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operation & maintenance

3208 Industrial and Generator Set Engines

29A225-UP 30A210-UP 90N1-UP 3Z1-UP

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Foreword

This guide contains operation instructions and lubrication and maintenance information.

The operation section is a reference for the new operator and a refresher for the experienced one. Read — study — and keep it handy.

Illustrations guide the operator through the correct procedures of checking, starting, operating and stopping the engine.

The maintenance section is a guide to equipment care. The illustrated, step-by-step instructions are grouped by servicing intervals. Items without specific intervals are listed under "When Required." Items in the "Lubrication and Maintenance Chart" are reference to detailed instructions that follow.

The lubrication and maintenance items are organized for a Preventive Maintenance Program, they are identified by PM-1, PM-2 and PM-3.

If the Preventive Maintenance Program is followed, a periodic tune-up is not required.

Use the service meter to determine servicing intervals. Calendar intervals shown (daily, weekly, monthly, etc.) may be used instead of service meter intervals if they provide more convenient servicing schedules and approximate the indicated service meter reading. Recommended service should always be performed at the interval that occurs first.

Under extremely severe, dusty or wet operating conditions, more frequent lubrication than is specified in the "Lubrication and Maintenance Chart" may be necessary.

Some photographs in this publication may show details or attachments that may be different from your engine. Also, guards and covers may have been removed for illustrative purposes.

Continuing improvement and advancement of product design may have caused changes to your engine which may not be covered in this publication.

Whenever a question arises regarding your engine, or this publication, please consult your Caterpillar dealer for the latest available information.

Engine Identification

Caterpillar engines are identified with SERIAL NUMBERS and ARRANGEMENT NUMBERS. In some cases MODIFICATION NUMBERS are also used. These numbers are shown on the serial number plate mounted on the engine.

Caterpillar dealers need all of these numbers to determine which components were included on the engine when it was assembled at the factory. This permits accurate identification of replacement part numbers.

Ordering Parts

Quality Caterpillar replacement parts are available from Caterpillar dealers throughout the world. Their parts stocks are up to date and include all parts normally required to protect your investment in Caterpillar engines. When ordering parts, your order should specify the quantity, part number, part name and serial number, arrangement number and modification number of the engine for which the parts are needed. If in doubt about the part number, please provide your dealer with a complete description of the needed item.

Safety

Warning Signs and Labels

Read and understand all warning signs and labels before operating, lubricating or repairing this equipment. Do not attempt any repairs you do not understand.

General

Do not allow unauthorized personnel on or near the engine while it is being serviced.

Do not wear loose clothing, and jewelry whenever working around engines or machine.

Stop engine before making adjustments or repairs to the engine or driven equipment unless specified otherwise.

Attach a "DO NOT OPERATE" tag on the start switch, start button or air start knob, before servicing the engine. These tags, Form SEHS7332, are available from your Caterpillar dealer.

Be sure the remote starting system is inoperative on engine being serviced. Remove the starter key.

Disconnect and tape the battery ground lead before working on an engine to prevent accidental starting.

To prevent injury, install guards over all exposed drive shafts, pulleys, any application with exposed rotating parts.

Always use tools that are in good condition and be sure you understand how to use them before performing any service work. Remove all tools, electrical cords and any other loose items from the engine before starting.

Engine speeds, temperatures and load are the best indications of performance. Rely on your instruments, record and compare readings to detect developing abnormalities.

Wear a hard hat, face shield, clothing, shoes, respirator or other protective items when necessary.

When using pressure air, wear protective glasses and protective clothing.

Wear ear protective devices to prevent hearing damage, if working inside an enclosed engine room with engine running.

Fire or Explosion Prevention

A flash fire may result in personal injury if crankcase covers are removed within 15 minutes after an emergency shutdown.

Fire may result from lubricating oil or fuel sprayed on hot surfaces causing personal injury and property damage. Inspect all lines and tubes for wear or deterioration. They must be routed, supported or clamped securely. Tighten all connections to the recommended torque.

Stop any fuel or oil leak as soon as it is discovered.

Keep all exhaust manifold and turbocharger shields in place to reduce fire hazard.

Collect drained liquids and wipe up all oil, fuel or coolant spills.

Store oily rags in proper containers. Do not leave rags on engine.

Never store flammable liquids near the engine.

Keep all lubricants stored in properly marked containers.

Never put maintenance fluids into glass containers.

Provide adequate and safe waste oil disposal.

Oil and fuel filters must be properly installed and tightened when being changed.

Safety

Diesel fuel and all lubricants are flammable. Do not weld on pipes or tubes that contain oil. Clean them thoroughly with nonflammable solvent before welding.

Do not smoke while refueling.

Loose or damaged lines, or tubes that allow oil, fuel or coolant to leak can cause overheating and/or fire.

Do not bend or strike high pressure lines. Do not install bent or damaged lines and tubes. Do not replace steel tubes with copper tubes.

Do not allow debris, dirt and foreign material to accumulate around or on the engine. Overheating or fire could result.

Wiring must be kept in good condition, properly routed and firmly attached. Routinely inspect wiring for wear or deterioration. Loose, unattached, or unnecessary wiring must be eliminated. All wires and cables must be of the recommended gauge and fused if necessary. Do not use smaller gauge wire or bypass fuses.

Tight connections, recommended wiring and cables properly cared for will help prevent arcing or sparking which could cause a fire.

Batteries must be kept clean, covers on all cells, recommended cables and connections used and battery box covers in place when operating.

Do not smoke when observing battery electrolyte level. Batteries give off flammable fumes.

Never disconnect any charging unit circuit or battery circuit cable from the battery when charging unit is operating. A spark can cause the flammable vapor mixture of hydrogen and oxygen to explode.

When starting from an external power source attach the ground cable last, and remove it first, to prevent sparks from occurring near the battery. Attach the ground cable from the booster source to the starter ground terminal.

Always have a fire extinguisher on hand and know how to use it. Inspect and have it serviced as recommended on its instruction plate or decal.

Burn Prevention

To prevent personal injury, do not step up on engine to remove the radiator filler cap. Use an adequate ladder.

Always inspect the cooling system with the engine stopped and cool.

