the poppet valve closes, the flow path for the fuel that is leaving the plunger cavity is blocked. The plunger continues to push fuel from the plunger cavity and the fuel pressure builds up. When the fuel pressure reaches approximately 34500 kPa (5000 psi), the force of the high-pressure fuel overcomes the spring force. This holds the nozzle check in the closed position. The nozzle check moves off the nozzle seat and the fuel flows out of the injector tip. This is the start of injection.

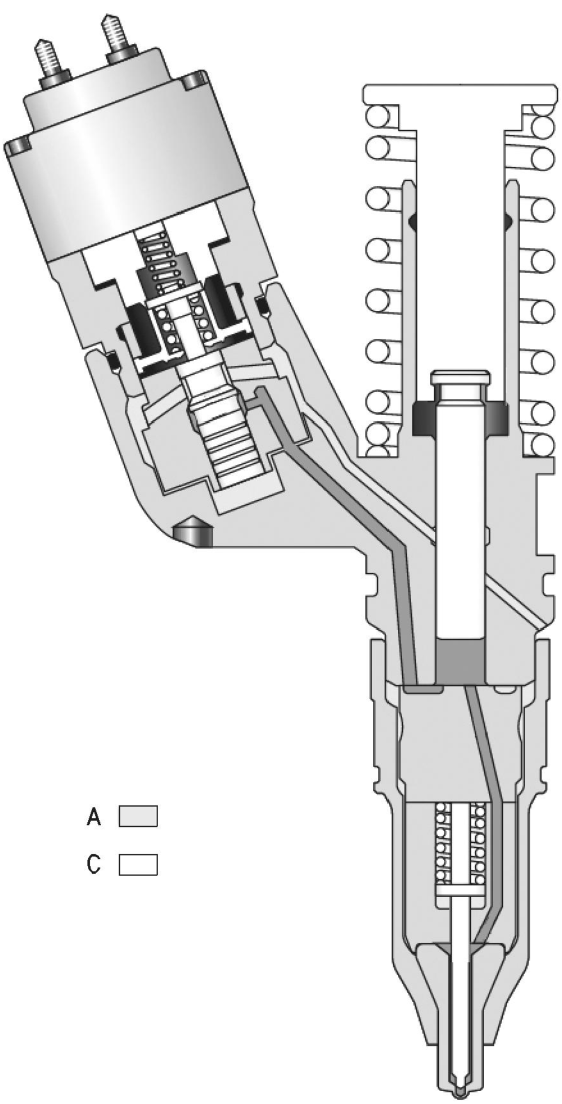

Illustration 7 g00942801

End of injection

(A) Fuel supply pressure
(C) Moving parts

Injection is continuous while the injector plunger moves in a downward motion and the energized solenoid holds the poppet valve closed. When injection pressure is no longer required, the ECM stops current flow to the solenoid. When the current flow to the solenoid stops, the poppet valve opens. The poppet valve is opened by the fuel injector spring and the fuel pressure. High-pressure fuel can now flow around the open poppet valve and into the fuel supply passage. This results in a rapid drop in injection pressure. When the injection pressure drops to approximately 24000 kPa (3500 psi), the nozzle check closes and injection stops. This is the end of injection.

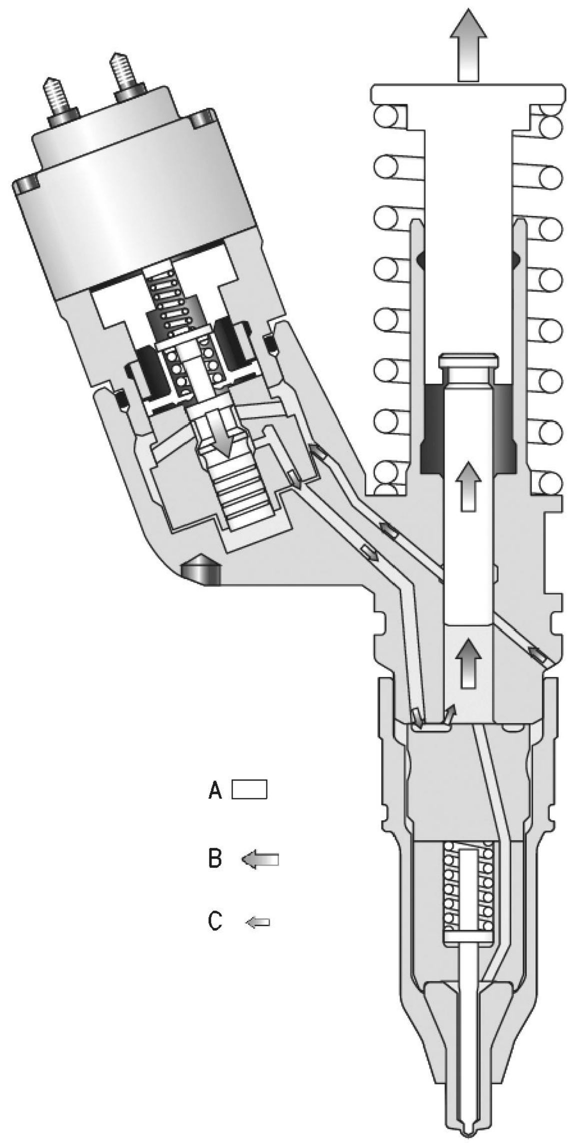

Illustration 8 g00942802

Fill

(A) Moving parts
(B) Mechanical movement
(C) Fuel movement.

When the plunger reaches the bottom of the barrel, fuel is no longer forced from the plunger cavity. The plunger is pulled up by the tappet and the tappet spring. The upward movement of the plunger causes the pressure in the plunger cavity to drop below fuel supply pressure. Fuel flows from the fuel supply passage around the open poppet and into the plunger cavity as the plunger travels upward. When the plunger reaches the top of the stroke, the plunger cavity is full of fuel and fuel flow into the plunger cavity stops. This is the beginning of pre-injection.

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Air Inlet and Exhaust System

SMCS Code: 1050

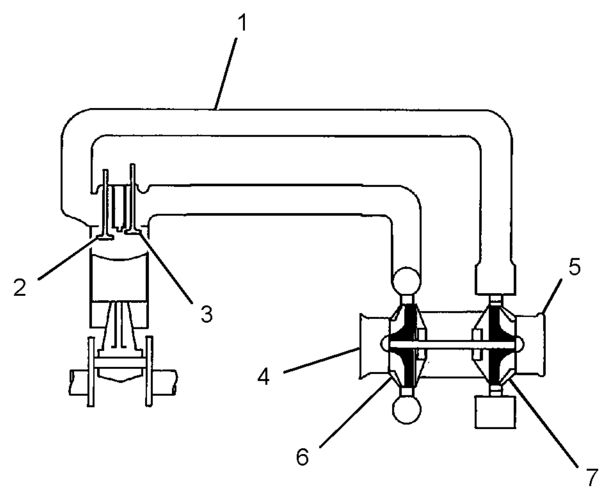

Illustration 9 g01323375

Air inlet and exhaust system

(1) Exhaust manifold
(2) Exhaust valve
(3) Inlet valve
(4) Air inlet
(5) Exhaust outlet
(6) Compressor side of the turbocharger
(7) Turbine side of the turbocharger

Basic Operation

The following components make up the air inlet and exhaust system:

- Turbocharger
- Cylinder head
- Valves and valve train components
- Piston and cylinder
- Exhaust manifold

These engines are equipped with a turbocharger. Turbocharged engines are more responsive and turbocharged engines have increased horsepower.

Turbocharger

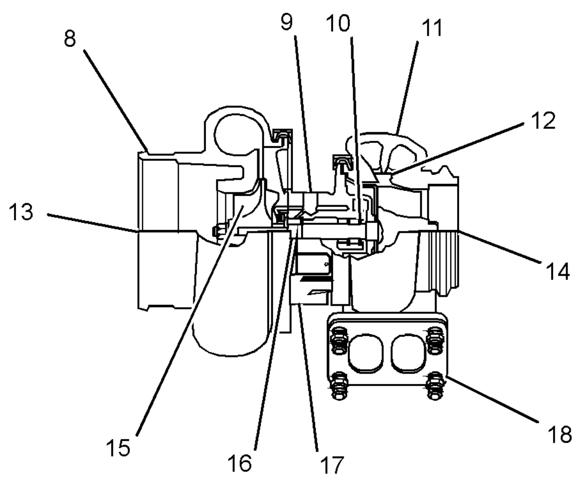

Illustration 10 g01323377

(8) Compressor housing
(9) Oil inlet port
(10) Bearing
(11) Turbine housing
(12) Turbine wheel
(13) Air inlet
(14) Exhaust outlet
(15) Compressor wheel
(16) Bearing
(17) Oil outlet port
(18) Exhaust inlet

The turbocharger works in order to produce boost across the entire engine RPM range. The increased boost at low RPM fills the combustion chamber with dense air. The dense air mixes with the fuel in order to promote a complete combustion.

The turbocharger has a compressor wheel (15) and a turbine wheel (12). The compressor wheel and the turbine wheel are connected to a common shaft. The shaft is supported by bearing (10) and bearing (16). The bearings are lubricated by pressurized engine oil. The oil enters through oil inlet port (9). The engine oil lubricates the bearings and the oil removes heat. The oil returns to the oil pan through oil outlet port (17).

Valve System Components

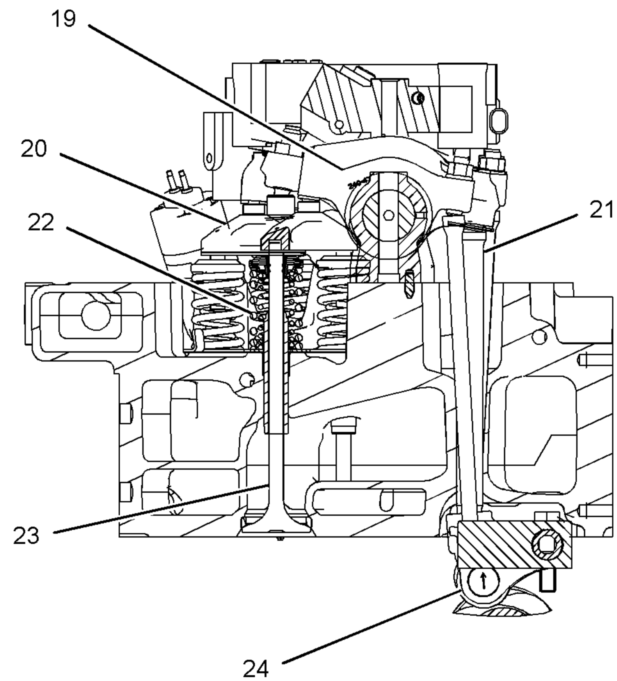

Illustration 11 g01323378

(19) Rocker arm
(20) Valve bridge
(21) Pushrod
(22) Valve spring
(23) Valve
(24) Lifter

The valve system components control the flow of inlet air into the cylinders and out of the cylinders during engine operation. The valve mechanism also operates the fuel injector.

The camshaft must be timed to the crankshaft in order to get the correct relation between the piston movement and the valve movement.

The camshaft has three camshaft lobes for each cylinder. The lobes operate the inlet valves, exhaust valves and unit injectors. As the camshaft turns, lobes on the camshaft cause lifters (24) to move pushrods (21) up and down. Upward movement of the pushrods against rocker arms (19) results in downward movement (opening) of valves (23).

Each cylinder has two inlet valves and two exhaust valves. The valves are actuated at the same time by a valve bridge (20). Valve springs (22) close the valves when the lifters move down.

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Lubrication System

SMCS Code: 1300

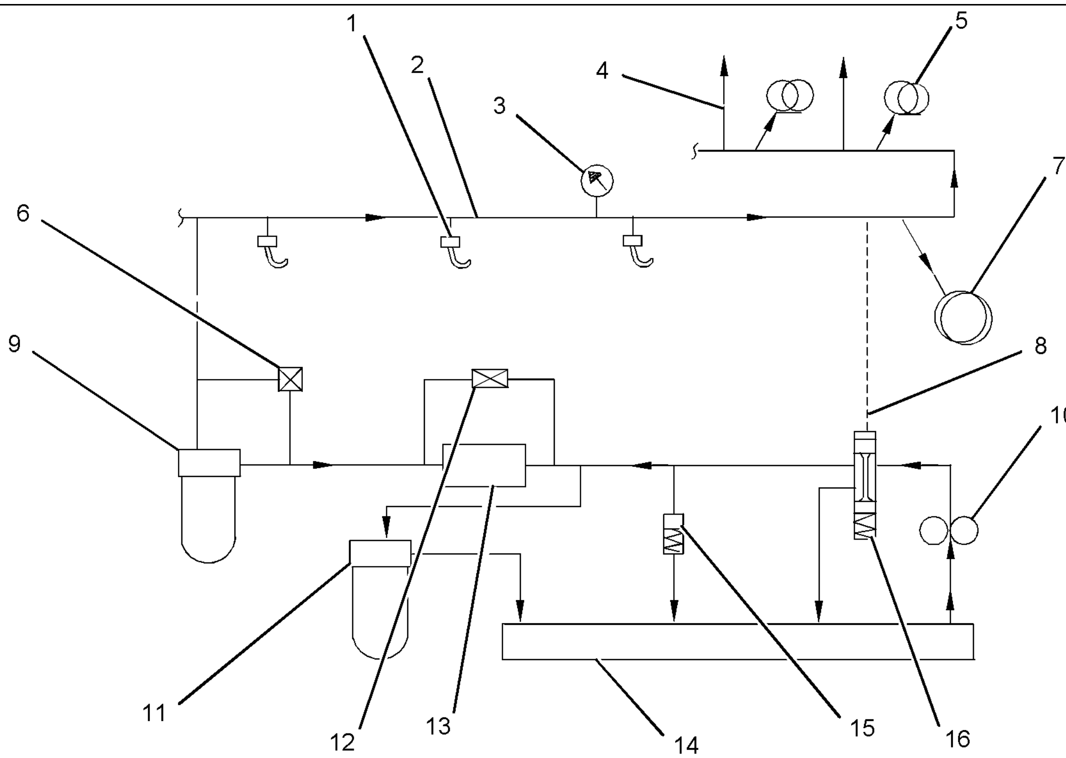

Illustration 12 g01091921

Lubrication system schematic

(1) Piston cooling jets
(2) Main oil gallery in cylinder block
(3) Engine pressure sensor
(4) Oil flow to valve mechanism
(5) Camshaft journals
(6) Oil filter bypass valve
(7) Main bearings
(8) Signal line
(9) Primary engine oil filter
(10) Engine oil pump
(11) Secondary oil filter
(12) Oil cooler bypass valve
(13) Engine oil cooler
(14) Oil pan sump
(15) High pressure relief valve
(16) Oil pump bypass valve

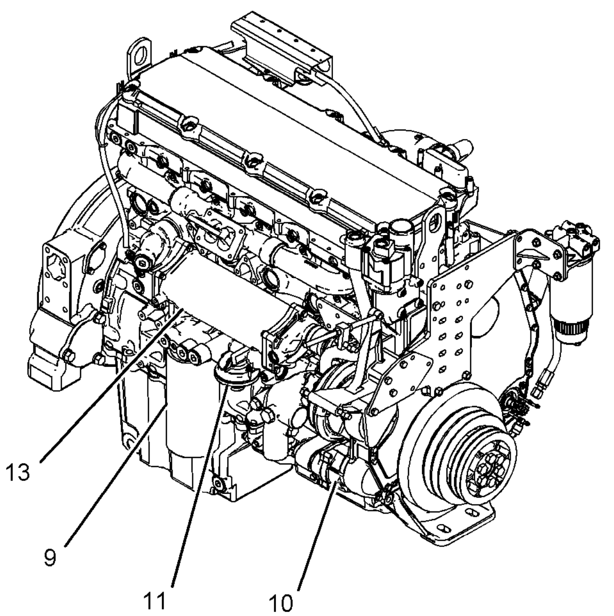

Illustration 13 g01098792

Right side view of engine

(9) Primary engine oil filter
(10) Engine oil pump
(11) Secondary oil filter (not shown)
(13) Engine oil cooler

The lubrication system supplies 110 °C (230 °F) filtered oil at approximately 275 kPa (40 psi) at rated engine operating conditions. Oil pump bypass valve (18) is controlled by the engine oil manifold pressure, rather than the oil pump pressure. The engine oil manifold pressure is independent of the pressure drop that is caused by the engine oil filter and the engine oil cooler.

Oil cooler bypass valve (14) maintains the engine oil temperature to 110 °C (230 °F). High pressure relief valve (17), which is located in the filter base, protects the filters and other components during cold starts. The opening pressure of the high pressure relief valve is 695 kPa (100 psi). Secondary oil filter (13) is a five micron filter which filters five percent of the oil flow before returning the oil to the sump. The opening pressure of the oil filter bypass valve is 170 kPa (25 psi). Engine oil pressure sensor (5) is part of the engine protection system.

The turbocharger cartridge bearings are lubricated by the oil supply line from the main oil gallery, and the oil drain line returns the oil flow to the sump.

Oil Flow Through The Lubrication System

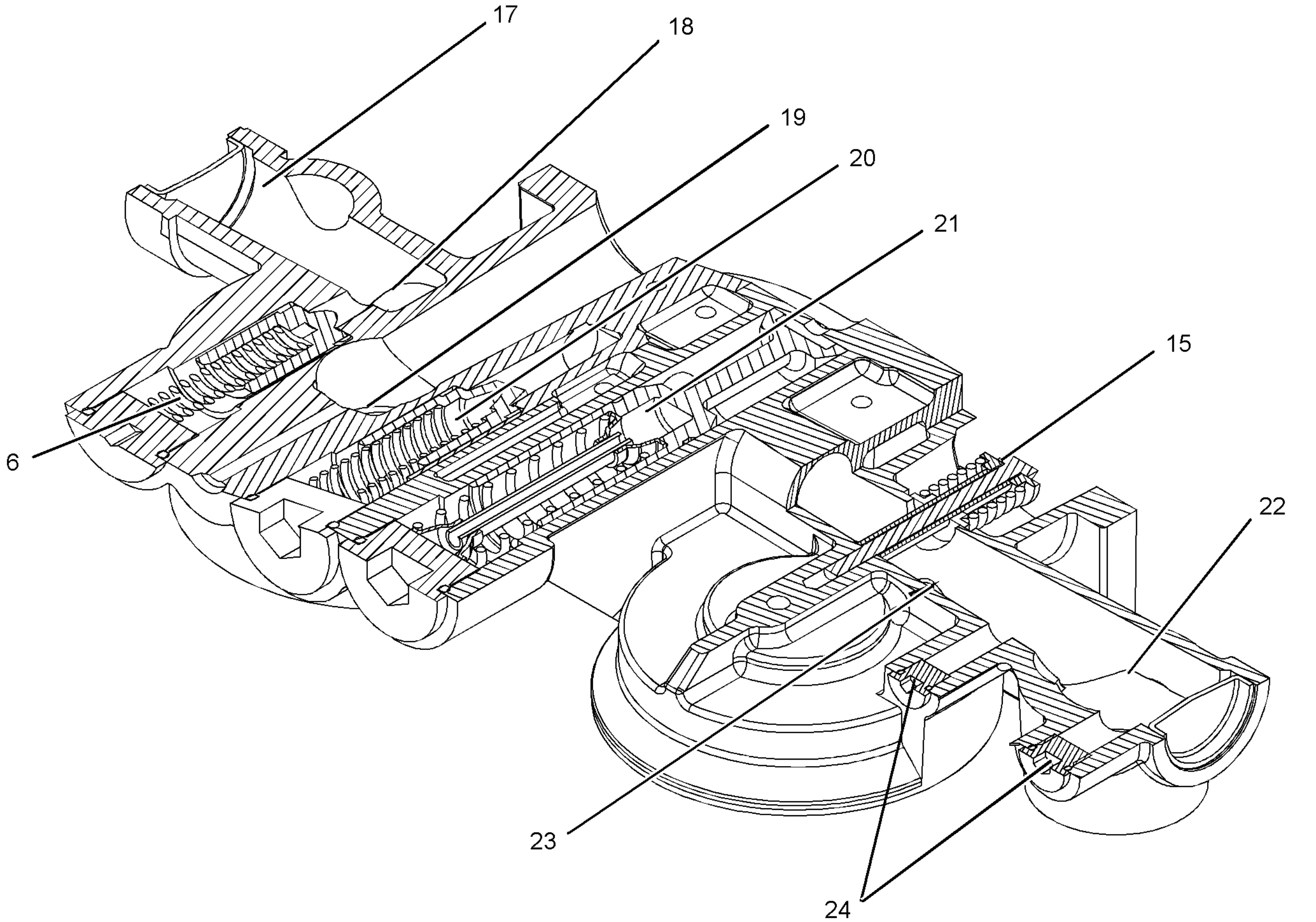

Illustration 14 g01609090

Oil filter base

(17) Oil from engine oil cooler
(18) Passage to engine oil filter
(19) Filtered oil
(20) Cooler bypass valve
(21) Bypass valve for the engine oil pump
(6) Engine oil filter bypass valve
(15) High pressure relief valve
(22) Oil from engine oil pump
(23) Passages to secondary oil filter
(24) S·O·S ports

The engine oil pump is mounted to the back of the front gear train on the lower right hand side of the engine. The engine oil pump is driven by an idler gear from the crankshaft gear. Oil is pulled from the sump through oil pump bypass valve (21) on the way to the engine oil cooler. The bypass valve controls the oil pressure from the engine oil pump. The engine oil pump can supply excess oil for the lubricating system. When this situation is present, the oil pressure increases and the bypass valve opens. The open bypass valve allows the excess oil to return to the sump.

High pressure relief valve (15) regulates high pressure in the system. The high pressure relief valve will allow the oil to return to the sump when the oil pressure reaches 680 kPa (100 psi). The oil then flows through the engine oil cooler. The engine oil cooler uses engine coolant in order to cool the oil. The oil cooler bypass valve (20) directs the oil flow through the engine oil cooler by two different methods.

Approximately five percent of the oil flow is directed through an orificed passage that leads to the secondary oil filter (if equipped). The oil flows through the bypass filter and to the engine oil sump. The main oil flow now flows toward the primary engine oil filter. When the oil pressure differential across oil filter bypass valve (6) reaches 200 kPa (29 psi), the valve allows the oil flow to bypass the primary engine oil filter in order to lubricate the engine parts. The bypass valve provides immediate lubrication to the engine components when there is a restriction in the primary engine oil filter due to the following conditions:

- Cold oil with high viscosity
- Plugged primary engine oil filter

Note: Refer to Specifications, "Engine Oil Filter Base" for a cross section of the valves in the engine oil filter base.

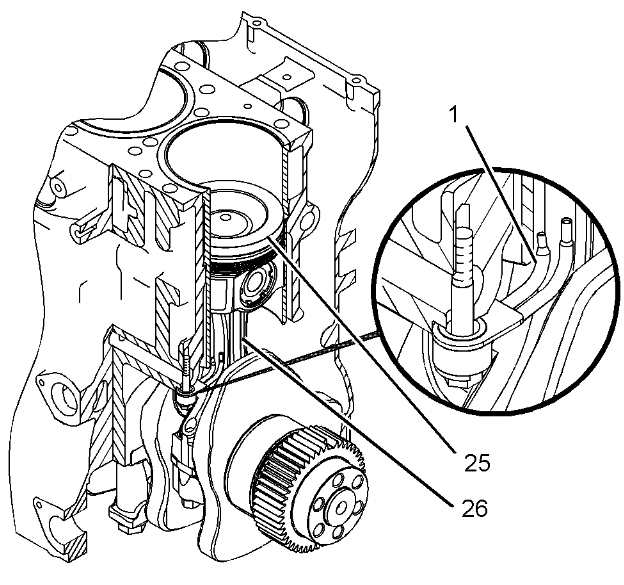

Illustration 15 g01611705

Interior of cylinder block

(1) Piston cooling jets
(25) Piston
(26) Connecting rod

Filtered oil flows through main oil gallery (2) in the cylinder block to the following components:

- Piston cooling jets (1)
- Valve mechanism
- Camshaft bearings
- Crankshaft main bearings
- Turbocharger

The piston cooling jets provide the underside of the piston with liberal amounts of oil. The oil is used to remove heat from the piston. The oil is also used as a lubricant.

The breather allows engine blowby to escape from the crankcase. The engine blowby is discharged into the atmosphere through a hose. This prevents pressure from building up that could cause seals or gaskets to leak.

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Cooling System

SMCS Code: 1350

Coolant Flow

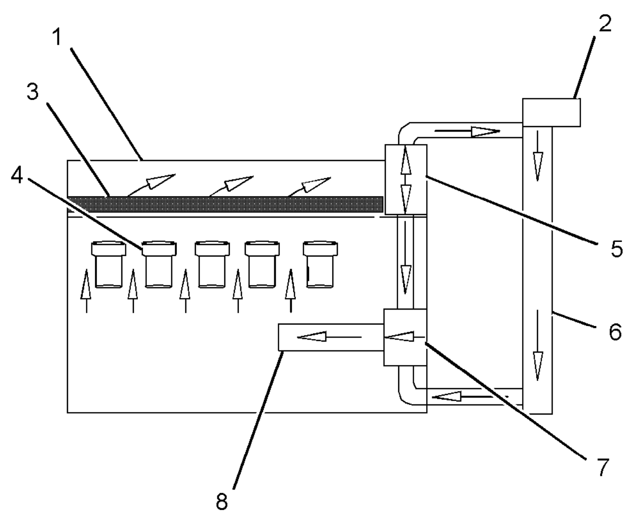

Illustration 16 g01085911

Cooling system schematic

(1) Cylinder head
(2) Expansion tank
(3) Return manifold
(4) Cylinder liners
(5) Temperature regulator housing
(6) Radiator
(7) Water pump
(8) Engine oil cooler

The water pump is gear-driven. The water pump is located on the right hand side of the engine. The water pump supplies the coolant for the engine cooling system. The coolant is supplied to the following components:

- Cylinder head (1)
- Cylinder liners (4)
- Engine oil cooler (8)
- Air compressor (not shown)

- Coolant conditioner element (not shown)

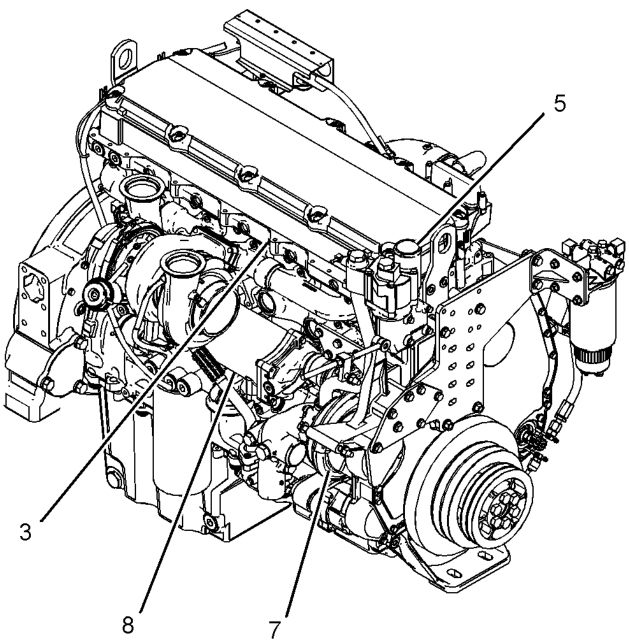

Illustration 17 g01121906

Right side view of engine

(3) Return manifold
(5) Temperature regulator housing
(7) Water pump
(8) Engine oil cooler

Water pump (7) pulls the coolant from the bottom of radiator. The water pump is located on the right hand side of the front timing gear housing.

The water pump impeller rotates at 1.37 times the engine speed. The water pump is driven by an idler gear. The idler gear is turned by the crankshaft gear. The water pump shaft is supported by two ball bearings. One ball bearing is located in the water pump housing. The other ball bearing is located in the front timing gear housing. The water pump impeller face is open. The impeller is made out of cast iron. The rear cover is an aluminum die casting. The water pump seal is a cartridge seal that is located on the inlet side of the water pump in order to provide good water flow around the seal for cooling.

The coolant is pumped through engine oil cooler (9). The coolant then flows to the supply manifold. The supply manifold, which is located in the cylinder block, distributes coolant around the upper portion of the cylinder liners. At each cylinder, the coolant flows from the cylinder liner to the cylinder head. The cylinder head is divided into single cylinder cooling sections. In the cylinder head, the coolant flows across the center of the cylinder and across the injector seat boss. At the center of the cylinder, the coolant flows around the injector sleeve over the exhaust port. The coolant then exits into return manifold (3). The return manifold collects the coolant from each cylinder and the return manifold directs the flow to temperature regulator housing (5). When the coolant temperature regulator is in the closed position, the coolant flows through the coolant temperature regulator. This allows the coolant to flow directly back to the water pump for recirculation by bypassing the radiator. When the coolant temperature regulator is in the open position, the coolant is directed through the radiator and back to the water pump inlet.

Supply Manifold

Cooling is provided for only the portion of the cylinder liner above the seal in the cylinder block. The coolant enters the cylinder block at each cylinder through slits in the supply manifold. The supply manifold is an integral casting in the cylinder block. The coolant flows around the circumference of the cylinder liner and into the cylinder head through a single drilled passage for each liner. The coolant flow is split at each cylinder liner so that 60 percent flows around the cylinder liner and the remainder flows directly to the cylinder head.

Temperature Regulator Housing

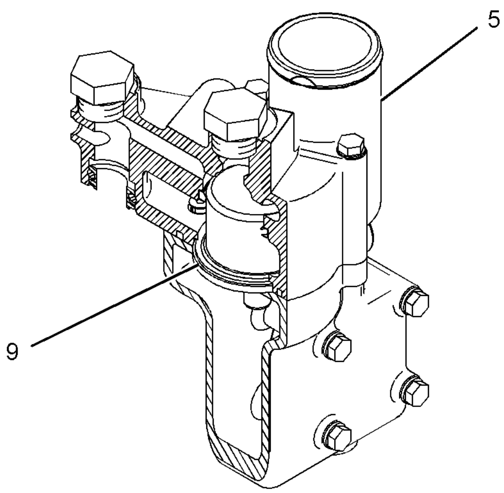

Illustration 18 g01612076

Section view of the temperature regulator housing

(5) Temperature regulator housing
(9) Coolant temperature regulator

The coolant temperature regulator is a full flow bypass type that is used to control the outlet temperature of the coolant. When the engine is cold, the coolant temperature regulator is in the closed position. This allows the coolant to flow through the coolant temperature regulator from the return manifold. This allows the coolant to bypass the radiator. The coolant goes directly to the water pump for recirculation. As the coolant temperature increases, the coolant temperature regulator begins to open directing some of the coolant to the radiator and bypassing the remainder to the water pump inlet. At the full operating temperature of the engine, the coolant temperature regulator moves to the open position. This allows all the coolant flow to be directed to the radiator. The coolant then goes to the water pump. This route provides the maximum heat release from the coolant. A vent line is recommended from the manifold to the radiator overflow tank in order to provide venting for the cooling system.

Coolant for Air Compressor

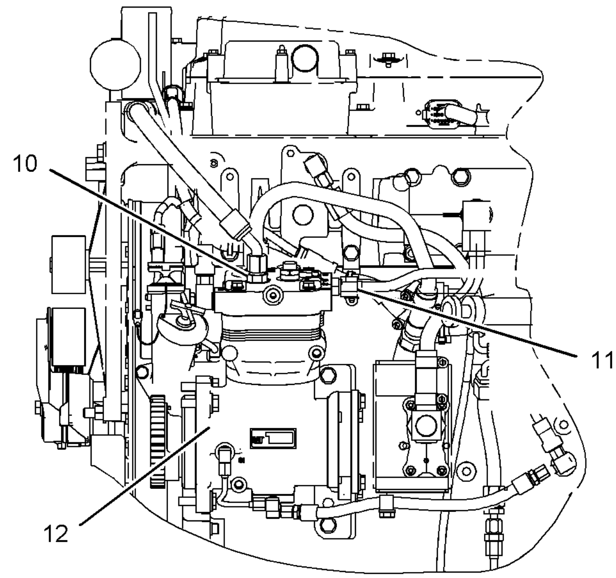

Illustration 19 g01612094

(10) Outlet hose
(11) Inlet hose
(12) Air compressor

The coolant that is used for air compressor (12) comes from the cylinder head through inlet hose (11). The coolant exits the air compressor through outlet hose (10) and flows back to the cylinder head.

i02919740

Basic Engine

SMCS Code: 1200

Cylinder Block

The cylinder block is a unique design with a deep counterbore that supports the cylinder liner. The cylinder block also forms the coolant jacket. Two oil manifolds are provided in the cylinder block for engine lubrication. The manifold on the lower right side of the cylinder block provides oil to the following components:

- Piston cooling jets
- Crankshaft bearings
- Oil filter base

The manifold on the upper left side of the cylinder block provides oil to the following components:

- Camshaft bearings
- Valve mechanism

The manifold on the right supplies oil to the manifold on the left. The oil travels through the cut above the number one main bearing and the cut above the number four main bearing.

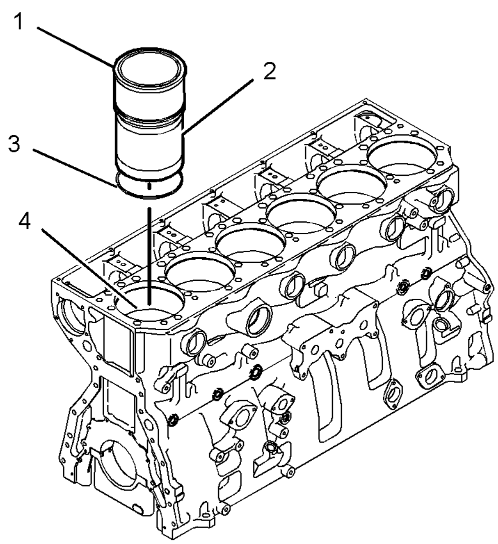

Illustration 20 g01451294

Cylinder liners (1) are seated on a ridge (4) in the middle of the cylinder wall between the crankcase and the coolant jacket. The ridge is created by a counterbore in the cylinder block. The cylinder liners have a lip (2) which rests on the ridge. The seals of the coolant jacket are located in the upper regions and middle regions of the cylinder liners. The lower barrier uses a D-ring seal (3) that is located above the seating surface of the cylinder liner. The upper barrier is the head gasket which is above the coolant jacket.

The cylinder block has seven main bearings in order to support the crankshaft. Each main bearing cap is fastened to the cylinder block with two bolts.

Pistons, Rings, and Connecting Rods

The high compression ratio of the engine requires the use of steel one-piece pistons.

The pistons have three rings:

- Compression ring
- Intermediate ring
- Oil ring

The rings are located in grooves in the piston. The rings seal the crankcase from the combustion gases and the rings also provide control of the engine oil. The design of the compression ring is a barrel face with a plasma face coating. The design of the intermediate ring is a tapered shape and a chrome finish. The oil ring is double railed with a coil spring expander. The oil ring has a ground profile and a chrome finish.

The connecting rod is a conventional design. The cap is fastened 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. This allows a larger surface area on the piston, and connecting rod in order to minimize bearing load.

Crankshaft

The crankshaft converts the linear motion of the pistons into rotational motion. 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
- Engine oil pump
- Air compressor
- Fuel transfer pump
- Accessory drive

The crankshaft is held in place by seven main bearings. The oil holes and the oil grooves in the shell of the upper bearing supply oil to the connecting rod bearings. The oil holes for the connecting rod bearings are located at the following main bearing journals: 2, 3, 5 and 6.

Hydrodynamic seals are used at both ends of the crankshaft to control oil leakage. The hydrodynamic grooves in the seal lip move lubrication oil back into the crankcase as the crankshaft turns. The front seal is located in the front housing. The rear seal is installed in the flywheel housing.

Camshaft

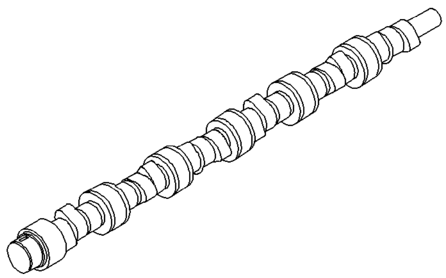

Illustration 21 g00762808

The camshaft has three lobes at each cylinder in order to operate the unit injector, the exhaust valves, and the inlet valves. Seven bearings support the camshaft. The camshaft is driven by an idler gear that is turned by the crankshaft in the front gear train. Each bearing journal is lubricated from the oil manifold in the cylinder block. A thrust pin that is located at the rear of the block positions the camshaft through a circumferential groove. The groove is machined at the rear of the camshaft. Timing of the camshaft is accomplished by aligning marks on the crankshaft gear, idler gear, and camshaft gear with each other.

The injector lobe on the camshaft has a modified profile. The modified profile produces multiple injections.

Vibration Damper

The force from combustion in the cylinders and from driveline components will cause the crankshaft to twist. This is called torsional vibration. If the vibration is too great, the crankshaft will be damaged. Driveline components can excite torsional stress. This stress will cause damage to components. The vibration damper limits the torsional vibrations to an acceptable amount in order to prevent damage to the crankshaft.