Extreme caution should be used whenever draining a lubricant. The lubricant may be hot and could cause personal injury.

Relieve all pressure in air, oil, fuel or water systems before any lines, fittings or related items are disconnected or removed. Be alert for possible pressure when disconnecting any device from a system that utilizes pressure. Do not check for pressure leaks with your hand.

When inspecting the valve rotators, protective glasses or face shield and protective clothing must be worn, to prevent being burned by hot oil sprayed by the valves.

Do not touch any part of an operating engine. Allow the engine to cool before any repairs are performed on the engine.

Use caution when removing cover plates. Gradually loosen (do not remove) the last two bolts or nuts located at opposite ends of the cover or device. Pry cover loose to relieve any spring or other pressure, before removing the last bolts or nuts.

Use caution when removing radiator filler cap, grease fittings, pressure taps, breathers or drain plugs. Hold a rag over the cap or plug to prevent being sprayed or splashed by liquids under pressure.

Stop any fuel or oil leak as soon as it is discovered.

Cooling system conditioner contains alkali; do not drink, or let conditioner contact skin or get in eyes.

Battery electrolyte contains acid. Avoid contact with skin or eyes.

Preparing to Start

Be sure all protective guards and covers are installed if an engine must be started to make adjustments or checks. To help prevent an accident caused by parts in rotation, work carefully around them.

Never start an engine with the governor linkage disconnected.

Make provisions for shutting off air supply to stop the engine if there is an overspeed on start-up after servicing the engine.

Inspect engine for potential hazards.

See the "Maintenance Section" of this guide for adjustment, or the Service Manual for repairs.

Starting

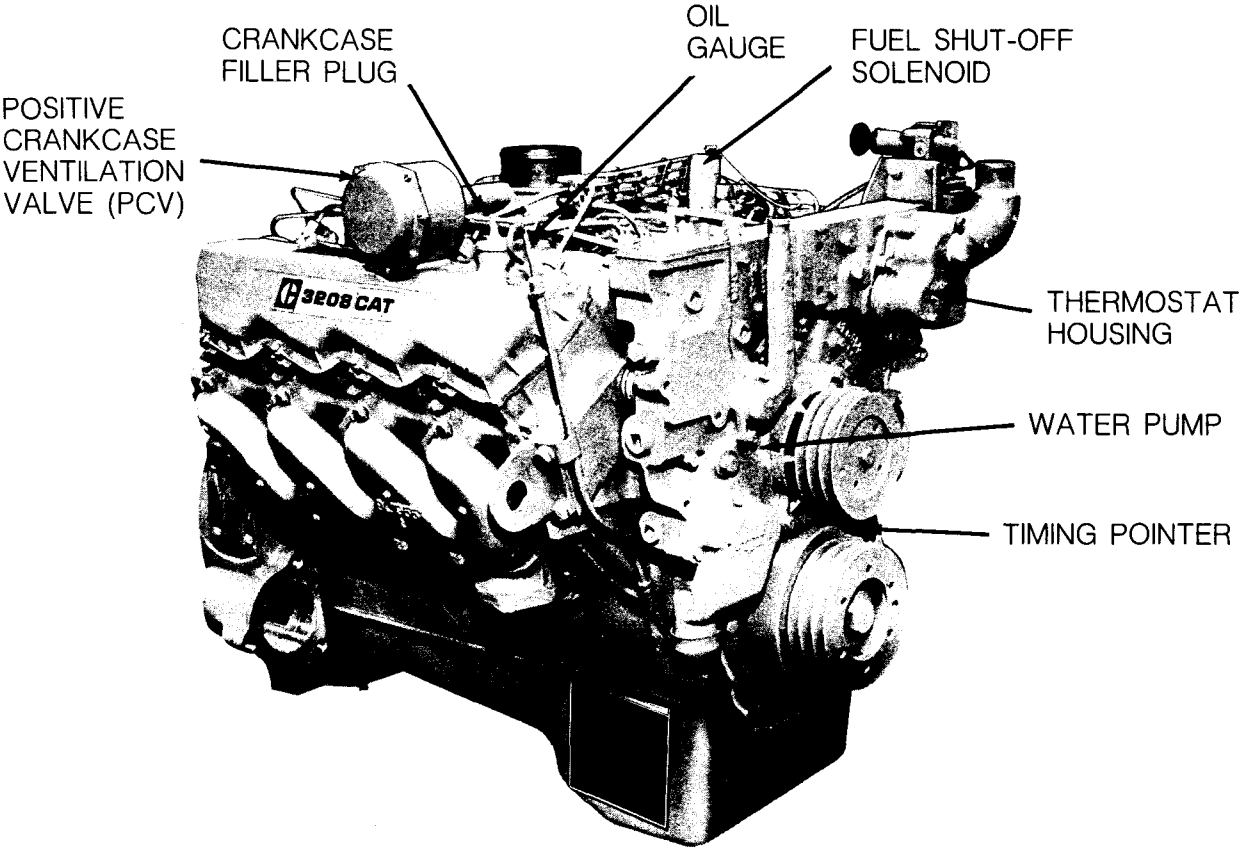
Do not start the engine or move any of the controls if there is a warning tag attached to the controls.

Make sure no one is working on, or close to the engine or engine driven components before starting it.