The viscous vibration damper is installed on the front of the crankshaft. The viscous vibration damper has a weight in a case. The space between the weight and the case is filled with a viscous fluid. The weight moves in the case in order to limit the torsional vibration.

i02639921

Electrical System

SMCS Code: 1400; 1550; 1900

Grounding Practices

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

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

To ensure proper functioning of the engine electrical systems, an engine-to-frame ground strap with a direct path to the negative battery post must be used. This may be provided by way of a starting motor ground, a frame to starting motor ground, or a direct frame to engine ground.

An engine-to-frame ground strap must be used in order to connect the grounding stud of the engine to the frame of the vehicle and to the negative battery post.

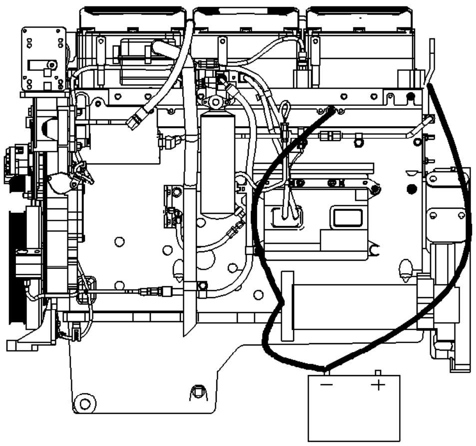

Illustration 22 g00766579

Typical example

Grounding Stud To Battery Ground ("-")

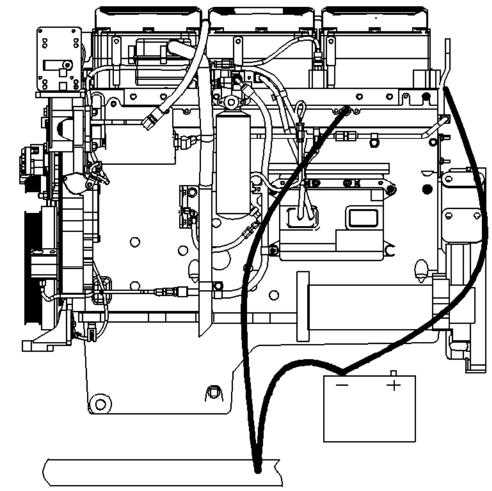

Illustration 23 g00766660

Typical example

Alternate Grounding Stud To Battery Ground ("-")

The engine must have a wire ground to the battery.

Ground wires or ground straps should be combined at ground studs that are only for ground use. All of the grounds should be tight and free of corrosion.

All of the ground paths must be capable of carrying any likely current faults. An AWG #0 or larger wire is recommended for the grounding strap to the cylinder head.

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

NOTICE

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

The Electronic Control Module (ECM) must be disconnected at the "J1/P1" and "J2/P2" locations before welding on the vehicle.

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

Unlike many electronic systems of the past, this engine is tolerant to common external sources of electrical noise. Buzzers that use electrical energy can cause disruptions in the power supply. If buzzers are used anywhere on the machine, the engine electronics should be powered directly from the battery system through a dedicated relay.

Engine Electrical System

The electrical system has the following separate circuits:

- Charging
- Starting (If equipped)
- Low amperage accessories

Some of the electrical system components are used in more than one circuit. The following components are common in more than one circuit:

- Battery or batteries
- Circuit breakers
- Battery cables
- Ammeter

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

The starting circuit is activated only when the start switch is activated.

The low amperage accessory 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 a belt from the crankshaft pulley. This alternator is a three-phase, self-rectifying charging unit, and the regulator is part of the alternator.

The alternator design has no need for slip rings and the only part that has movement is the rotor assembly. All conductors that carry current are stationary. The following conductors are in the circuit:

- Field winding
- Stator windings
- Six rectifying diodes
- Regulator circuit components

The rotor assembly has many magnetic poles that look like fingers with air space between each of the opposite poles. The poles have residual magnetism. The residual magnetism produces a small magnetic field 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. The AC current is produced in the stator windings from the small magnetic field. The AC current is changed to direct current (DC) when the AC current passes through the diodes of the rectifier bridge. The current is used for the following applications:

- Charging the battery
- Supplying the low amperage accessory circuit
- Strengthening the magnetic field

The first two applications use the majority of the current. As the DC current increases through the field windings, the strength of the magnetic field is increased. As the magnetic field becomes stronger, more AC current is produced in the stator windings. The increased speed of the rotor assembly also increases the current and voltage output of the alternator.

The voltage regulator is a solid-state electronic switch. The voltage regulator senses the voltage in the system. The voltage regulator switches ON and OFF many times per second in order to control the field current for the alternator. The alternator uses the field current in order to generate the required voltage output.

NOTICE

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

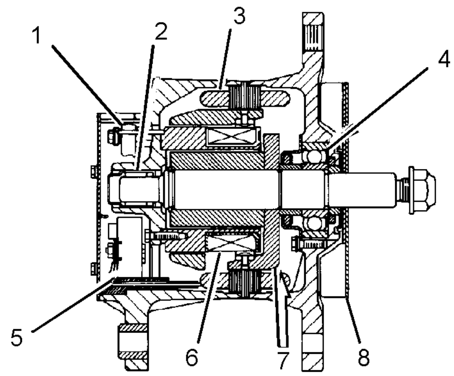

Illustration 24 g01324275

Typical alternator components

(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

Starting Solenoid

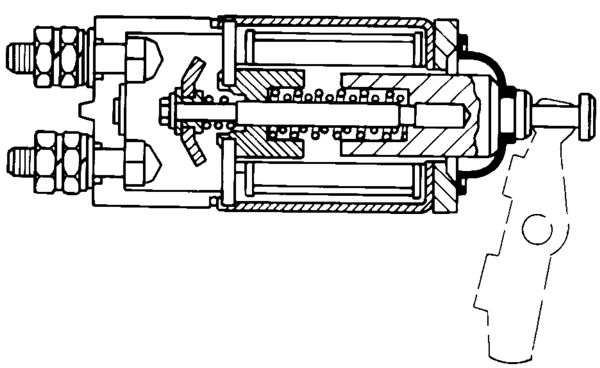

Illustration 25 g00317613

Typical starting solenoid

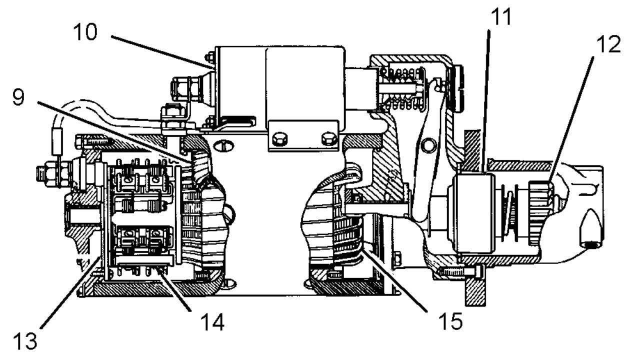

Illustration 26 g01324034

Typical starting motor components

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

The starting solenoid (10) is an electromagnetic switch that performs the following basic operations:

- The starting solenoid (10) closes the high current starting motor circuit with a low current start switch circuit.
- The starting solenoid (10) engages the pinion for the starting motor (12) with the ring gear.

Solenoid (10) has windings (one or two sets) around a hollow cylinder. A plunger that is spring loaded is inside of the cylinder. The plunger can move forward and backward. When the start switch is closed and electricity is sent through the windings, a magnetic field (9) is made. The magnetic field (9) pulls the plunger forward in the cylinder. This moves the shift lever in order to engage the pinion drive gear with the ring gear. The front end of the plunger then makes contact across the battery and motor terminals of solenoid (10). Next, the starting motor begins to turn the flywheel of the engine.

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

When two sets of solenoid windings are used, the windings are called the hold-in winding and the pull-in winding. Both sets of windings have the same number of turns around the cylinder, but the pull-in winding uses a wire with a larger diameter. The wire with a larger diameter produces a greater magnetic field (9). When the start switch is closed, part of the current flows from the battery through the hold-in windings. The rest of the current flows through the pull-in windings to the motor terminal. The current then flows through the motor to ground. Solenoid (10) is fully activated when the connection across the battery and the motor terminal is complete. When solenoid (10) is fully activated, the current is shut off through the pull-in windings. At this point, only the smaller hold-in windings are in operation. The hold-in windings operate for the duration of time that is required in order to start the engine. Solenoid (10) will now draw less current from the battery, and the heat that is generated by solenoid (10) will be kept at an acceptable level.

Testing And Adjusting Section

Fuel System

i07961515

Fuel System - Inspect

SMCS Code: 1250-040

Introduction

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

References

Reference: Testing and Adjusting, “Air in Fuel - Test”

Reference: Testing and Adjusting, “Fuel System - Prime”

Required Tools

Table 1

Required Tools			
Item	**Qty**	**Part Number**	**Part Name**
T1	1	175-7546	Oil Filter Cutter Gp

Test Procedure

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”.

i04962789

Air in Fuel - Test

SMCS Code: 1280-081

⚠ WARNING

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

Introduction

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

Required Tools

Table 2

Required Tools
2P-8278 Tube As

Test Preparation

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

Test Procedure

1. 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.

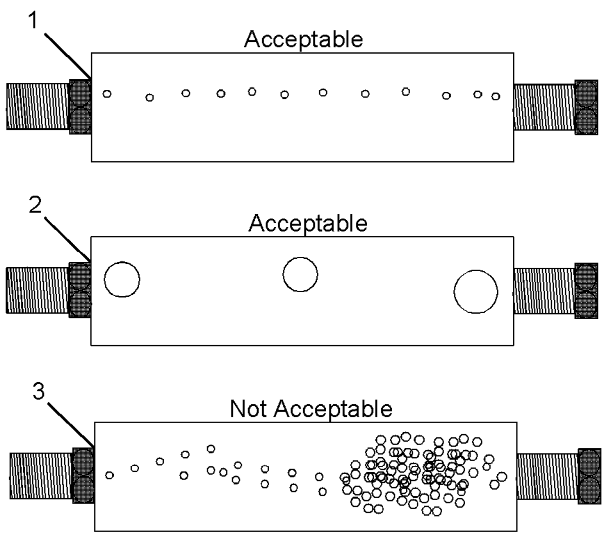

Illustration 27 g01096678

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 are 2 seconds to 3 seconds intervals between bubbles.
(3) Excessive air bubbles in the fuel are not acceptable.

2. 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 3 of “Adjustment Procedure”.

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

Adjustment Procedure

NOTICE

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

1. 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”.

2. 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 action corrects the problem, repair the fuel tank or the stand pipe in the fuel tank.

3. 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.

i03381213

Electronic Unit Injector - Adjust

SMCS Code: 1290-025

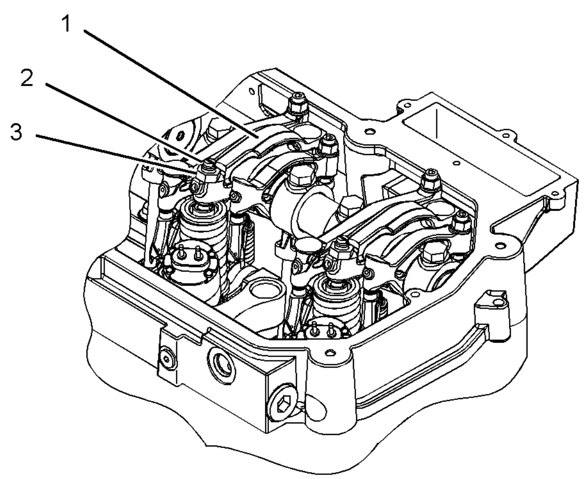

Illustration 28 g01126970

Injector Mechanism

(1) Rocker arm
(2) Adjustment screw
(3) Locknut

Follow the procedure in order to adjust your electronic unit injectors:

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

a. Cylinders 3, 5, and 6 can be adjusted with cylinder 1 at Top Center compression stroke.

b. Loosen the locknut.

c. Turn the adjustment screw until the screw makes contact with the electronic unit injector.

d. Tighten the adjustment screw to an additional 2 turns.

e. Turn the adjustment screw counterclockwise for 2.5 turns.

f. Turn the adjustment screw until the screw makes contact with the electronic unit injector.

g. Turn the adjustment screw through 180 degrees in a clockwise direction.

h. Tighten the locknut to a torque of 55 ± 10 N·m (41 ± 7 lb ft).

2. Rotate the engine in the normal operating direction by 360 degrees. Cylinder 1 will now be on Top Center exhaust stroke.

a. Cylinder 1, 2, and 4 can be adjusted with cylinder 1 at Top Center exhaust stroke.

b. Loosen the locknut.

c. Turn the adjustment screw until the screw makes contact with the electronic unit injector.

d. Turn the adjustment screw to an additional two turns.

e. Turn the adjustment screw counterclockwise for 2.5 turns.

f. Turn the adjustment screw until the screw makes contact with the electronic unit injector.

g. Turn the adjustment screw through 180 degrees in a clockwise direction.

h. Tighten the locknut to a torque of 55 ± 10 N·m (41 ± 7 lb ft).

i07724770

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 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 to 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. Refer to Troubleshooting, “Electrical Connectors - Inspect”. Inspect the posts of the solenoid for arcing. If arcing or evidence of arcing is found, remove the cap assembly. Refer to Disassembly and Assembly Manual, “Electronic Unit Injector - Remove”. Clean the connecting posts. Reinstall the cap assembly and tighten the solenoid nuts to a torque of 2.5 ± 0.25 N·m (22 ± 2 lb in).

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

4. 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 the bolt to a torque of 55 ± 10 N·m (41 ± 7 lb ft).

5. Remove the suspect unit injector and check the unit injector for signs of exposure to coolant. Refer to Disassembly and Assembly Manual, “Electronic Unit Injector - Remove”. 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. Refer to Disassembly and Assembly Manual, “Electronic Unit Injector Sleeve - Remove”. 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”.

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

i07569049

Finding Top Center Position for No. 1 Piston

SMCS Code: 1105-531

Table 3

Required Tools			
Tool	**Part Number**	**Part Name**	**Qty**
A	208-0888	Engine Turning Tool	1
B	350-7549	Engine Turning Tool	1
C	9S-9082	Engine Turning Tool	1
D	136-4632	Timing Pin	1
E	208-9387	Timing Pin	1
F	208-9388	Adapter	1
G	5P-7305(1)	Engine Turning Tool	1
H	456-7526(1)	Timing Pin	1

(1) This is for a 966H C11engine

Disassembly and Assembly of the Timing Pin

Use the following procedure in order to assemble the engine timing pin.

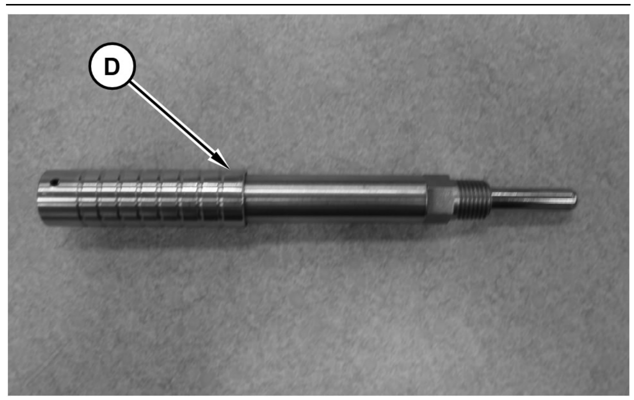

Illustration 29 g02506600

(D) 136-4632 Timing Pin

1. Begin with timing pin (D).

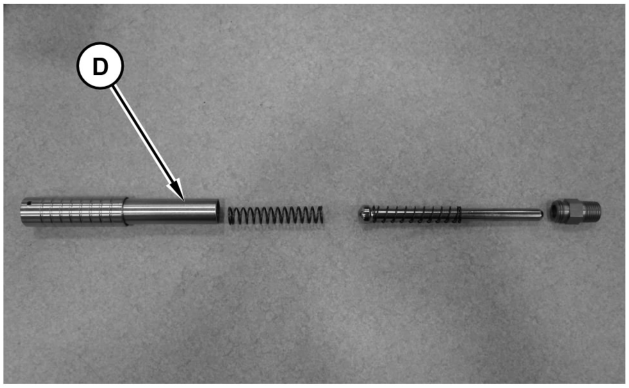

Illustration 30 g02506616

Disassembled 136-4632 Timing Pin timing pin

2. Disassemble timing pin (D).

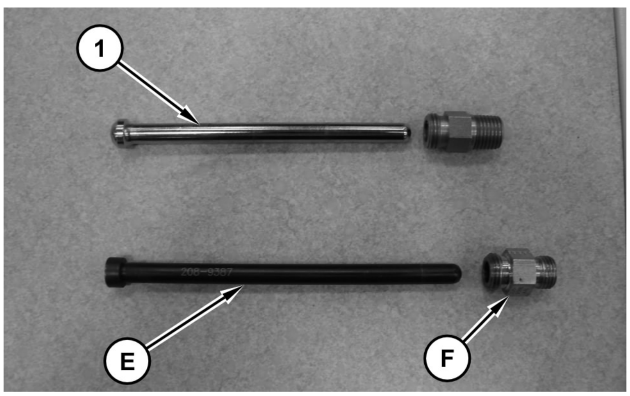

Illustration 31 g02506619

Comparing timing pins

(E) 208-9387 Timing Pin
(F) 208-9388 Adapter
(1) Pin that is removed from 136-4632 Timing Pin

3. Install timing pin (E) and adapter (F) into timing pin assembly (D). Utilize both the springs that were removed during the disassembly.

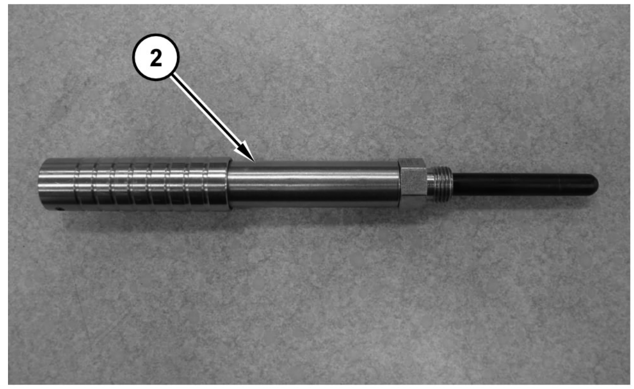

Illustration 32 g01974153

(2) Timing pin assembly (D) with the 208-9387 Timing Pin installed

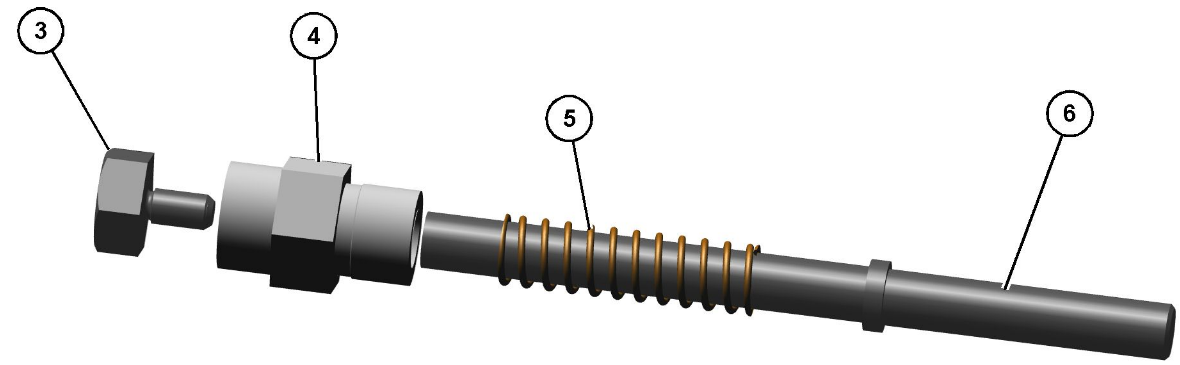

Illustration 33 g06218688

456-7526 Timing Pin

(3) Screw end
(4) 208-9388 Adapter
(5) 3N-6233 Spring
(6) Pin

Procedure for Pin Timing

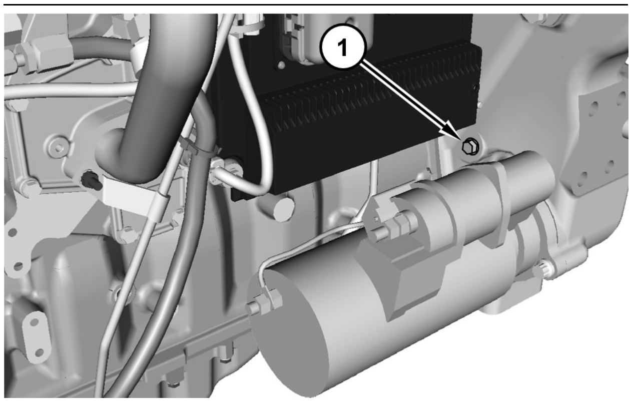

Illustration 34 g01925035

Flywheel housing

(1) Timing hole

Note: The opposite side of the flywheel housing can be used for this procedure. When using the opposite side, the shorter timing pin will need to be used to perform the procedure.

1. Remove plug (1) from the timing hole that is located in the flywheel housing. Install the assembled timing pin into the timing hole.

Note: If the flywheel is turned beyond the point of engagement, the flywheel must be turned in the direction that is reverse of normal engine rotation. Turn the flywheel by approximately 30 degrees. Then turn the flywheel in the direction of normal rotation until the timing pin engages with the threaded hole. This procedure eliminates the backlash from the gears when the No. 1 piston is at the top center position.

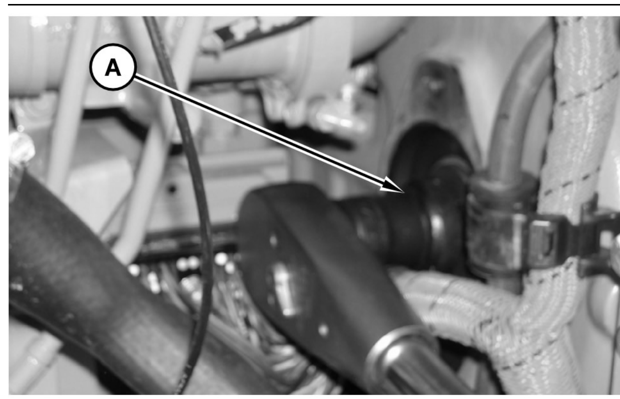

Illustration 35 g02235474

2. Install tool (A) into the gear in the top left-hand side of the flywheel housing.

Tool (A) is used for turning the flywheel in the flywheel housing. Turn the engine in the direction of engine rotation. The direction of engine rotation is counterclockwise, as the engine is viewed from the flywheel end. Turn the engine until the timing pin engages with the threaded hole in the flywheel.

Note: Tooling (B) or (C) may also be used to turn the flywheel. Either of the three tools may be used depending on the application and available space.

3. Remove the valve mechanism cover from the engine.

Refer to Disassembly and Assembly, “Valve Mechanism Cover - Remove and Install”.

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

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

i03142863

Fuel Quality - Test

SMCS Code: 1280-081

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

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

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

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

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

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

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

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

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

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

- Cetane number of the fuel
- Air in the fuel

- Other fuel characteristics

i02224162

Fuel System - Prime

SMCS Code: 1258-548

⚠ 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.

If the fuel system runs out of fuel or if air is introduced into the fuel system the following procedure may be followed.

1. Turn the ignition switch to the “OFF” position.

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

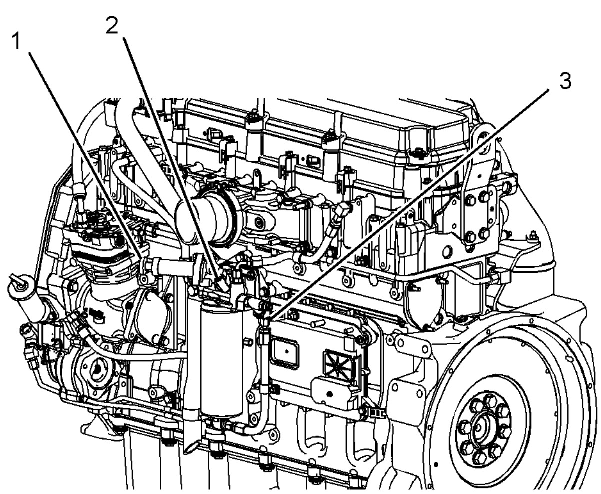

Illustration 36 g01127321

(1) Fuel priming pump
(2) Air bleed
(3) Priming valve (If Equipped)

3. Turn the priming valve (3) (If Equipped) to the “Closed (Prime)” position in order to prime the fuel system.

4. Purging air from the fuel system requires the air bleed to be opened three full turns. Open air bleed (1). Do not remove the 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.

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 2 minutes.

Note: Most of the air should be purged from the system after four or five cranking cycles.

6. Repeat Step 5 until the engine starts and runs. If the engine runs rough, continue to operate the engine at low idle until the engine runs smoothly.

7. Observe air bleed (2). When a small drop of fuel appears at the threads of the air bleed, close and tighten air bleed (2).

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

8. After the engine has operated smoothly for 30 seconds, turn the priming valve (3) to the “Open (Run)” position.

Note: Shortened injector life may occur if the priming valve (3) is left in the “Closed (Prime)” position.

9. Clean any residual fuel from the engine components.

10. Once the engine runs smoothly, stop the engine. Turn the ignition switch to the OFF position.

Note: You may use the hand priming pump for the fuel filter (if equipped) instead of cranking the engine and running the engine. Perform the following procedure when the hand priming pump is used:

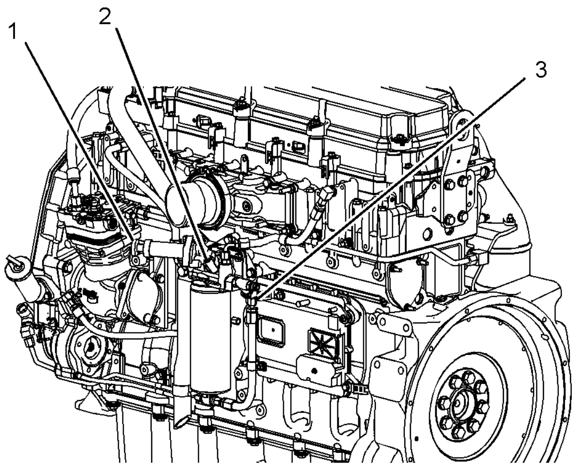

Illustration 37 g01127321

(1) Fuel priming pump
(2) Air bleed
(3) Priming valve (If Equipped)

a. Turn the priming valve (3) (If Equipped) to the “Closed (Prime)” position in order to prime the fuel system.

b. Purging air from the fuel system requires the air bleed (1) for the fuel filter to be opened three full turns. Open air bleed (1). Do not remove the screw.

c. While you operate the hand priming pump, observe the air bleed (2). When a small drop of fuel appears at the threads of the air bleed, close and tighten the air bleed (2).

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

d. Clean any residual fuel from the engine components.

e. Continue to operate the fuel priming pump (1) until a strong resistance is felt. Listen for an audible click from the fuel manifold. The click will indicate that the valve has opened and the fuel system is pressurized. Lock the fuel priming pump.

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

f. Crank the engine. If the engine starts but the engine runs rough, continue to operate the engine at low idle until the engine runs smoothly.

Note: If the engine will not start, further priming is necessary. If the engine starts but the engine continues to misfire or smoke, further priming is necessary.

g. After the engine has operated smoothly for 30 seconds, turn the priming valve (3) to the “Open (Run)” position.

Note: Shortened injector life may occur if the priming valve (3) is left in the “Closed (Prime)” position.

Note: Some C11 Engines and C13 Engines may be equipped with a electric fuel priming pump.

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.

If the engine's fuel system is run dry, fill the fuel tank. Then prime the fuel system in order to remove any air bubbles from the system.

NOTICE
Do not loosen fuel lines at the fuel manifold. The engine components may be damaged and/or loss of priming pressure may occur when the fuel lines are loosened.

The fuel system is equipped with an electronic fuel priming pump. When the ignition is turned to the ON position, the fuel system is automatically primed.

i05984958

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
- Contamination in the check valves for the fuel priming pump
- 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
- Contamination 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

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

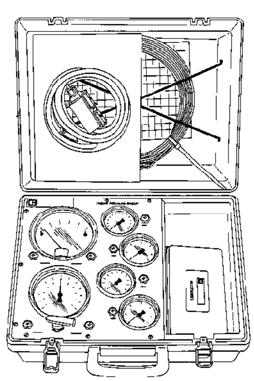

Illustration 38 g00293196

1U-5470 Engine Pressure Group

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

WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire. Clean up fuel spills immediately.

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, "Dealer Service Tool Catalog" for tools and supplies suitable to collect and contain fluids on Cat products.

Dispose of all fluids according to local regulations and mandates.

Note: Place pressure gauges in-line with fuel lines when taking readings. Do not plug the outlet port of a fuel system component to take pressure readings.

1. Use the following procedure in order to measure the fuel pressure that is after the secondary filter:

Note: Fuel pressure readings near the fuel supply manifold have pressure spikes. The pressure spikes are caused by excess fuel that is returning to the fuel system from the injectors. Excessive needle movement at the gauge may be present. Connect the gauge with a section of suitable hose. The air in the hose absorbs the spikes. This achieves an average reading and a steady needle. Keep the gauge above the measuring point.

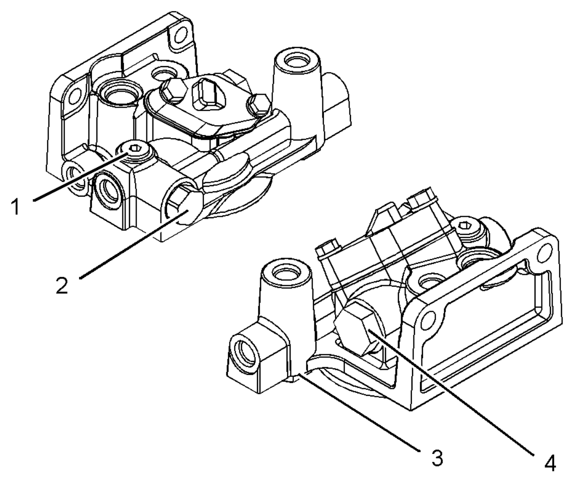

Illustration 39 g01133865

(1) Test port
(2) Air purge
(3) Pressure regulating valve
(4) Bypass valve for the Fuel filter

a. Install the 1U-5470 Engine Pressure Group into port (1). This port is the proper test port.

b. Adjust the engine speed to 1800 rpm with no load.

c. The fuel pressure should be 586 kPa (85 psi) nominal. Record the pressure.

d. If excessive pressure is found, check the conditions that are listed previously under the "High Fuel Pressure" heading.

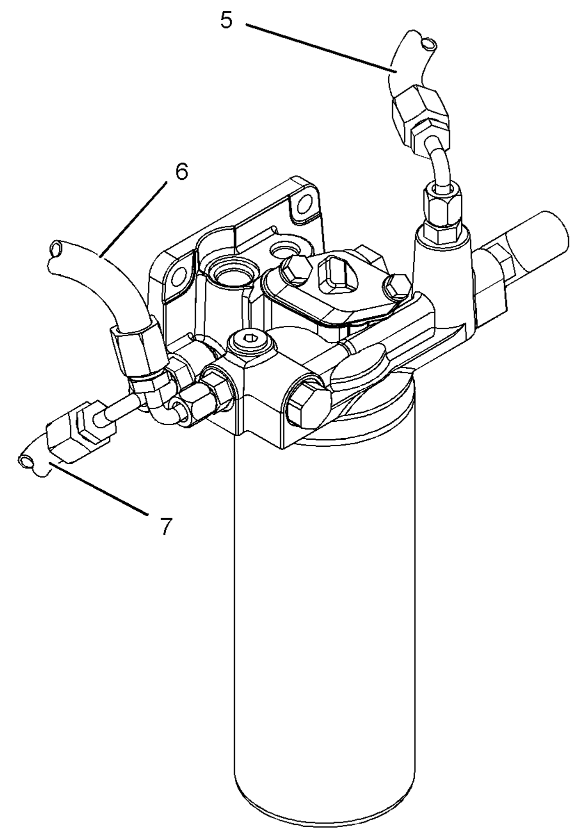

Illustration 40 g01133866

Standard secondary fuel filter base

(5) Fuel line from head
(6) Fuel line to head
(7) Fuel line from transfer pump

2. Use the following procedure to check the output of the fuel transfer pump:

a. Remove return fuel line (5).

b. Install the 1U-5470 Engine Pressure Group into the port that contained the return fuel line fitting.

c. Adjust the engine speed to 600 rpm with no load.

d. The fuel pressure should be 690 kPa (100 psi) to 724 kPa (105 psi).

e. If the fuel pressure is within the specified range, proceed to Step 3.

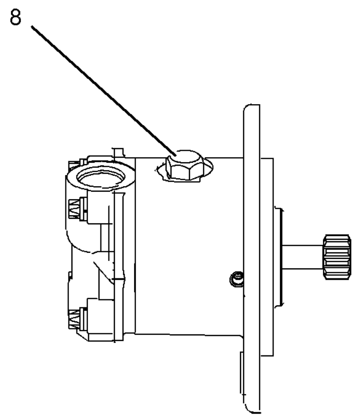

Illustration 41 g01133870

Fuel transfer pump (side view)

(8) Access plug

f. If the pressure is less than 655 kPa (95 psi), the fuel transfer pump is weak. The pressure regulating valve in the pump may be stuck or worn. The pressure regulating valve is located under access plug (8). Remove the access plug. Remove the pressure regulating valve, the spring, and the pin. Inspect the pressure regulating valve. If contamination is not found and the pressure regulating valve is worn, replace the fuel transfer pump. If dirt is found, clean the valve assembly and reinstall the valve assembly. Reinstall access plug (8).

g. Check the fuel pressure again. Replace the fuel transfer pump if the fuel pressure still measures less than 655 kPa (95 psi). The fuel transfer pump is operating properly if the fuel pressure measures at least 690 kPa (100 psi) to 724 kPa (105 psi).

h. Once the fuel transfer pump has been confirmed as properly operating, check the fuel pressure again at the secondary fuel filter base. Refer to Step 2. If the fuel pressure is not at the nominal specification, continue to Step 3.

3. Use the following procedure to inspect the return fuel pressure regulating valve:

a. Return fuel pressure regulating valve (3) is located on the bottom of the fuel filter base.

b. Inspect return fuel pressure regulating valve (3) for wear.

c. Check the fuel pressure again at the secondary fuel filter base. Refer to Step 2a. If the fuel pressure is not up to 586 kPa (85 psi), then perform Step 4. If the primary filter is sized correctly and the fuel lines are sized correctly, replace the secondary fuel filter base.

4. Use the following procedure to measure the vacuum at the primary filter:

a. Adjust the engine speed to 1800 rpm with no load.

b. Measure the vacuum at the outlet of the primary filter.

c. The vacuum should be 10.14 kPa (3 in Hg) to 13.52 kPa (4 in Hg). If the vacuum is more than 30.42 kPa (9 in Hg), measure the vacuum at the inlet of the primary filter. The differential across the primary filter should be less than 3.38 kPa (1 in Hg) with a new filter installed. If the differential is higher by more than 3.38 kPa (1 in Hg), the filter is undersized. The filter should be rated at 341 L (90 US gal) per hour. If the filter is sized correctly, ensure that the fittings and lines are correctly sized. The fuel lines should be 12.7 mm (0.5 inch). Also check for debris in the fuel tank that may be plugging the supply tube.

i02185619

Gear Group (Front) - Time

SMCS Code: 1206-531

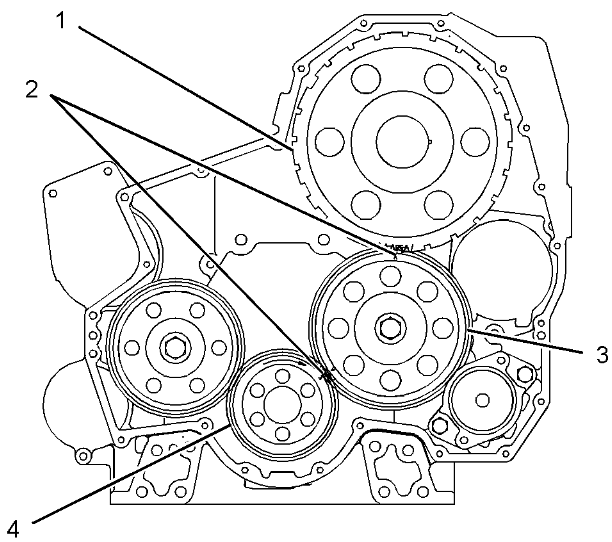

Illustration 42 g01105321

Front gear group

(1) Camshaft gear and timing reference ring
(2) Timing marks
(3) Idler gear
(4) Crankshaft gear

The basis for correct fuel injection timing and valve mechanism operation is determined by the timing reference ring and the alignment of the front gear group. The timing reference ring is located on the end of the camshaft. The timing reference ring is used to measure crankshaft rotation. During installation of the front gear, timing marks (2) on idler gear (3) must be in alignment with the timing marks on crankshaft gear (4) and the timing marks on camshaft gear (1).