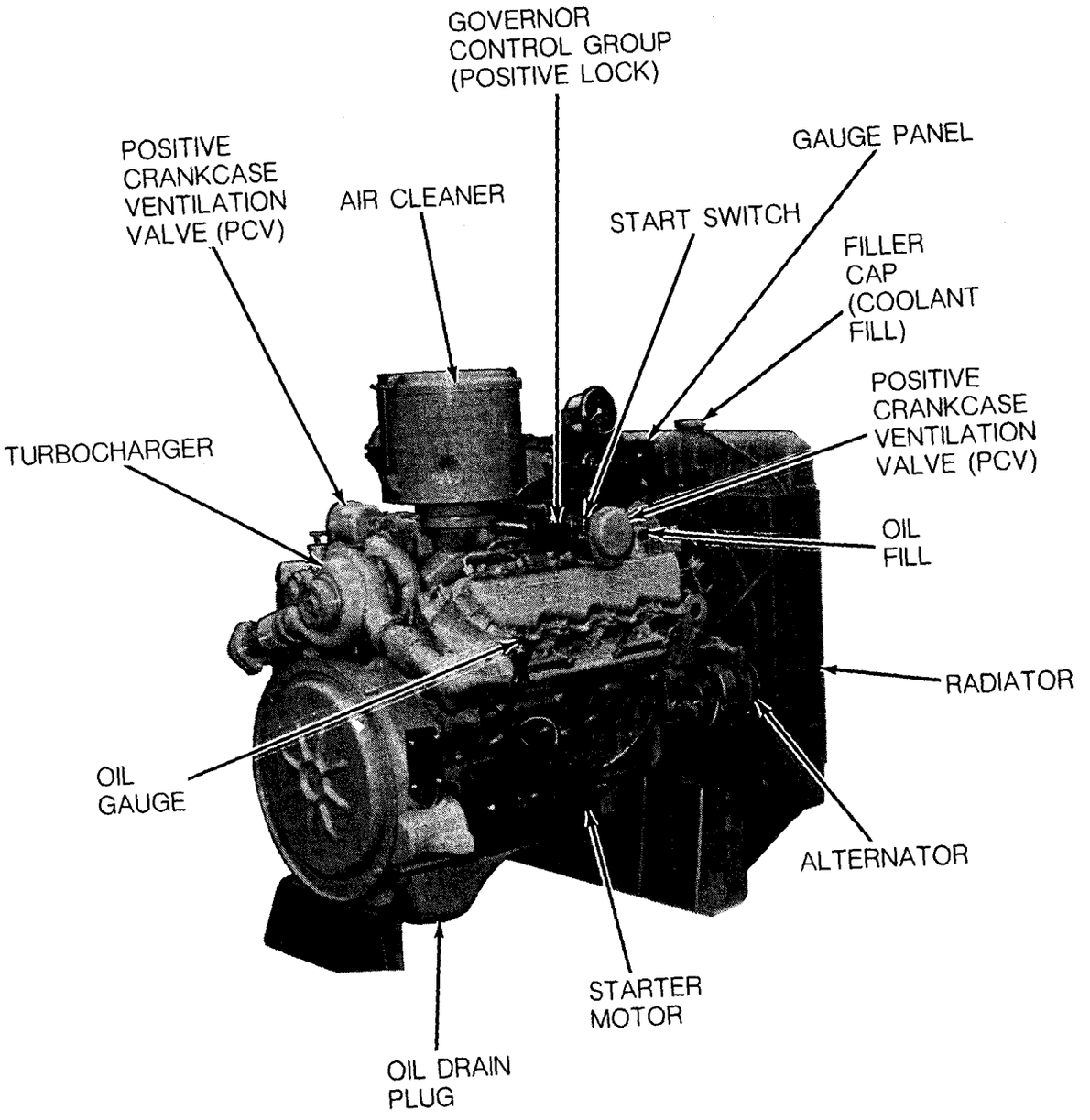
Start and operate engine in well ventilated area. If it is necessary to operate in a closed area, vent exhaust to the outside.