Refer to Disassembly and Assembly, " Gear Group (Front) - Remove" and Disassembly and Assembly, " Gear Group (Front) - Install".

Note: If timing reference ring (1) is installed backward the engine will not start.

Check for proper alignment of the camshaft gear and timing reference ring (1) on the camshaft assembly. Inspect the key between the timing reference ring and the camshaft gear. Check the teeth on the timing ring. The teeth should not be defaced. The teeth should have sharp clean edges and the teeth should be free of contaminants.

Note: The electronic injection timing must be calibrated after reassembly of the front gear train. Refer to Troubleshooting, " Engine Speed/Timing Sensor - Calibrate".

Air Inlet and Exhaust System

i03143324

Air Inlet and Exhaust System - Inspect

SMCS Code: 1050-040

Air Inlet Restriction

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

Table 5

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

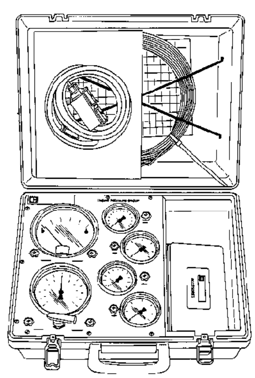

Illustration 43 g00293196

1U-5470 Engine Pressure Group

Refer to Special Instruction, SEHS8907, "Using the 1U-5470 Engine Pressure Group" for the instructions that are needed to use the 1U-5470 Engine Pressure Group. Refer to Operation Manual, NEHS0818, "Using the 198-4240 Pressure Indicator Tool Gp" for the instructions that are needed to use the 198-4240 Pressure Indicator Tool Gp.

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.

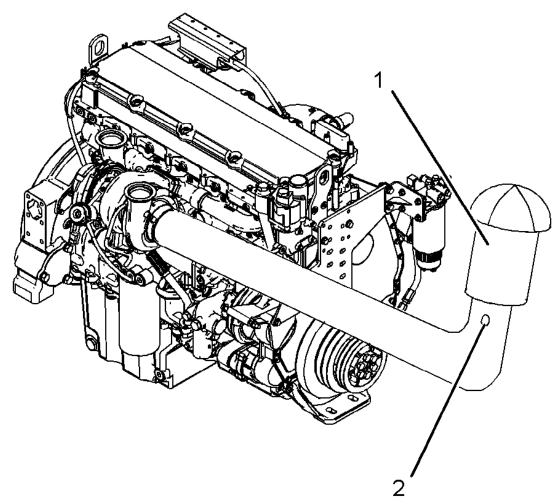

Illustration 44 g01099496

Right side view of engine

(1) Air cleaner
(2) Test location

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

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

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

d. Record the value.

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

f. Compare the result from Step 4e 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

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

Table 6

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

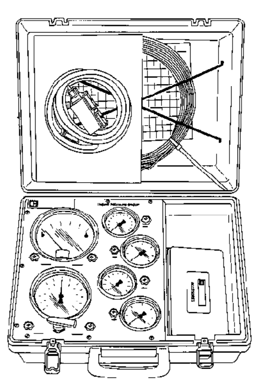

Illustration 45 g00293196

1U-5470 Engine Pressure Group

Refer to Special Instruction, SEHS8907, “Using the 1U-5470 Engine Pressure Group” for the instructions that are needed to use the 1U-5470 Engine Pressure Group. Refer to Operation Manual, NEHS0818, “Using the 198-4240 Pressure Indicator Tool Gp” for the instructions that are needed to use the 198-4240 Pressure Indicator Tool Gp.

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:

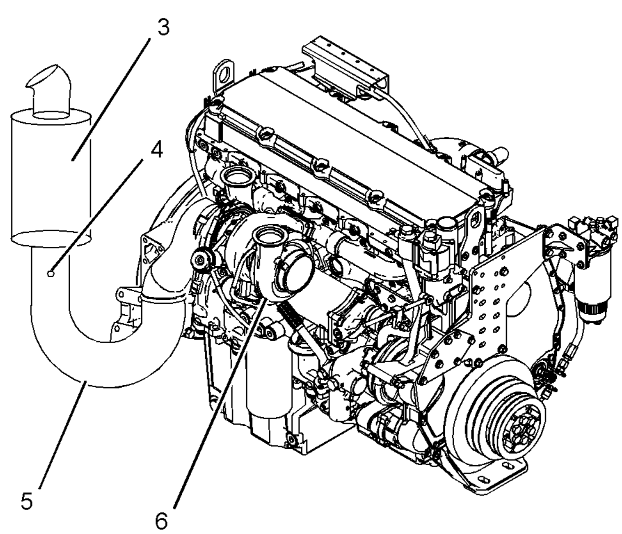

Illustration 46 g01618348

Right side view of engine

(3) Catalytic converter/muffler
(4) Test location
(5) Exhaust piping
(6) Turbocharger

1. Connect the pressure port of the differential pressure gauge to test location (4). Test location (4) can be located anywhere along the exhaust piping after the turbocharger but before the muffler.

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

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

4. Record the value.

5. 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 .... 12.4 kPa ((50 inch of H_2O))

i02919873

Turbocharger - Inspect

SMCS Code: 1052-040

WARNING

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

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, "Dealer Service Tool Catalog" for tools and supplies suitable to collect and contain fluids on Cat 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 wastegate

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 intake system. Replace the turbocharger. If there is no damage, go to Step 3.

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

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

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

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

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

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

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

e. If Steps 4a through 4d 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 housing.

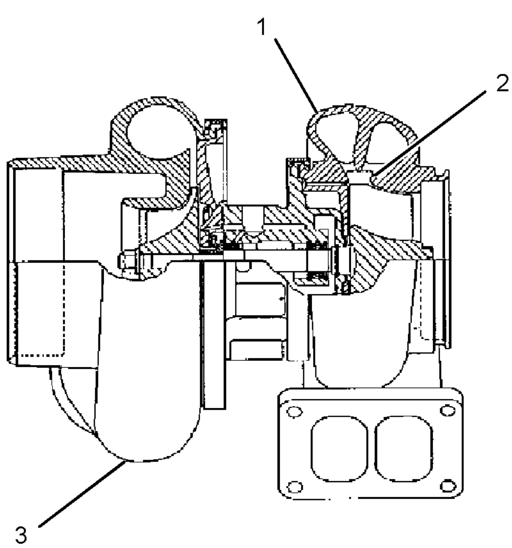

Illustration 47 g01451412

(1) Turbine housing
(2) Turbine wheel
(3) Turbocharger

1. Inspect the turbine for damage by a foreign object. If there is damage, determine the source of the foreign object. Replace turbocharger (3). If there is no damage, go to Step 2.

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

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

4. Inspect the turbine and turbine housing (1) for oil leakage. Inspect the turbine and turbine housing (1) 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 4a. Otherwise go to "Inspection of the Wastegate".

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 turbine housing (1). Oil flow may be forced in the wrong direction and the oil may not drain. Check the crankcase pressure and correct any problems.

c. If the oil drain 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 4a through 4d did not reveal the source of the oil leakage, turbocharger (3) has internal damage. Replace turbocharger (3).

Inspection of the Wastegate

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

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

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

The following levels of boost pressure indicate a possible problem with the following components: Wastegate, Wastegate solenoid and Air lines

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

Note: The housing assembly for the wastegate is preset at the factory and no adjustments can be made.

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.

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

- The engine rating
- The horsepower demand on the engine
- The high idle rpm
- The height above sea level for engine operation
- Inlet air restriction
- Exhaust system restriction

i03385882

Inlet Manifold Pressure - Test

SMCS Code: 1058-081

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 TMI (Technical Marketing Information). 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. The correct pressure is also on the Fuel Setting and the related Service Information System. 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. The pressure will also be less than the pressure that is listed on the Fuel Setting and the Related Service Information System. If the fuel is rated below 35 API, the inlet manifold pressure can be more than the pressure listed in the TMI. The pressure will also be more than the pressure that is listed on the Fuel Setting and the Related Service Information System.

Note: Ensure that the air inlet and the exhaust are not restricted when you are checking the inlet manifold pressure.

Table 7

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

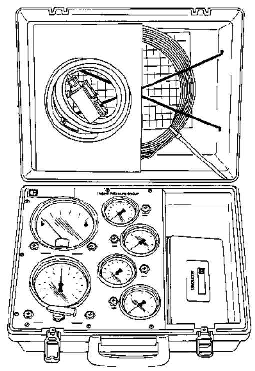

Illustration 48 g00293196

1U-5470 Engine Pressure Group

Refer to Special Instruction, SEHS8907, "Using the 1U-5470 Engine Pressure Group" for the instructions that are needed to use the 1U-5470 Engine Pressure Group. Refer to Operation Manual, NEHS0818, "Using the 198-4240 Digital Pressure Indicator" for the instructions that are needed to use the 198-4240 Digital Pressure Indicator.

Use the following procedure in order to measure the inlet manifold pressure:

1. Remove the plug from the air inlet elbow.
2. Connect the 1U-5470 Engine Pressure Group to the air inlet elbow at the pressure test location.
3. Record the value.
4. Compare the value that was recorded in Step 3 to the pressure that is given in the TMI.

i04073629

Exhaust Temperature - Test

SMCS Code: 1088-081

Measure the Exhaust Temperature

Table 8

Required Tools		
Part Number	**Part Name**	**Qty**
349-4201	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 high temperature can indicate that too much fuel is flowing to the cylinder. A malfunctioning fuel injection nozzle could cause this high temperature.

Use the 349-4201 Infrared Thermometer to check this exhaust temperature.

i04643912

Engine Crankcase Pressure (Blowby) - Test

SMCS Code: 1215; 1317

Table 9

Tools Needed		
Part Number	**Part Name**	**Quantity**
348-5430	Multi-Tool Gp	1
285-0900	Blowby Tool Group	1
NETG5049	Software License	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 a normal amount of blowby fumes rising from the crankcase breather. The breather can then become restricted in a 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 49 g02709261

348-5430 Multi-Tool Gp

The 348-5430 Multi-Tool Gp, or the 285-0900 Blowby Tool Group is used to check the amount of blowby. Refer to Tool Operating Manual, NEHS1087, "348-5430 Multi-Tool Gp" for the test procedure for checking the blowby.

i07964251

Compression - Test

SMCS Code: 1215

Introduction

An engine that runs roughly can have a leak at the valves. An engine that runs roughly can also have valves that need an adjustment. Remove the head and inspect the valves and valve seats. This action is necessary to find those small defects that would not normally cause problems. Repairs of these problems are normally performed when you are reconditioning the engine.

Recommendations

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.

i02793330

Engine Valve Lash - Inspect/ Adjust

SMCS Code: 1102-025

⚠ WARNING

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

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

⚠ WARNING

This engine uses high voltage to control the fuel injectors.

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

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

Note: Valve lash is measured between the rocker arm and the bridge for the inlet valves. Valve lash is measured between the rocker arm and the valve stem for the exhaust valve. All of the clearance measurements and the adjustments must be made with the engine stopped. The valves must be fully closed.

Valve Lash Check

Table 10

	Inlet Valves	Exhaust Valves
Valve Lash Check (Stopped Engine)	0.38 ± 0.08 mm (0.0150 ± 0.0031 inch)	0.64 ± 0.08 mm (0.0252 ± 0.0031 inch)
TC Compression Stroke	**1-2-4**	**1-3-5**

(continued)

(Table 10, contd)

	Inlet Valves	Exhaust Valves
TC Exhaust Stroke(1)	3-5-6	2-4-6
Firing Order	1-5-3-6-2-4(2)	

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

An adjustment is not necessary if the measurement of the valve lash is in the acceptable range. Adjust the valve lash while the engine is stopped. The range is specified in Table 10 .

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

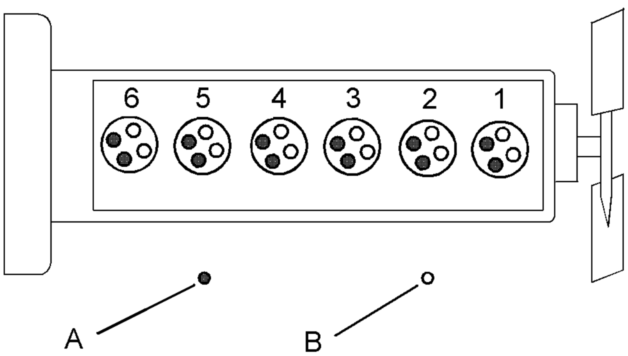

Illustration 50 g01193938

Cylinder and Valve location

(A) Exhaust valves
(B) Inlet valves

Valve Lash and Valve Bridge Adjustment

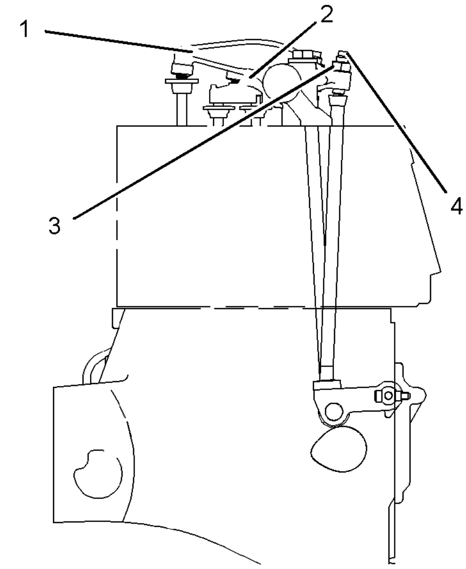

Illustration 51 g01229786

(1) Exhaust rocker arm
(2) Inlet valve bridge
(3) Rocker arm adjustment screw locknut for the exhaust rocker arm
(4) Rocker arm adjustment screw for the exhaust rocker arm

Table 11

Valve Lash	
Valves	Dimension of Gauge
Inlet	0.38 ± 0.08 mm (0.0150 ± 0.0031 inch)
Exhaust	0.64 ± 0.08 mm (0.0252 ± 0.0031 inch)

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

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".

Table 12

TC Compression Stroke	Inlet Valves	Exhaust Valves
Valve Lash	0.38 ± 0.08 mm (0.0150 ± 0.0031 inch)	0.64 ± 0.08 mm (0.0252 ± 0.0031 inch)
Cylinders	1-2-4	1-3-5

2. Adjust the valve lash according to Table 12 .

a. Lightly tap the rocker arm at the top of the adjustment screw with a soft mallet. This will ensure that the lifter roller seats against the camshaft's base circle.

b. Loosen the adjustment locknut.

c. Place the appropriate feeler gauge between rocker arm and the valve bridge. Then, turn the adjustment screw in a clockwise direction. Slide the feeler gauge between the rocker arm and the valve bridge. Continue turning the adjustment screw until a slight drag is felt on the feeler gauge. Remove the feeler gauge.

d. Tighten the adjustment locknut to a torque of 30 ± 7 N·m (22 ± 5 lb ft). Do not allow the adjustment screw to turn while you are tightening the adjustment locknut. Recheck the valve lash after tightening the adjustment locknut.

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

Table 13

TC Exhaust Stroke(1)	Inlet Valves	Exhaust Valves
Valve Lash	0.38 ± 0.08 mm (0.0150 ± 0.0031 inch)	0.64 ± 0.08 mm (0.0252 ± 0.0031 inch)
Cylinders	3-5-6	2-4-6

(1) Position for No. 1 cylinder

4. Adjust the valve lash according to Table 13 .

a. Lightly tap the rocker arm at the top of the adjustment screw with a soft mallet. This will ensure that the lifter roller seats against the camshaft's base circle.

b. Loosen the adjustment locknut.

c. Place the appropriate feeler gauge between rocker arm and the valve bridge. Then, turn the adjustment screw in a clockwise direction. Slide the feeler gauge between the rocker arm and the valve bridge. Continue turning the adjustment screw until a slight drag is felt on the feeler gauge. Remove the feeler gauge.

d. Tighten the adjustment locknut to a torque of 30 ± 7 N·m (22 ± 5 lb ft). Do not allow the adjustment screw to turn while you are tightening the adjustment locknut. Recheck the valve lash after tightening the adjustment locknut.

5. Remove the timing bolt from the flywheel after all adjustments to the valve lash have been made. Reinstall the timing cover.

i02693687

Variable Valve Actuators - Inspect/Adjust

SMCS Code: 1105-025; 1105-040

⚠ WARNING

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

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

⚠ WARNING

This engine uses high voltage to control the fuel injectors.

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

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

Note: Lash for the Variable Valve Actuator (VVA) is measured between the rocker arm and the actuator piston. All measurements and adjustments must be made to a cold engine with the valves closed.

Checking the Variable Valve Actuator Lash

An adjustment is not necessary if the measured lash is in the acceptable range in Table 14 . All engines may not have actuator pistons for both the inlet rocker arm and the exhaust rocker arm. Check and adjust your lash setting accordingly.

Table 14

	Inlet Rocker Arm
Variable Valve Actuator Lash	0.610 ± 0.075 mm (0.0240 ± 0.0030 inch)
TC Compression Stroke	**1-2-4**
TC Exhaust Stroke(1)	3-5-6
Firing Order	1-5-3-6-2-4(2)

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

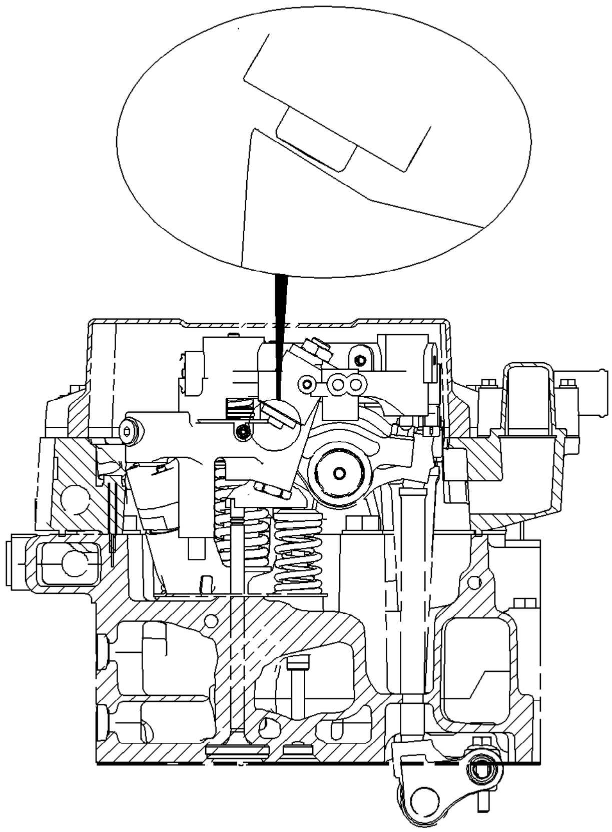

Illustration 52 g00948824

Intake rocker arm and actuator piston

If the measurement is not within this range, an adjustment is necessary. Refer to “Adjusting the Variable Valve Actuator Lash” for the proper procedure.

Adjusting the Variable Valve Actuator Lash

Note: The valve lash must be set prior to setting the lash for the variable valve actuator.

Use the following procedure to adjust the lash for the variable valve actuator:

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”. The valve lash must be set before the lash of the variable valve actuator can be adjusted. Also, the valve cover base must be torqued before the lash of the variable valve actuator can be adjusted.

Table 15

TC Compression Stroke	Inlet Rocker Arm
Variable Valve Actuator Lash	0.610 ± 0.075 mm (0.0240 ± 0.0030 inch)
Cylinders	1-2-4

2. Adjust lash for the variable valve actuator according to Table 15 .

a. Loosen the jam nut.

b. Place the appropriate feeler gauge between the actuator piston and the rocker arm. Then, turn the adjustment screw in a clockwise direction. Slide the feeler gauge between the actuator piston and the rocker arm. Continue turning the adjustment screw until the piston of the variable valve Actuator prevents the feeler gauge from being removed. There should be a tight hold on the feeler gauge. Turn the adjustment screw counterclockwise in order to loosen the feeler gauge. Refer to Table 15 for the correct variable valve actuator lash. Remove the feeler gauge.

c. Tighten the jam nut to a torque of 50 ± 10 N·m (37 ± 7 lb ft). Do not allow the adjustment screw to turn while you are tightening the jam nut. Recheck the lash setting after tightening the jam nut.

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

Table 16

TC Exhaust Stroke	Inlet Rocker Arm
Variable Valve Actuator Lash	0.610 ± 0.075 mm (0.0240 ± 0.0030 inch)
Cylinders	3-5-6

4. Adjust lash for the variable valve actuator according to Table 16 .

a. Loosen the jam nut.

b. Place the appropriate feeler gauge between the actuator piston and the rocker arm. Then, turn the adjustment screw in a clockwise direction. Slide the feeler gauge between the actuator piston and the rocker arm. Continue turning the adjustment screw until the piston of variable valve actuator prevents the feeler gauge from being removed. There should be a tight hold on the feeler gauge. Turn the adjustment screw counterclockwise in order to loosen the feeler gauge. Refer to Table 16 for the correct variable valve actuator lash setting. Remove the feeler gauge.

c. Tighten the jam nut to a torque of 50 ± 10 N·m (37 ± 7 lb ft). Do not allow the adjustment screw to turn while you are tightening the jam nut. Recheck the lash setting after tightening the jam nut.

5. Remove the timing bolt from the flywheel after all adjustments have been made. Reinstall the timing cover.

Note: The valve lash must be adjusted before adjusting the compression brake, if equipped.

Refer to Testing and Adjusting, “Electronic Unit Injector - Adjust”.

Lubrication System

i02185655

Engine Oil Pressure - Test

SMCS Code: 1304-081

The engine oil pressure may be checked electronically by using the electronic service tool. The engine oil pressure can be measured with the electronic service tool. Refer to Troubleshooting for information on the use of the electronic technician.

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, "Dealer Service Tool Catalog" for tools and supplies suitable to collect and contain fluids on Cat products.

Dispose of all fluids according to local regulations and mandates.

Table 17

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

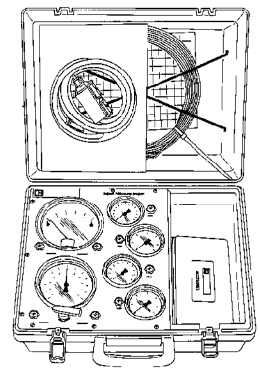

Illustration 53 g00296486

1U-5470 Engine Pressure Group

Tool (A) 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. Refer to Operating Manual, NEHS0818, "Using the 198-4240 Digital Pressure Indicator" for more information.

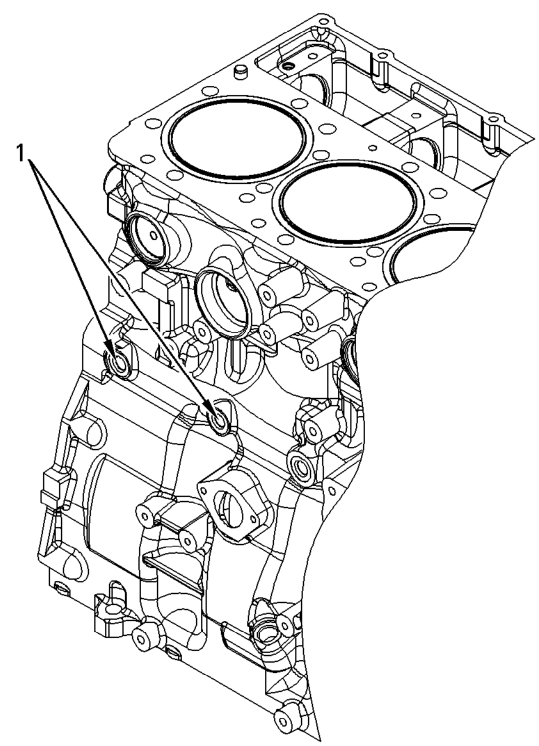

Illustration 54 g00977330

Oil gallery plug

(1) Plug

1. Install Tool (A) 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 15W40 oil. Refer to Operation and Maintenance Manual, “Refill Capacities and Recommendations” for the recommendations of engine oil.

3. Record the value of the engine oil pressure when the engine is at operating temperature 100 °C (212 °F).

The minimum engine oil pressure at 1800 rpm should be approximately 275 to 414 kPa (40 to 59 psi). Minimum engine oil pressure at low idle rpm (600 to 800 rpm) should be approximately 68 kPa (10 psi).

4. Compare the recorded engine oil pressure with the oil pressure indicators on the instrument panel and the engine oil pressure that is displayed on the electronic service tool.

5. 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.

6. If low engine oil pressure is determined, refer to “Reasons for Low Engine Oil Pressure”.

7. If high engine oil pressure is determined, 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, “Dealer Service Tool Catalog” for tools and supplies suitable to collect and contain fluids on Cat products.

Dispose of all fluids according to local regulations and mandates.

- Engine oil level is low. Refer to Step 1.
- Engine oil is contaminated. Refer to Step 2.
- The engine oil bypass valves are open. Refer to Step 3.
- The engine lubrication system is open. Refer to Step 4.
- The oil pickup tube has a leak or a restricted inlet screen. Refer to Step 5.
- The engine oil pump is faulty. Refer to Step 6.
- Engine Bearings have excessive clearance. Refer to Step 7.

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

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

NOTICE

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

3. If the engine oil bypass valves are held in the open position, a reduction in the oil pressure can be the result. This may be due to debris in the engine oil. If the engine oil bypass valves are stuck in the open position, remove each engine oil bypass valve and clean each bypass valve in order to correct this problem. You must also clean each bypass valve bore. Install new engine oil filters. New engine oil filters will prevent more debris from causing this problem. 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. Determine the reason for an open lubrication system of the engine and make the necessary repairs.

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 pickup 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.

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

Dispose of all fluids according to local regulations and mandates.

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

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i07964341

Excessive Bearing Wear - Inspect

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

Introduction

Use the following procedure to inspect for excessive bearing wear.

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

Inspection Procedure

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 restriction will result in early wear.

i03993149

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 oil level gauge 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 increased engine temperature.

i07964353

Increased Engine Oil Temperature - Inspect

SMCS Code: 1348-040

Introduction

Use the procedure that follows to inspect an increase of engine oil temperature.

Inspection Procedure

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

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

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

Cooling System

i02139836

Cooling System - Check (Overheating)

SMCS Code: 1350-535

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

WARNING

Personal injury can result from escaping fluid under pressure.

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

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

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

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

4. Check the fan clutch, 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 according to the OEM specifications. An undersized radiator does not have enough area for the effective release of heat. This may cause the engine to run at a temperature that is higher than normal. The normal temperature is dependent on the ambient temperature.

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

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

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

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

10. Check for loose drive belts. A 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, “Belts - Inspect/Adjust/Replace”.

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. 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.

19. 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.

20. 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.

i02163324

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, “Refill Capacities and Recommendations”.

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

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

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

3. Look for leaks in the system.

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

4. 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.

i04529395

Cooling System - Test

SMCS Code: 1350-081; 1350-040

This engine has a pressurized cooling system. A pressurized 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 pressurized cooling system helps to prevent pockets of air from forming.

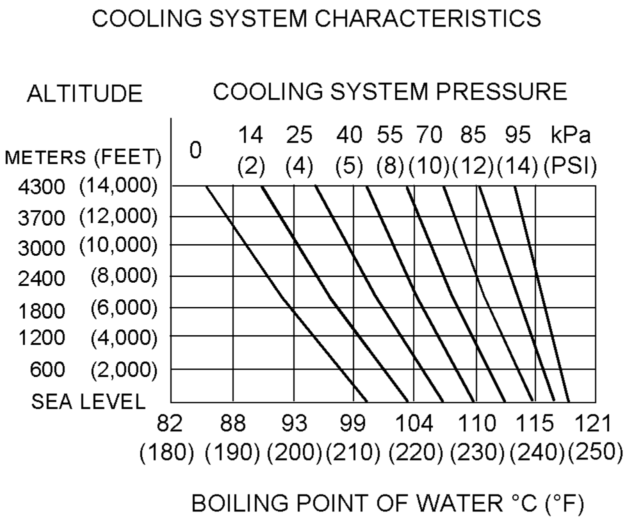

Illustration 55 g01106438

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 affects the cooling system temperature. For an example, refer to Illustration 55 . The chart will show the effect of pressure on the boiling point (steam) of water. The chart 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 at 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 18

Required Tools		
Part Number	Part Name	Quantity
348-5430	Digital Thermometer, part of Multi-Tool Gp	1
348-5430	Multi-Tool Gp	1
9S-8140	Pressurizing Pump	1
308-7265	Multitach Tool Gp	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.

The 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 Operating Manual, NEHS1087 for the testing procedures.

Illustration 56 g02709261

348-5430 Multi-Tool Gp

Table 19

Required Tools		
Part Number	Part Name	Quantity
348-5430	Multi-Tool Gp	1
285-0900	Blowby Tool Group	1
NETG5049	Software License	1

The 348-5430 Multi-Tool Gp is used to check the air flow through the radiator core.

The 308-7265 Multitach Tool Gp, part of the 348-5430 Multi-Tool Gp, is used to check the fan speed for an engine. Refer to the tool Operating Manual for the testing procedure.

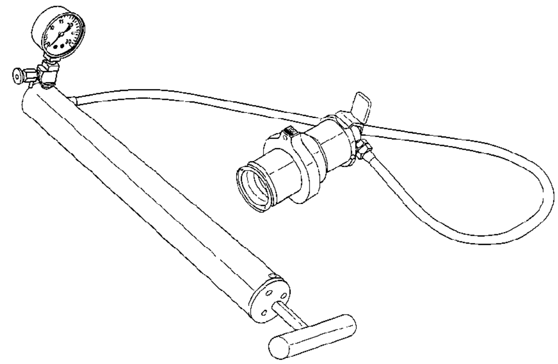

Illustration 57 g00286369

9S-8140 Pressurizing Pump

The 9S-8140 Pressurizing Pump is used to pressure test the radiator 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 and/or coolants that contain ethylene or propylene glycol.

Test and Inspect the Filler Cap

Table 20

Required Tool		
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.

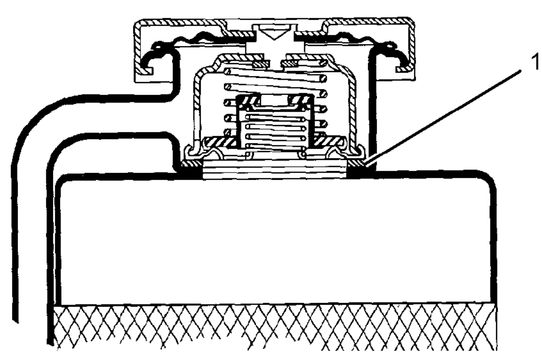

Illustration 58 g01096114

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 21

Required Tool		
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 5 minutes.

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

- The pressure reading on the cooling system decreases in a 5 minute period.
- You do not observe any outside leakage.

Repair the cooling system, as required.

Test for the Water Temperature Gauge

Table 22

Required Tool		
Part Number	**Part Name**	**Quantity**
348-5430	Digital Thermometer, Part of Multi-Tool Gp	1

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

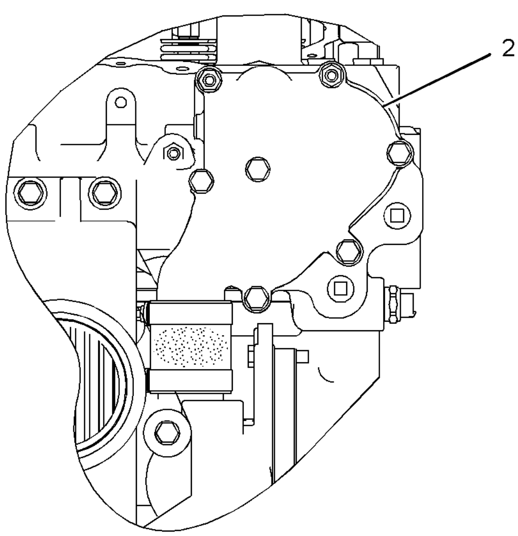

Illustration 59 g01425262

Typical example

(2) Water manifold assembly

Remove a plug from water manifold assembly (2). Install the348 - 5430 Digital Thermometer, Part of Multi-Tool Gp into the open port:

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.

i07814425

Water Temperature Regulator - Test

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

WARNING

Personal injury can result from escaping fluid under pressure.

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

References

Reference: Refer to Specifications, “Water Temperature Regulator” for information on the water temperature regulator.

Introduction

Use this procedure to test the water temperature regulator.

Test Preparation

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.
3. Stir the water in the pan. This will distribute the temperature throughout the pan.

Test Procedure

1. 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.
2. Keep the water at the correct temperature for 10 minutes.
3. After 10 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.

i03146393

Water Pump - Test

SMCS Code: 1361-081

Table 23

Required Tools		
Part Number	**Part Name**	**Quantity**
6V-7775	Air Pressure Gauge	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.

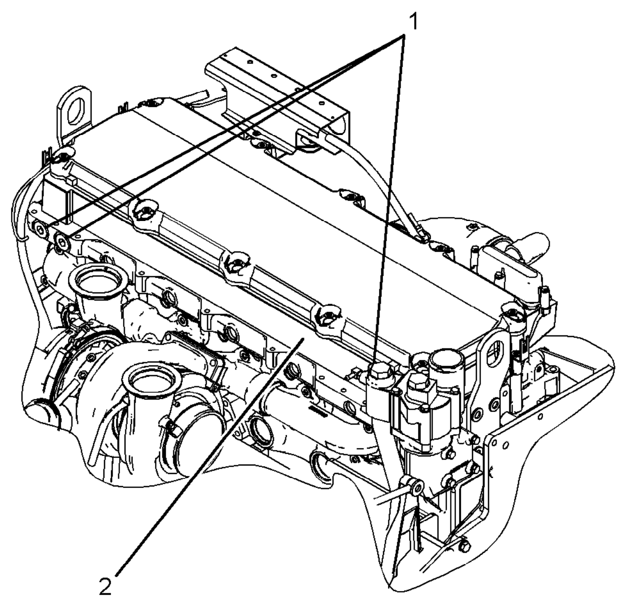

Illustration 60 g01097015

(1) Port
(2) Water manifold

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

1. Remove the plug from port (1).
2. Install the 6V-7775 Air Pressure Gauge in port (1).
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 100 to 125 kPa (15 to 18 psi).

Basic Engine

i02223629

Piston Ring Groove - Inspect

SMCS Code: 1214-040

The pistons of the engine have a keystone design ring groove. The piston rings are a keystone ring. The 1U-6431 Piston Ring Groove Gauge Gp is available to check the top ring groove in the piston. Use the 8T-3149 Plug Gauge that is part of this Gauge Group to check the top ring groove on the piston. Refer to the instruction card for correct use of the 1U-6431 Piston Ring Groove Gauge Gp.

i03624456

Connecting Rod Bearings - Inspect

SMCS Code: 1219-040

The connecting rod bearings fit tightly in the bore in the rod. If there is excess movement between the connecting rod and the crankshaft, check the bore size. This can be an indication of wear because of a loose fit. Refer to the Reuse And Salvage Guidelines , SEBF8009, “Visual Inspection of Main Bearings and Connecting Rod Bearings”.

i03624685

Main Bearings - Inspect

SMCS Code: 1203-040

Main bearings for crankshafts that have been ground are available. Main bearings are also available with a larger outside diameter than the original size bearings. These bearings with a larger outside diameter are used for the cylinder blocks with the main bearing bore that is made larger than the bore's original size. Refer to the appropriate publication Specifications, “Main Bearing Journal” for either case.

Refer to Special Instruction, SMHS7606, “Use of 1P-4000 Line Boring Tool Group” for the instructions that are needed to use the 1P-4000 Line Boring Tool Group. The 1P-4000 Line Boring Tool Group 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. Refer to Special Instruction, GMG00981, “ 1P-3537 Dial Bore Gauge Group” for the instructions that are needed to use the 1P-3537 Dial Bore Gauge Group.

i07999525

Cylinder Block - Inspect

SMCS Code: 1201-040

Specifications

Table 24

C13B Main Bore Alignment Specification	
Item	**Specification**
Main bearing bore alignment	Less than 0.08 mm (0.003 inch)

Introduction

Use the following procedure to measure the alignment of the main bearing bore holes in the cylinder block.

References

Reference: Specifications, “Cylinder Block”

Required Tools

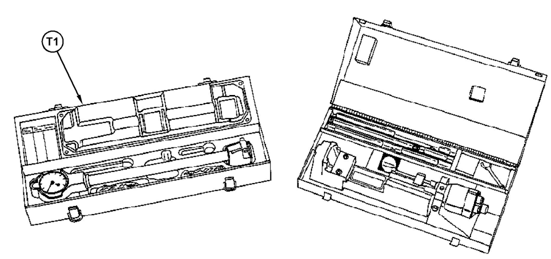

Illustration 61 g06502020

(T1) 1P-3537 Dial Bore Gauge Group

Table 25

Required Tools			
Item	**Quantity**	**Part Number**	**Part Name**
T1	1	1P-3537	Dial Bore Gauge Group

Procedure

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.

i07999544

Cylinder Liner Projection - Inspect

SMCS Code: 1216-040

Specifications

Table 26

C13B Liner Specifications	
Item	**Specification**
Liner Projection	0.06 to 0.18 mm (0.0024 to 0.0071 inch)
Maximum Variation in Each Liner	0.050 mm (0.0020 inch)
Maximum Average Variation Between Adjacent Liners	0.08 mm (0.0031 inch)
Maximum Variation Between All 6 Liners	0.100 mm (0.0040 inch)

Introduction

Use the following procedure to measure the liner projection of an engine.