Model Views

3208 NATURALLY ASPIRATED ENGINE

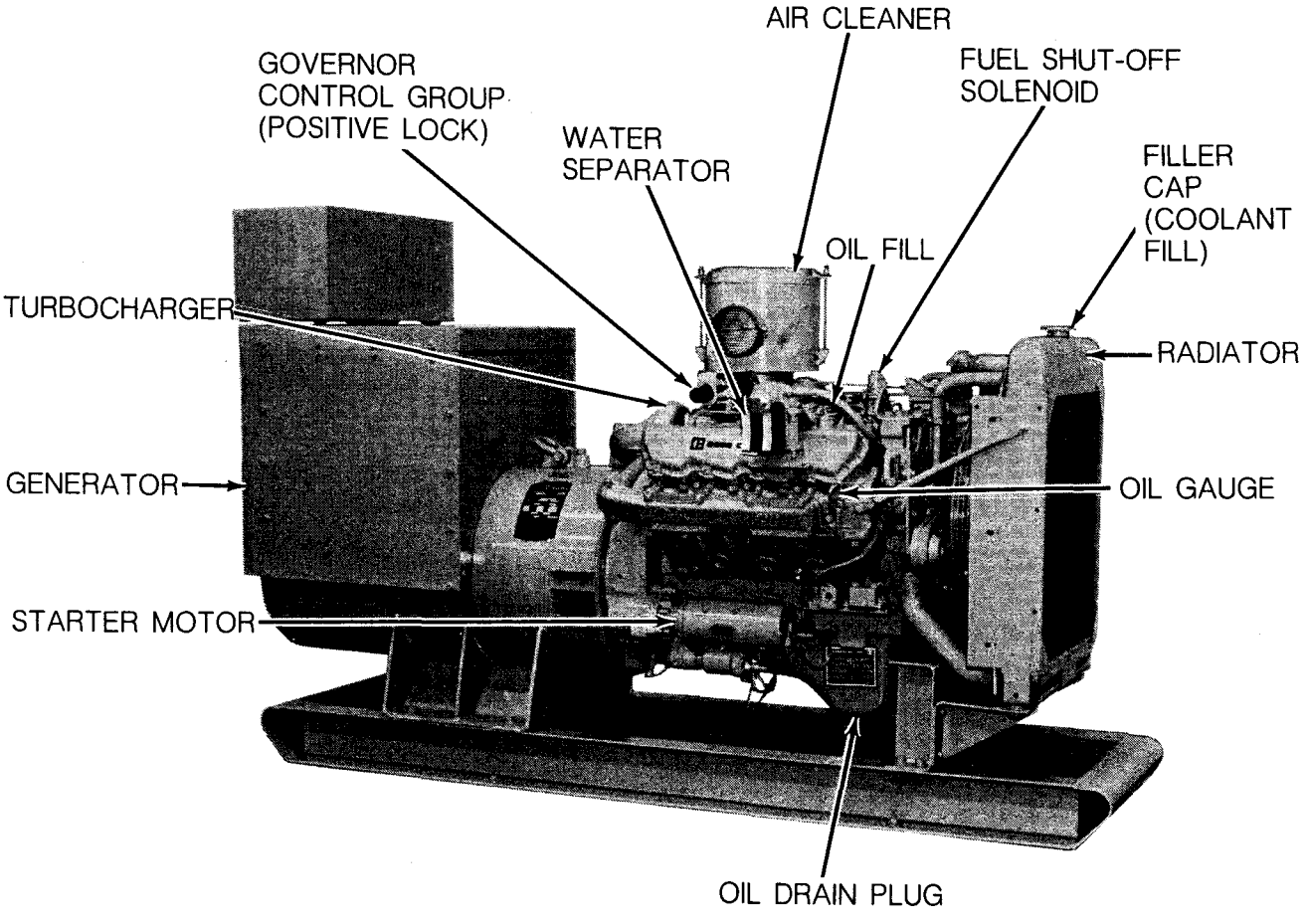


3208 INDUSTRIAL ENGINE



Model Views

3208 GENERATOR SET ENGINE



General Information

The Caterpillar 3208 Engine is a 10.4 liters (636 cu. in.) displacement, 114 mm (4.5 in.) bore, 127 mm (5.0 in.) stroke, four stroke cycle, 8 cylinder 90° Vee design engine. The firing order is 1-2-7-3-4-5-6-8 and the direction of rotation is counterclockwise, as viewed from the flywheel. The engine can be either naturally aspirated or turbocharged, with direct fuel injection.

A mechanical governor controls the fuel injection pump output to maintain the engine rpm selected by the operator.

Individual injection pumps, one for each cylinder, meter and pump fuel under high pressure to an injection valve for each cylinder. Automatic timing advance provides the best fuel injection timing over the full range of engine speed.

The cooling system consists of a belt driven centrifugal pump, with two thermostats which regulate engine coolant temperature, an oil cooler and a radiator incorporating a shunt system.

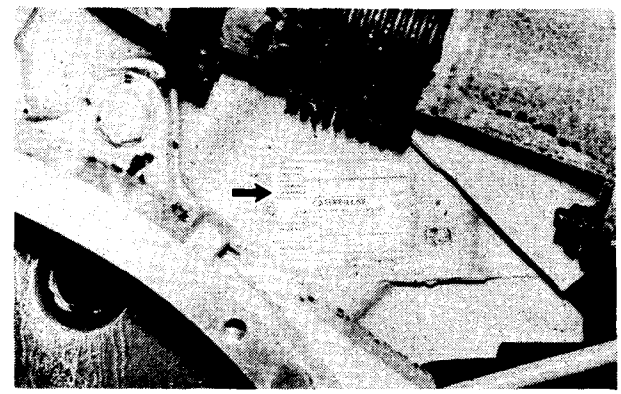
The engine lubricating oil, which is both cooled and filtered, is supplied by a gear-type pump. Bypass valves provide unrestricted flow of lubrication oil to the engine parts when oil viscosity is high, or if either the oil cooler or the oil filter elements should become clogged.

Efficient engine performance depends on adherence to proper operation and maintenance recommendations, and use of recommended fuels and lubrication oils.

Follow the recommended maintenance schedule.

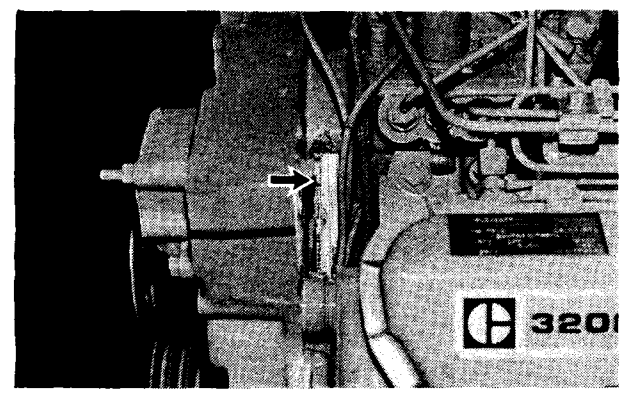
Serial Number and Information Plate Location

Serial Number Plate (Earlier Engines)



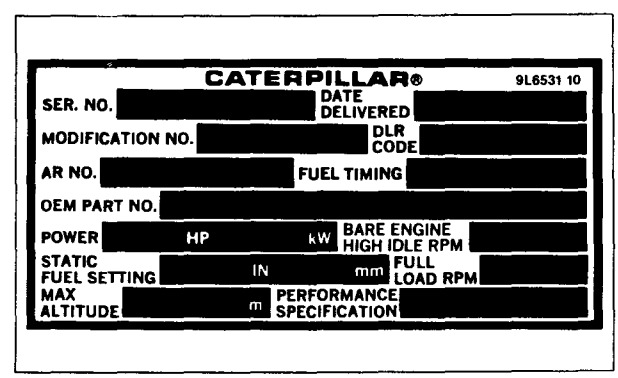
Located on the right rear side of the cylinder block.

Serial Number Plate (Later Engines)



Located on the left front side of the cylinder block.

Information Plate

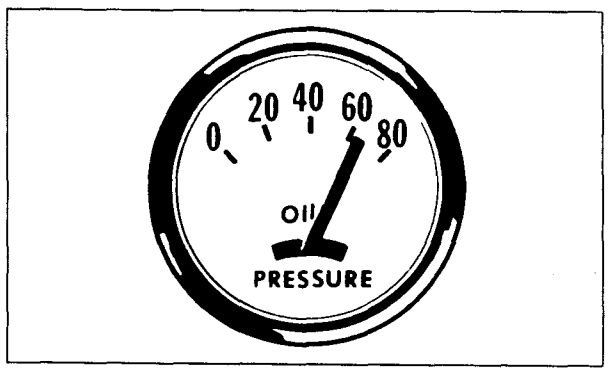


Located on the left valve cover.

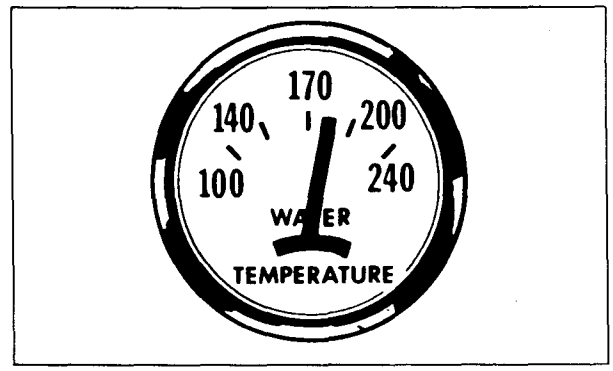
Gauges

Your engine may not have the same or all of the gauges as shown in the illustrations. The illustrations shown are of typical gauges.