Required Tools

Table 27

Required Tools			
Item	**Qty**	**Part Number**	**Part Name**
T1	1	8T-0455	Liner Projection Tool Group
T2	6(1)	8T-4193	Bolt
T3	6 (1)	2S-5658	Hard Washer
T4	6 (1)	8F-1484	Washer
T5	6 (1)	7K-1977	Washer

(1) This quantity is the amount needed for each cylinder.

Procedure

1. Clean the cylinder liner flange and the cylinder block surface. Remove any nicks on the top of the cylinder block.

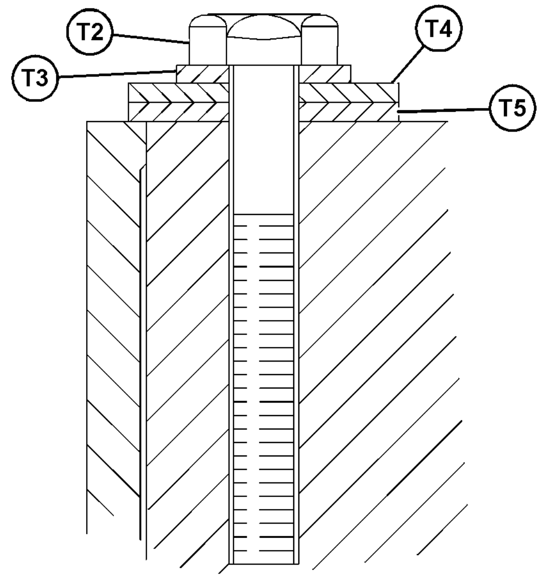

Illustration 62 g06502044

Location of the components

(T2) Bolt
(T3) Washer
(T4) Washer
(T5) Washer

2. The components should be assembled in the order that is shown in Illustration 62 . 7K-1977 Washer (T5) is made of a cotton fabric that is impregnated with resin. The washer will not damage the sealing surface of the cylinder block.

Note: Inspect the washer before measuring the liner projection. Replace the washer if the washer is worn or damaged.

3. Evenly tighten bolts (1) to a torque of 14 N·m (10 lb ft).

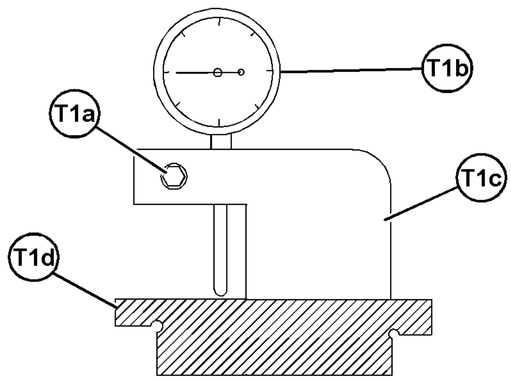

Illustration 63 g06502048

(T1) 8T-0455 Liner Projection Tool Group
(T1a) Bolt
(T1b) Dial indicator
(T1c) Gauge body
(T1d) Gauge block

4. Loosen bolt (T1a) until dial indicator (T1b) can be moved. Place gauge body (T1c) and dial indicator (T1b) on the long side of gauge.

5. Slide dial indicator (T1b) into the correct position. When the point of the dial indicator contacts gauge block (T1d), the dial indicator is in the correct position. Slide the dial indicator until the needle of the gauge makes a quarter of a revolution clockwise. The needle should be in a vertical position. Tighten bolt (T1a) and zero the dial indicator.

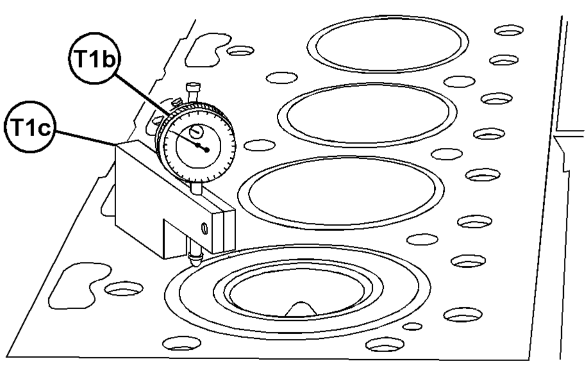

Illustration 64 g06502057

Measure the liner projection.

(T1b) Dial indicator
(T1c) Gauge body

6. Place gauge body (T1c) on the plate for the cylinder block. The indicator point should be on the liner flange. Read the dial indicator to find the amount of liner projection. Check the projection at four locations (every 90 degrees) around each cylinder liner.

7. If a liner does not meet the recommended cylinder liner projection specification, check the following parts:

- The depth of the cylinder block bore should be 100.00 ± 0.03 mm (3.937 ± 0.001 inch).
- The liner flange should be 100.12 ± 0.03 mm (3.942 ± 0.001 inch).

If the dimensions for the liner flange do not match the specifications, replace the liner. Then repeat the liner projection measurements. If the dimensions for the depth of the cylinder block bore do not match the specifications, replace the cylinder block. Then repeat the liner projection measurements.

i07999586

Flywheel - Inspect

SMCS Code: 1156-040

Specification

Table 28

C13B Flywheel Specification	
Item	**Specification**
Flywheel Face Runout	0.13 mm (0.005 inch) or less
Flywheel Bore Runout	0.15 mm (0.006 inch) or less

Introduction

Use the following procedure to measure the runout for the flywheel.

References

Reference: Testing and Adjusting, “Finding Top Center Position for No. 1 Piston”

Required Tooling

Table 29

Required Tools			
Item	**Qty**	**Part Number**	**Description**
T1	1	8T-5096	Dial Indicator Gp
T1a	1	7H-1645	Holding Rod
T1b	1	7H-1945	Holding Rod
T1c	1	7H-1942	Dial Indicator
T1d	1	7H-1940	Universal Attachment

Face Runout (Axial Eccentricity) of the Flywheel Procedure

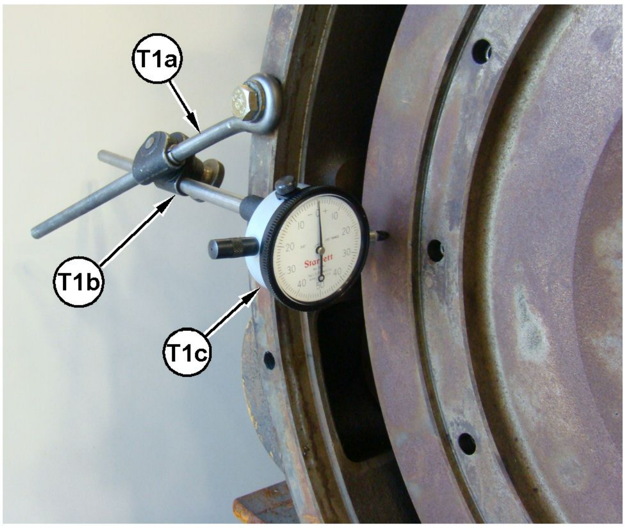

Illustration 65 g06502105

Checking face runout of the flywheel

(T1a) 7H-1645 Holding Rod
(T1b) 7H-1945 Holding Rod
(T1c) 7H-1942 Dial Indicator

1. Refer to Illustration 65 and install the dial indicator. Always put a force on the crankshaft in the same direction before the dial indicator is read. The applied force 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. Refer to Testing and Adjusting, “Finding Top Center Position for No. 1 Piston”.
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 0.13 mm (0.005 inch), which is the maximum permissible face runout (axial eccentricity) of the flywheel.

Bore Runout (Radial Eccentricity) of the Flywheel Procedure

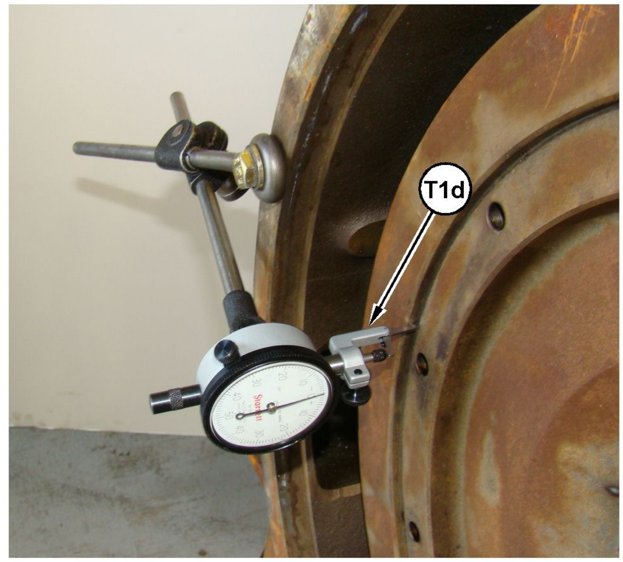

Illustration 66 g06502145

Checking bore runout of flywheel

(T1d) 7H-1940 Universal Attachment

1. Install dial indicator (T1c). Make an adjustment of universal attachment (T1d) 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 0.15 mm (0.006 inch), which is the maximum permissible bore runout (radial eccentricity) of the flywheel.

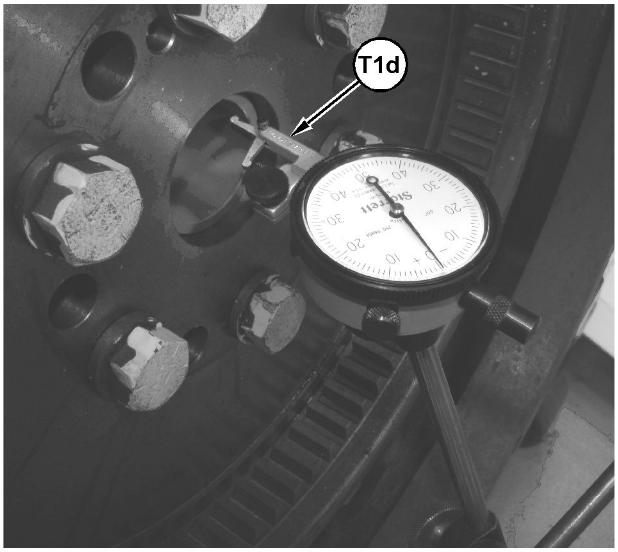

Illustration 67 g06502146

Flywheel clutch pilot bearing bore

(T1d) 7H-1940 Universal Attachment

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 0.13 mm (0.005 inch).

i08024782

Flywheel Housing - Inspect

SMCS Code: 1157-040

WARNING

Do not operate or work on this engine unless you have read and understand the instructions and warnings in the Operation and Maintenance Manual. Failure to follow the instructions or heed the warnings could result in injury or death. Contact any Caterpillar dealer for replacement manuals. Proper care is your responsibility.

WARNING

Accidental engine starting can cause injury or death to personnel working on the equipment.

To avoid accidental engine starting, disconnect the battery cable from the negative (−) battery terminal. Completely tape all metal surfaces of the disconnected battery cable end in order to prevent contact with other metal surfaces which could activate the engine electrical system.

Place a Do Not Operate tag at the Start/Stop switch location to inform personnel that the equipment is being worked on.

Specifications

Table 30

Parameter	Value
Face Runout (Axial Eccentricity) of the Flywheel Housing	0.38 mm (0.015 inch)

Introduction

Use this procedure to check the axial and radial runout of the flywheel housing.

Required Tools

Table 31

Required Tools				
Item		Qty	Part Number	Part Name
T1		1	8T-5096	Tool Gp
	T1a	1	7H-1942	Dial Indicator
	T1b	1	7H-1945	Holding Rod
	T1c	1	7H-1948	Swivel Clamp
	T1d	1	8S-2327	Post
	T1e	1	8S-2329	Base

Face Runout (Axial Eccentricity) of the Flywheel Housing - Check

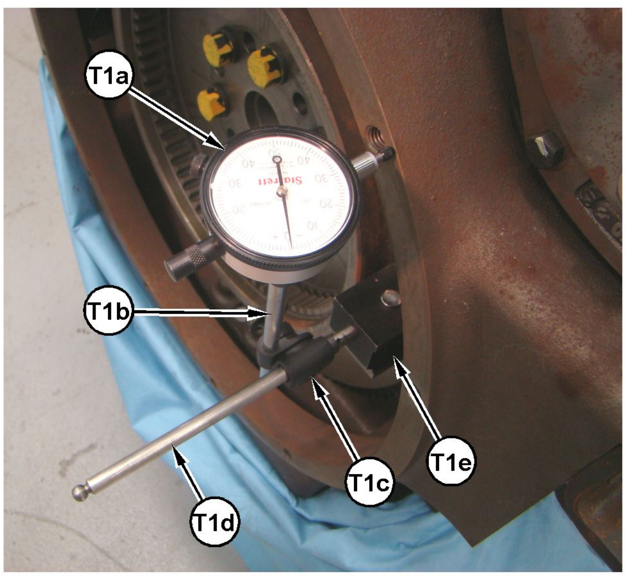

Illustration 68 g06442987

8T-5096 Dial Indicator Gp

(T1a) 7H-1942 Dial Indicator
(T1b) 7H-1945 Holding Rod
(T1c) 7H-1948 Swivel Clamp
(T1d) 8S-2327 Post
(T1e) 8S-2329 Base

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

1. Fasten Tooling (T1e) to the flywheel so the anvil of Tooling (T1a) 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.

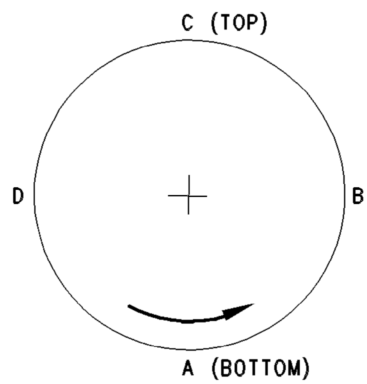

Illustration 69 g00285932

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 - Check

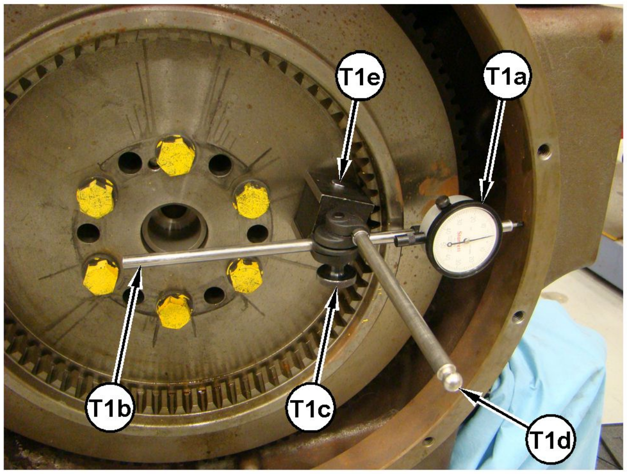

Illustration 70 g06442992

8T - 5096 Dial Indicator Gp

(T1a) 7H-1942 Dial Indicator
(T1b) 7H-1945 Holding Rod
(T1c) 7H-1948 Swivel Clamp
(T1d) 8S-2327 Post
(T1e) 8S-2329 Base

1. Fasten Tooling (T1e) to the flywheel so the anvil of Tooling (T1a) will contact the bore of the flywheel housing.

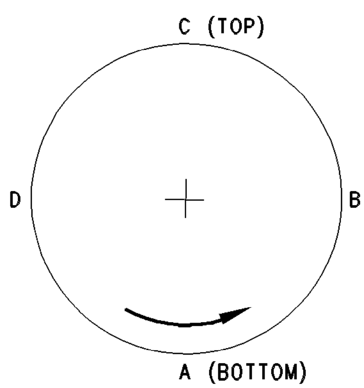

Illustration 71 g00285932

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 72 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 72 . 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 to put the dial indicator at position (A). Adjust the dial indicator to 0.0 mm (0.00 inch).
5. Turn the flywheel counterclockwise to put the dial indicator at position (B). Write the measurements in the chart.
6. Turn the flywheel counterclockwise to put the dial indicator at position (C). Write the measurement in the chart.
7. Turn the flywheel counterclockwise to put the dial indicator at position (D). Write the measurement in the chart.
8. 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.

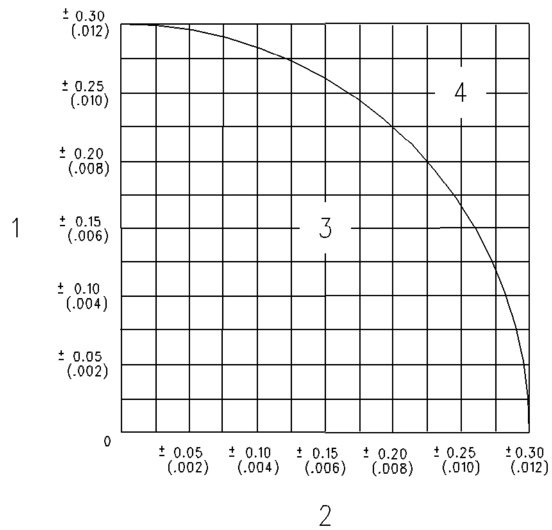

Illustration 73 g00286046

Graph for total eccentricity

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

9. Find the intersection of the eccentricity lines (vertical and horizontal) in Illustration 73 .

10. 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.

i02111962

Vibration Damper - Check

SMCS Code: 1205-535

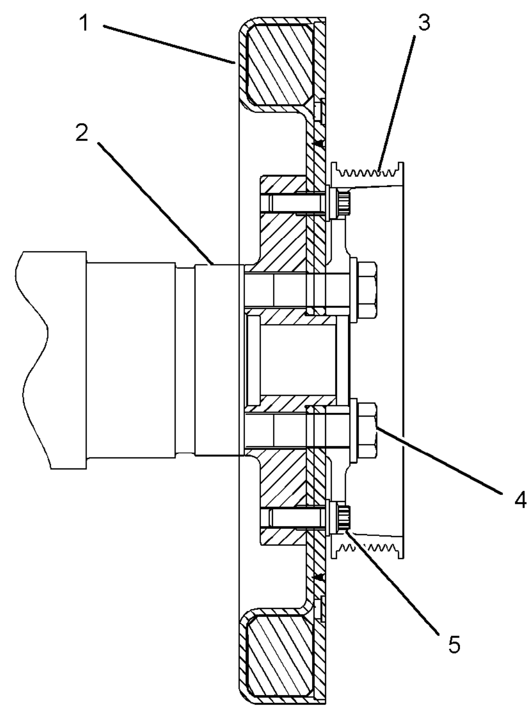

Illustration 74 g01100265

Viscous vibration damper and pulley

(1) Damper assembly
(2) Crankshaft
(3) Pulley
(4) Bolt
(5) Bolt

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.