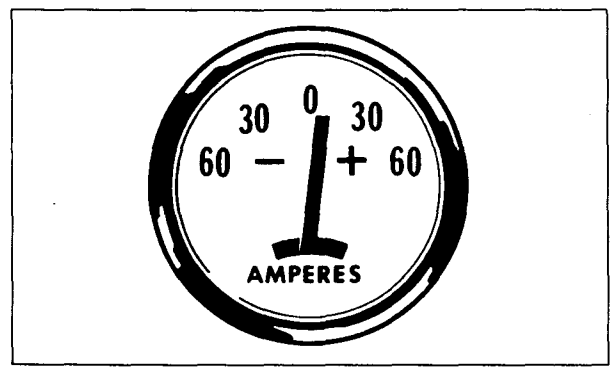
Gauges provide a "look" inside the engine. Be sure they are in good working order. You can determine what is "normal" operating range by observing the gauges over a period of time. The cause of any sudden or significant change in the readings should be determined and corrected.



Oil Pressure — Indicates engine oil pressure. The oil pressure should be between 240 and 480 kPa (35 and 70 psi) when the engine is running at rated engine speed, with SAE 10W30 oil, at operating temperature. A lower pressure is normal at low idling speed. If no pressure is indicated, stop the engine.

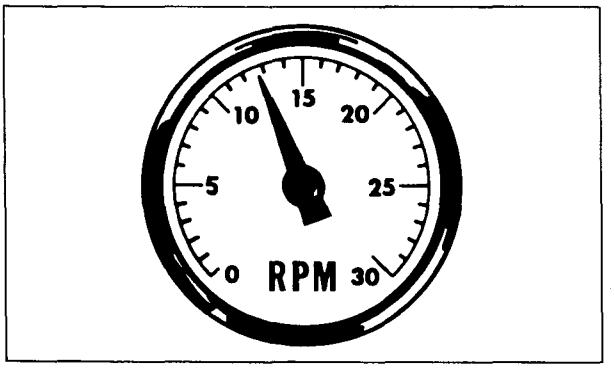


Water Temperature — Indicates engine coolant temperature. It should normally indicate between 71°C (160°F) and 93°C (200°F). Somewhat higher temperatures may occur under certain conditions. Maximum allowable temperature is 99°C (210°F) with the cooling system pressurized.

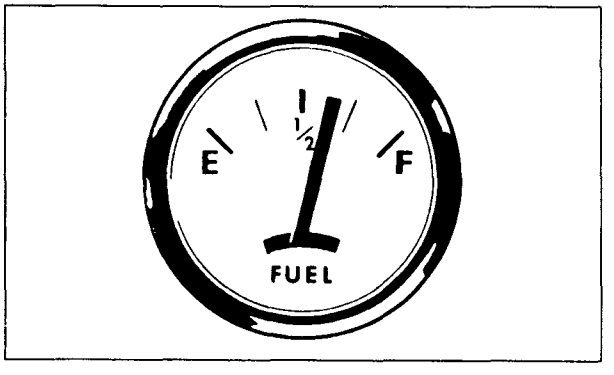


Ammeter — Indicates the amount of charge or discharge in the battery charging circuit. Normal operation of the indicator should be slightly to the positive (right) side of "0" (zero).

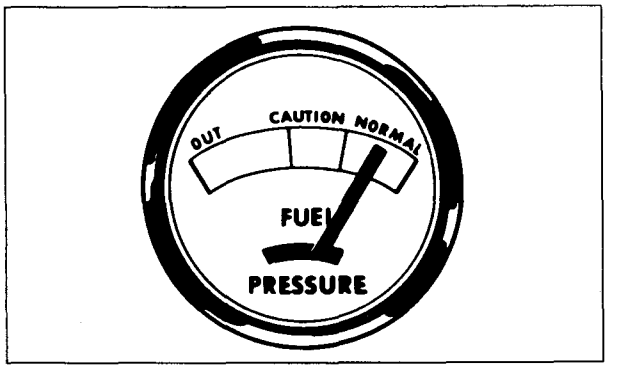
With the engine running, during normal operation, if the indicator is constantly to the negative (left) side of "0" (zero) or shows excessive charge, have the charging system checked for malfunction.



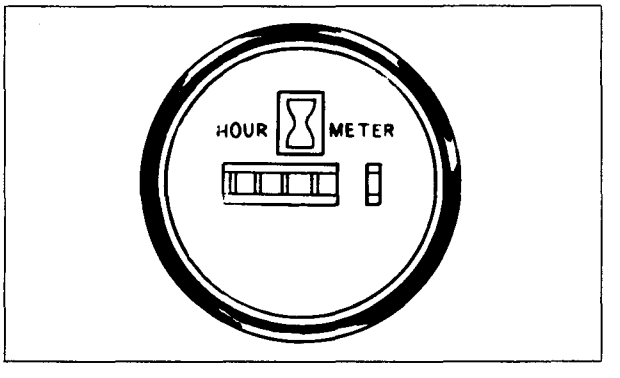
Tachometer — Indicates engine rpm (speed).



Fuel Level — Indicates fuel level in the fuel tank. Electrically operated, it registers only when the switch is ON.



Fuel Pressure — Indicates fuel pressure to the injection pump. The indicator should register in the NORMAL (green) range. When the filter element becomes clogged the indicator will move to the OUT position or if equipped with a numerical indicator and it registers below 140 kPa (20 psi), wash the primary fuel filter and replace the secondary filter element.



Service Hour Meter — Indicates the total number of hours the engine has operated.

Automatic Start-Stop

An automatic start-stop system ensures that power is supplied to a load when the normal power source is interrupted.

The cranking panel is the heart of the system. It consists of the failure warning system and relays to start and stop the engine.