Compression Brake

i03660681

Compression Brake Lash - Adjust

SMCS Code: 1129-025

⚠ WARNING

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

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

⚠ WARNING

This engine uses high voltage to control the fuel injectors.

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

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

Note: The valve lash must be adjusted before adjusting the Cat compression brake lash.

Table 32

Setting	Tightening torque for the jam nut
0.7112 ± 0.050 mm (0.028 ± 0.0020 inch)	15 ± 3 N·m (11 ± 2 lb ft)

Refer to Testing and Adjusting, "Engine Valve Lash - Inspect/Adjust".

Note: The Cat compression brake lash is measured between the Cat compression brake pin and the exhaust rocker pad. Make all adjustments while the engine is stopped and the exhaust valves are closed.

Use the following procedure to adjust the slave piston lash on cylinders 1, 3, and 5:

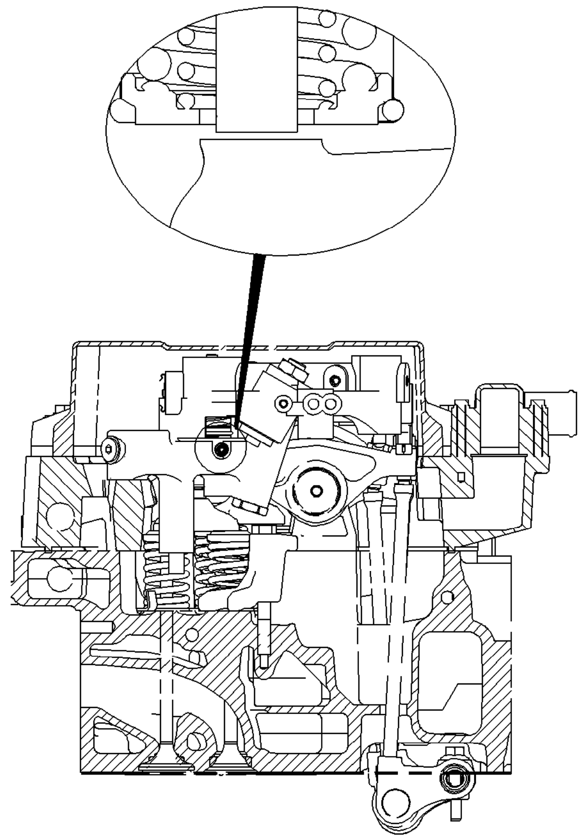

Illustration 75 g00948608

Exhaust rocker arm and actuator piston

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".

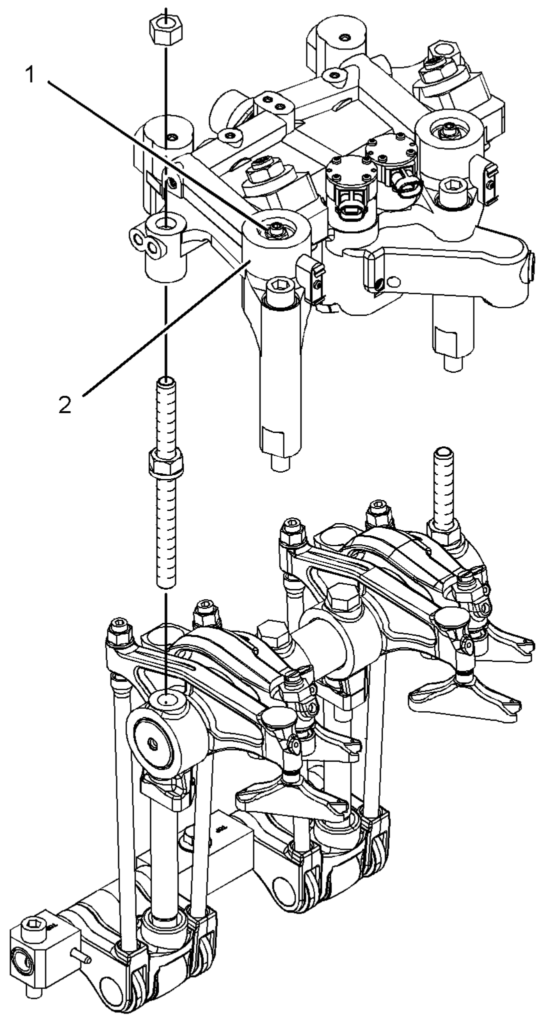

Illustration 76 g01268108

Assembly for the variable valve actuator

(1) Jam nut
(2) Housing for the slave piston

2. Loosen the jam nut (1).

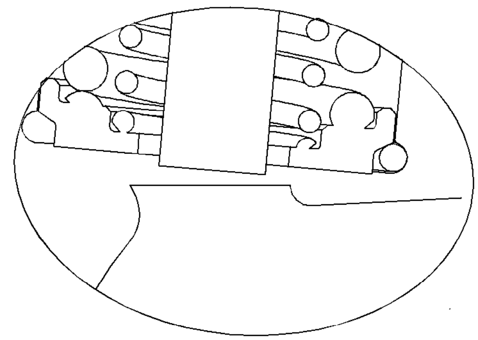

Illustration 77 g01018798

An example of incorrect centering of the Cat compression brake pin

3. Make sure that the Cat compression brake pin is centered in the housing. Place the appropriate feeler gauge between the Cat compression brake pin and the exhaust rocker pad. Then, turn the adjustment screw in a clockwise direction. Slide the feeler gauge between the Cat compression brake pin and the exhaust rocker pad. Continue turning the adjustment screw until a slight drag is felt on the feeler gauge. Remove the feeler gauge.

4. Tighten jam nut (1) to a torque of 15 ± 3 N·m (11 ± 2 lb ft). Recheck the slave piston lash after tightening the locknut.

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

To adjust the slave piston lash on cylinders 2, 4, and 6, perform Steps 2 through 4.

6. Remove the timing bolt from the flywheel after all adjustments have been performed. Reinstall the timing cover.

Refer to Testing and Adjusting, “Electronic Unit Injector - Adjust”.

Electrical System

i07999747

Battery - Test

SMCS Code: 1401-081

⚠ WARNING

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

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.

Specifications

Table 33

C13B Battery Specifications	
Item	**Battery Voltage**
Measured battery voltage	12.45V or higher

Introduction

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

References

Reference: Operating Manual, NEHS0764, “Using the 177-2330 Battery Analyzer”

Reference: Operating Manual, SEHS9249, “Use of 4C-4911 Battery Load Tester for 6 V, 8 V, and 12 V Lead Acid Batteries”

Required Tools

Table 34

Required Tools			
Item	**Qty**	**Part Number**	**Part Name**
T1	1	177-2330	Battery Analyzer (DIGITAL)
T2	1	4C-4911	Battery Load Tester

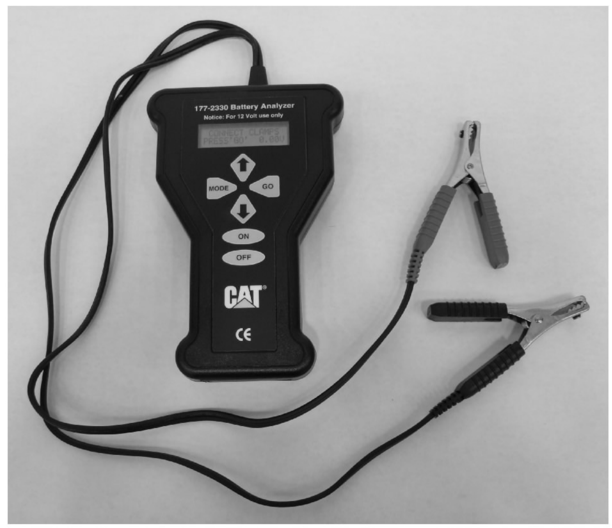

Illustration 78 g02231076

177-2330 Battery Analyzer

Refer to Operating Manual, NEHS0764, “Using the 177-2330 Battery Analyzer” for detailed instruction on the use of the 177-2330 Battery Analyzer

Illustration 79 g02231156

4C-4911 Battery Load Tester

Refer to Operating Manual, SEHS9249, "Use of 4C-4911 Battery Load Tester for 6 V, 8 V, and 12 V Lead Acid Batteries" for detailed instruction on the use of the 4C-4911 Battery Load Tester.

Use the 4C-4911 Battery Load Tester or the 177-2330 Battery Analyzer to test a battery that does not maintain a charge when the battery is active. The 4C-4911 Battery Load Tester and the 177-2330 Battery Analyzer are portable units. The 4C-4911 Battery Load Tester or the 177-2330 Battery Analyzer can be used under field conditions and under high temperatures.

Procedure

1. Check the voltage of the battery.

a. If the voltage is above 12.45 V, then the battery is good.

b. If the voltage of the battery is below 12 V, then the battery needs replaced.

c. If the voltage of the battery is between 12 V to 12.3 V, then run the machine at mid-throttle for 60 minutes and recheck the battery voltage. If the voltage is not above 12.45 V, then replace the battery.

d. If the voltage of the battery is between 12.3 V to 12.45 V, then run the machine at mid-throttle for 30 minutes and recheck the battery voltage. If the voltage is not above 12.45 V, then replace the battery.

i07999760

Charging System - Test

SMCS Code: 1406-081

Introduction

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 1 oz of water per a cell per a week or per every 100 service hours.

Testing of the charging system components on the engine is preferred, including the wiring and other components that are a permanent part of the system. Off-engine testing or bench testing of the operation of the charging system components is acceptable as a last resort. This testing will give an indication of needed repair. After repairs are made, test the charging system to verify that the charging system meets specifications.

References

Reference: Operation Manual, NEHS0678

Reference: Specifications for alternator output

Reference: Special Instruction, REHS0354, "Charging System Troubleshooting"

Required Tools

Table 35

Required Tools			
Item	**Quanti-ty**	**Part Number**	**Part Name**
T1	1	225-8266	Ammeter Tool Gp
T2	1	237-5130 or 146-4080	Digital Multimeter Gp or Digital Multimeter Gp
T3	1	8T-9293	Torque Wrench
T4	1	261-0444	Adapter
T5	1	2P-8267	Hex Bit Socket
T6	1	8H-8517	Combination Wrench
T7	1	8T-5314	Adapter

225-8266 Ammeter Tool Gp

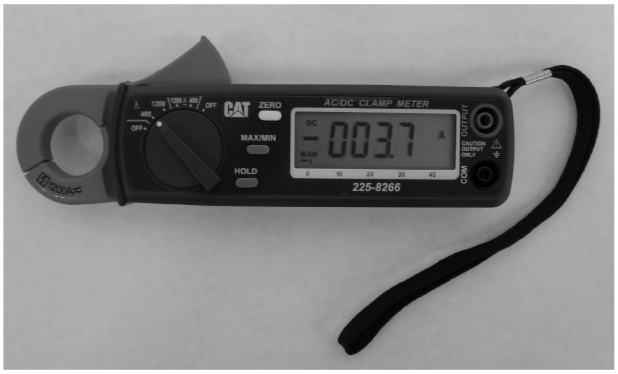

Illustration 80 g02231196

225-8266 Ammeter Tool Gp

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

The ammeter contains a digital display that is used to monitor current directly within a range between 1 A and 1200 A. To view current readings of less than 1 A use the multimeter display. In order to read the multimeter display, connect a 6V-6014 Cable between the digital multimeter and the ammeter. The ammeter then sends the current measurement to the multimeter display.

A lever opens the ammeter jaws over a conductor. The conductor diameter cannot 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 is turned to the OFF position, the reading appears in the digital display for 5 seconds. This meter accurately measures currents in areas with limited access. For example, these areas include areas that are beyond the sight of the operator. For DC operation, the ammeter contains a zero control. Batteries inside the handle supply the power.

Note: Refer to the user manual for more information about using the 225-8266 Ammeter Tool Gp.

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

Illustration 81 g02231214

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 portable, hand-held service tool with a digital display. 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.

Note: Refer to the manual that is provided by the supplier for more information on the use of the 237-5130 Digital Multimeter Gp. Refer to Operation Manual, NEHS0678 for complete information for the use of the 146-4080 Digital Multimeter Gp.

Charging System Procedures

Charging System

To check for correct output of the alternator, see the Specifications module. Refer to Special Instruction, REHS0354, “Charging System Troubleshooting”. If the part number for the alternator to be tested is not listed in the Special Instruction, refer to the appropriate Specifications manual for the information needed to test the alternator.

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

1. The battery must be at least 75 percent (1.225 Sp Gr) of the full charge. The battery must be held tightly in place. The battery holder must not put too much stress on the battery.
2. Cables between the battery, the starter, and the engine ground must be the correct size. Wires and cables must be free of corrosion. Wires and cables must have cable support clamps to prevent stress on battery connections (terminals).
3. Leads, junctions, switches, and panel instruments that have direct relation to the charging circuit must give correct circuit control.
4. Inspect the drive components for the charging unit to be sure that the components are free of grease and oil. Be sure that the drive components can operate the charging unit.
5. Check the tension of the belt for the alternator pulley. Refer to the Belt Tension Chart for the correct tension of the belt.

Alternator

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

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

Tightening The Alternator Pulley Nut

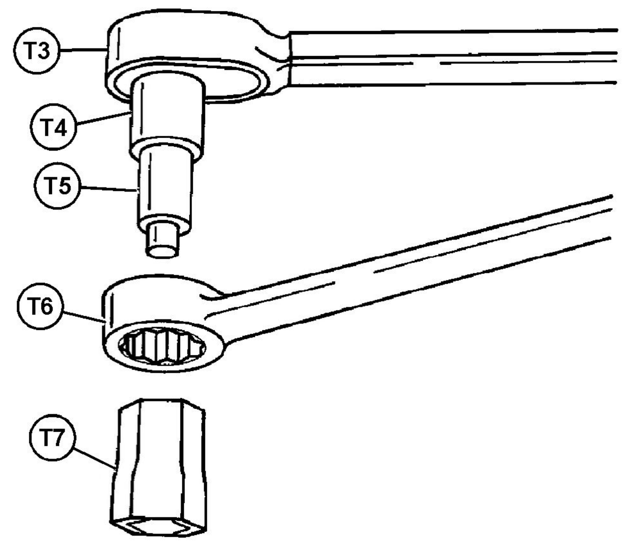

Illustration 82 g06502288

Tools for tightening the alternator pulley nut

(T3) 8T-9293 Torque Wrench
(T4) 261-0444 Adapter
(T5) 2P-8267 Hex Bit Socket
(T6) 8H-8517 Combination Wrench (1-1/8 inch)
(T7) 8T-5314 Adapter Socket

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

Regulator

The voltage regulator is a solid-state electronic switch. The regulator senses the voltage of the system and controls the field current to the alternator. The output voltage from the alternator will supply the needs of the battery. The output voltage will also supply the other components in the electrical system.

i07999772

Electric Starting System - Test

SMCS Code: 1450-081

Introduction

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.

References

Reference: Service Manual, SENR3581, "37-MT, 41-MT & 42-MT Series Starting Motors"

Procedure

The starting system consists of the following four components:

- Keyswitch
- 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.

i03635326

Pinion Clearance - Adjust

SMCS Code: 1454-025

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

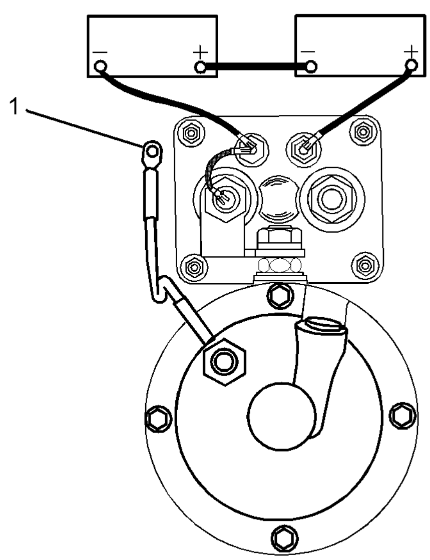

Illustration 83 g01364202

Connections for pinion clearance check

(1) Starting motor negative wire

1. Disconnect the starting motor negative wire (1) from the "G" ground terminal (2) of the solenoid.

2. Connect the batteries to the solenoid per Illustration 83 . Illustration 83 shows a 24 volt system with two 12 volt batteries that are connected in series to a starting motor. Connect four 8 volt batteries in series for a 32 volt system. Connect eight 8 volt batteries in series for a 64 volt system. Connect the positive side of the battery cable to the "S" terminal of the starting motor solenoid. Connect the negative side of the battery cable to the "G" terminal of the starting motor .

3. Temporarily, touch a wire from the "G" terminal to the "Mtr" terminal. The pinion will shift to the crank position and the pinion will stay there until the battery is disconnected.

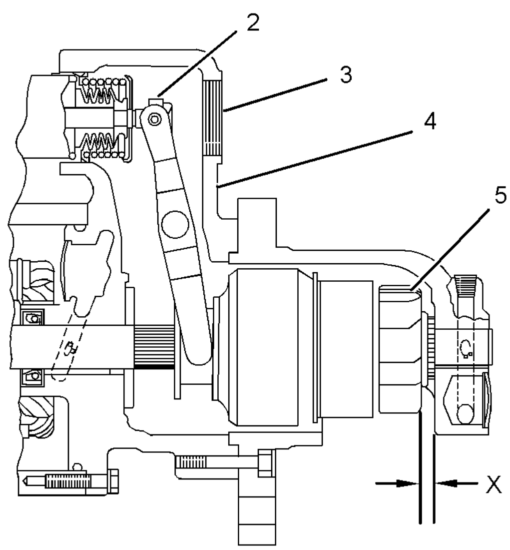

Illustration 84 g01958306

Pinion clearance check

(2) Adjustment nut
(3) Plug
(4) Pinion drive housing
(5) Pinion
(X) Pinion clearance

4. Push the pinion toward the commutator in order to remove free movement.

5. Measure the clearance (X) from the pinion to the pinion drive housing. Pinion clearance (X) must be 9.10 ± 0.8 mm (0.36 ± 0.03 inch).

6. If the clearance is not correct, remove the plug on the shift lever housing (3). Turn the adjustment nut (2) until the clearance is correct. Turning the nut clockwise will decrease the clearance (X).

Note: The plunger may turn when the adjustment nut (2) is being turned. If the plunger turns, disconnect the battery from the solenoid. Remove the solenoid from the starting motor. Hold the plunger from turning and adjust the nut (2). This procedure may need to be performed several times until the correct clearance is obtained.

7. Disconnect the batteries and install the plug into the shift lever housing.

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