When a power failure occurs the system senses the failure, starts the engine and transfers the load to standby. When power is restored, it senses power restoration, transfers the load from standby and stops the engine.

The major use of automatic start-stop systems is standby electric sets. This discussion is limited to that application.

The remote contacts close when a power failure occurs. This completes the circuit to the cranking timer and the start slave relay. The start slave relay completes the circuit to the starter motor and the engine begins cranking.

As the engine starts and increases in speed, a frequency sensing relay turns off the cranking timer and starts the slave relay. This disconnects the starter motor circuit and protects the starter from overspeed damage. If the engine fails to start, the cranking timer will time out and lock the start circuit open, preventing the batteries from being discharged.

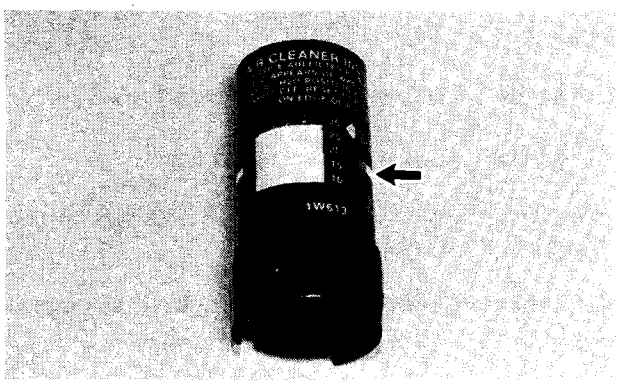
During the cranking cycle, the safety shutoffs are inoperative, and will not allow a low oil pressure shut down. When oil pressure reaches a safe level, the safety circuit is armed by the arming relay. High water temperature or low oil pressure will now stop the engine and prevent major damage.

If an unsafe engine condition exists, a sending unit completes the circuit to the safety relay and locking relay. The safety relay closes the fuel supply valve and the engine stops. The locking relay insures that the circuit to the safety relay is complete, even if the remote contacts open.

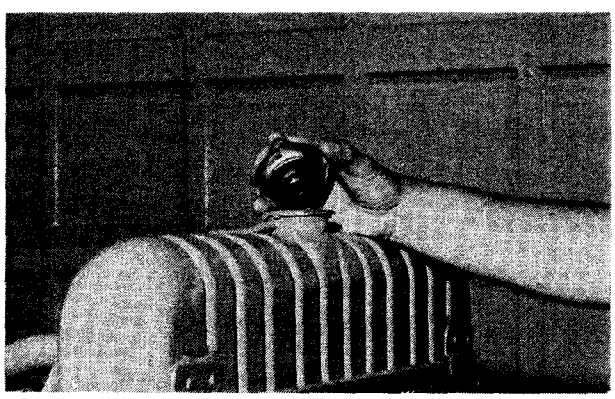
Before restarting any unit which has been shut down by the safety circuit, the cause must be determined and corrected. The safety circuit must be reset by moving the start selector switch to the OFF position.

Before Starting the Engine

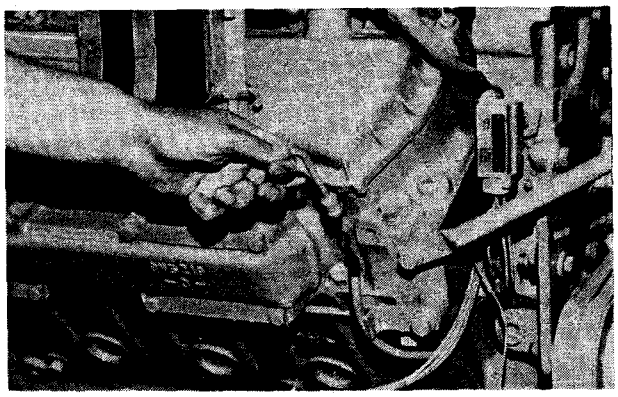
Perform required periodic maintenance before starting the engine. Make a "walk-around inspection" of the installation. It only takes a few minutes to correct minor discrepancies. This can prevent major repairs at a later date.



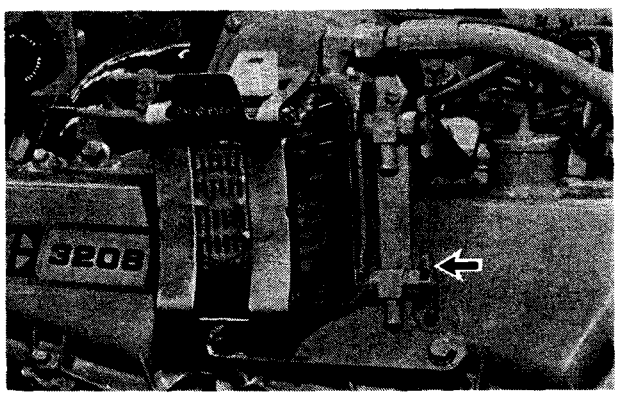
1. Inspect the air cleaner service indicator.-If the red piston is locked in the raised position, service the air cleaner.



2. Inspect the coolant level. The level must be to the bottom of the radiator filler neck.



3. Measure the crankcase oil level. The oil level must be between the ADD and FULL marks on the dipstick.



4. Drain water from the water separator.

5. Disconnect any battery chargers that are not protected against the starter current drain.

6. All guards must be in place. Repair or replace all guards that are damaged.

Starting the Engine

NOTICE

Do not engage starter when flywheel is turning.

Do not start engine under load.

Above −12°C (10°F)

1. Place transmission in NEUTRAL. Open the main electrical circuit breaker on generator sets.

NOTE: For air start systems, before starting the engine, check the air supply. There must be 690 kPa (100 psi) air pressure available.

2. Turn start switch to START position or push the air start button in. Release the switch or button as soon as the engine starts.

3. Allow the engine to idle for three to five minutes, or until the water temperature gauge has begun to rise.

4. Do not apply load to the engine or increase engine speed until the oil pressure gauge indicates normal.

NOTICE

If oil pressure does not raise within 15 seconds after the engine starts, stop the engine and make necessary corrections.

5. Operate the engine at low load and rpm until the coolant temperature is 66°C (150°F) or higher. Check all gauges during the warmup period.

Below −12°C (10°F)

⚠ WARNING

Ether is poisonous and flammable.

Breathing ether vapors or repeated contact of ether with skin can cause personal injury.

Use ether only in well ventilated areas.

Use ether with care to avoid fires.

Do not smoke while changing ether cylinders.

Do not store ether cylinders in the operator's compartment or living areas.

Do not store ether cylinders in direct sunlight or at temperatures above 49°C (102°F).

Discard ether cylinders properly. Do not puncture or burn ether cylinders.

Keep ether cylinders out of the reach of unauthorized personnel.

1. Depress ether switch, if equipped, and hold for 3 seconds, then release.

NOTE: For air start system, before starting the engine, check the air supply. There must be 690 kPa (100 psi) air pressure available.

2. Turn the start switch to START position or push the air start button in.

3. Begin cranking engine and depress ether switch and hold for 3 seconds then release. Additional injections of ether may be required to start and/or achieve low idle speed.

NOTICE

Do not use excessive starting fluid during starting or after the engine is running.

After every 30 seconds of engine cranking, allow 2 minutes for the starter motor to cool.

If oil pressure does not rise within 15 seconds after the engine starts, stop the engine and make necessary corrections.

4. As soon as the engine starts, release the starter switch and reduce rpm to low idle.

5. Do not apply load to the engine or increase engine rpm until the oil pressure gauge indicates normal.

6. Operate the engine at low load and rpm until the coolant temperature is 66°C (150°F) or higher. Check all gauges during the warmup period.

For starting below −18°C (0°F), use of optional cold weather starting aids are recommended. A coolant heater or extra battery capacity may be required.

Temperatures below −23°C (−10°F) consult your Caterpillar dealer, or refer to the Cold Weather Operation Guide, Form SEBU5338, available from your Caterpillar dealer.

Starting From External Electrical Source

⚠ WARNING

Always wear protective glasses when working with batteries.

Prevent sparks near the batteries. They could cause vapors to explode. Do not allow cable ends to contact each other or the engine.

Batteries give off flammable fumes that can explode.

Do not smoke when observing the battery electrolyte levels.

Electrolyte is an acid and can cause personal injury if it contacts skin or eyes.

Do not allow the free end of booster cables to make contact with each other or touch the engine. This will help avoid sparks.

NOTICE

Be sure the main power switch is in the OFF position before attaching the booster cables to the engine being started.

When using booster cables, be sure to connect in parallel: POSITIVE (+) to POSITIVE (+) and NEGATIVE (−) to NEGATIVE (−).

Use only equal voltage for boost starting. The use of a welder or higher voltage will damage the electrical system.

Starting the Engine

Engines without engine-to-frame ground straps can be damaged by electrical discharge.

To prevent electrical discharge damage, check to make sure the system has an engine-to-frame ground strap. For engines which have the alternator connected to an engine component, the ground strap must connect that component to the frame.

Some engines have starter-to-frame ground straps. But, many of these starters are not electrically grounded to the engine. They have electrical insulation systems. For this reason, the starter-to-frame ground strap may not be an acceptable ground.

Connect one end of cable to the POSITIVE (+) (ungrounded) terminal of the battery on the engine being started. Connect the other end to the POSITIVE (+) terminal of the power source.

Connect one end of the second cable to the NEGATIVE (−) terminal of the power source. Connect the other end to the frame of the engine to be started.

Turn the start switch on.

Start the engine.

Disconnect the cable from the engine frame first. Disconnect the other end from the NEGATIVE (−) terminal of the power source. Disconnect the cable from the POSITIVE (+) terminal of the battery. Disconnect the other end from the POSITIVE (+) terminal of the power source.

After Starting the Engine

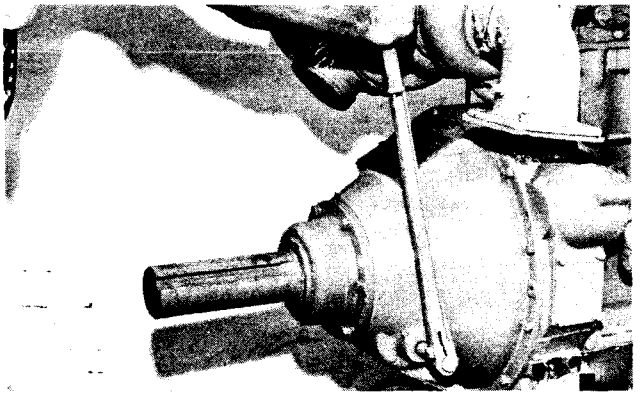
NOTICE

If oil pressure does not rise within 15 seconds after the engine starts, stop the engine and make necessary corrections.

1. Do not apply a load to the engine, or increase the speed, until oil pressure gauge indicates normal.

2. Operate the engine at low load until all systems reach operating temperatures. Check all gauges during the warmup period.

Operating the Engine



1. Move the governor control to half engine speed.

2. Engage the driven equipment.

3. Check the engine gauges and equipment.

4. Move the governor control to high idle (full load) position.

5. Apply the load to the driven equipment.

Stopping the Engine

NOTICE

Stopping the engine immediately after it has been working under load, can result in overheating and accelerated wear of the engine components. Follow the stopping procedure, outlined below, to allow the engine to cool. Excessive temperatures in the turbocharger centerhousing will cause oil coking problems.

1. Reduce engine speed to low idle.

2. Shift into NEUTRAL. On generators, open the main electrical circuit breaker.

3. Increase engine speed to no more than half engine speed for five minutes to cool the engine.

4. Reduce engine speed to low idle.

5. Turn the start switch to the OFF position.

6. Check the crankcase oil level. Maintain the oil level between the ADD and FULL marks on the oil level gauge.

After Stopping the Engine

1. Fill the fuel tank to prevent accumulation of moisture in the fuel.

2. If below freezing temperatures are expected, allow the engine jacket water expansion tank to cool; then check the coolant for proper antifreeze protection. The cooling system must be protected against freezing to the lowest expected ambient temperature. Add permanent-type antifreeze if required.

Fill the expansion tank to 13 mm (1/2 inch) from bottom of the fill pipe.

3. Repair any leaks, perform minor adjustments, tighten loose bolts, etc.

4. Observe the service meter reading. Perform periodic maintenance as instructed in the Lubrication & Maintenance Chart.

Lifting the Engine

NOTICE

When it is necessary to remove a component on an angle, remember that the capacity of an eyebolt is less as the angle between the supporting members and the object becomes less than 90°. Eyebolts and brackets should never be bent and should only be loaded in tension.

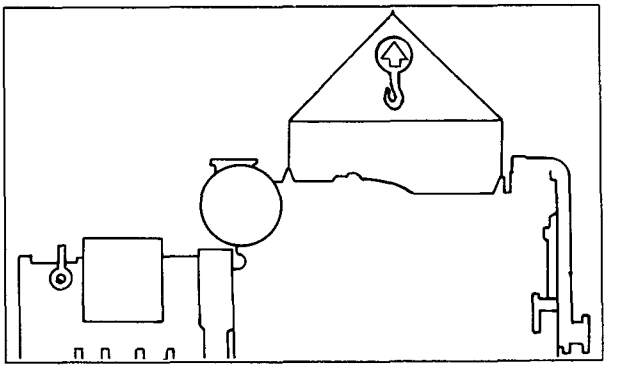
Use a hoist to remove heavy components. Lift the engine by using an adjustable lifting beam. All supporting members (chains and cables) should be parallel to each other, and as near perpendicular as possible to the top of the object being lifted.

Some removals require the use of lifting fixtures to obtain proper balance and to provide safe handling.

Lifting eyes are designed for the arrangement as sold. Alterations to lifting eyes and/or arrangement weight make the lifting devices obsolete.

If you make alterations, you are responsible for providing adequate lifting devices.

Engine With or Without Generator



To remove the engine only or the engine and generator together, use the two lifting eyes on the engine.

Engine Storage

General Information

These instructions give procedures and recommendations that will keep the possibility of damage at a minimum when engines are in storage for one year or less.

After one year, the complete protection procedure must be followed again if the engine is kept in storage.

The best protection for outside parts of the engine is by thorough use of paint. Paint is a good protection for storage of a period up to 2 years. Thoroughly clean the engine and repaint areas with paint damage with good quality paint.

If an engine is not used, oil can run off the cylinder walls, piston rings, main bearings, connecting rod bearings, crankshaft, gears and other parts that normally get lubrication. This lack of lubricant lets corrosion start on the metal, especially in areas of high humidity (water content of the air). When the engine is started again, before these surfaces get oil, the metal-to-metal contact will cause wear. To keep this wear at a minimum, use the starter to turn the engine with the throttle in fuel OFF position until oil pressure is shown on the pressure gauge.

Use an air compressor with a sprayer attachment to spray external engine parts with a mixture of 50% VCI oil and 50% engine oil for preparation of the engine for storage. It should be possible to change the nozzle adjustment to give either spray or fog. The fog adjustment is better if access to components is difficult. The spray is better for parts on the outside.

Volatile Corrosion Inhibitor (VCI) (NOX-RUST VCI #10 oil or equivalent) oil gives both liquid and vapor protection of ferrous metal surfaces against corrosion caused by moisture. In a closed compartment, protection is either by direct contact with VCI oil or by contact with the VCI vapors. See your local supplier for a similar type oil. Additional information as to ordering and use of NOX-RUST VCI #10 and NOX-RUST 1031B rust preventive and a list of suppliers outside the U.S.A. are available from:

Daubert Chemical Co.
1200 Jorie Blvd.
Oakbrook, IL 60521
Telephone: (312) 582-1000

NOTE: Attach a "DO NOT OPERATE" tag on the start switch, start button or air start knob, before servicing the engine. These tags, Form SEHS7332, are available from your Caterpillar dealer.

Storage Procedure

1. Clean the outside of the engine and repaint areas with paint damage with good quality paint.

2. Remove the batteries and use them in some other place or put them in storage where they can be checked and electrically charged again when needed. If the batteries are not removed, wash the tops. Put an electrical charge to the battery to a specific gravity of 1.275. Disconnect the battery terminals. Put a plastic cover over the battery.

3. Loosen all fan, alternator belts, etc. Attach a tag to indicate what work has been done.

Engine Storage

4. Put a waterproof cover over engines with enclosures stored outdoors. Make the cover tight, but loose enough to allow air to circulate around the engine to prevent damage to exposed metal parts from condensation.

NOTE: Remove the waterproof cover every two or three months and check the engine for corrosion. If the engine has signs of corrosion at the check period, follow the protection procedure again. To operate the engine, it is not necessary to remove the preservative oil mixture. If a compartment under protection of VCI vapors is opened, put more VCI mixture in to make up for the vapor loss.

NOTE: Install all covers and/or put tape over all openings, air intake, exhaust openings, flywheel housing, crankcase breathers, dipstick tubes, etc. Make sure all covers are air tight and weatherproof. Use a waterproof, weather resistant, tape.

5. Put lubricant on all points given in the Lubrication and Maintenance Chart.

6. Put a heavy amount of multipurpose grease on all outside parts that move; rod threads, ball joints, linkage, etc.

7. Oil and oil filter elements used less than 50 hours in the engine do not need to be changed. (Otherwise, change the oil, filling the engine to the "add oil" mark on the dipstick.) Add 3% to 4% of VCI oil per engine volume. If the engine is drained, install a mixture of 50% VCI oil and 50% engine oil in the crankcase and in all lubricating oil compartments at the rate of one part VCI oil mixture per fifteen parts of compartment capacity at full level. If possible, operate the engine three to five minutes. Put tape over all openings to seal VCI vapors in the engine.

NOTE: If necessary, drain some lubricant to add the mixture.

8. Remove any dirt from the air cleaner. Check all seals and gaskets.

9. Remove the air filter elements. Turn the engine at cranking speed with throttle control in fuel OFF position, remove pressure plug for boost pressure and use a sprayer to add a mixture of 50% VCI oil and 50% engine oil. Minimum application rate is 5.5 milliliters per liter (3 oz. per 1000 cubic inches) of engine displacement.

10. Fill the oil reservoir for the air starter with a mixture of 50% VCI oil and 50% engine oil.

11. Use a sprayer to put a mixture of 50% VCI oil and 50% engine oil into the exhaust openings. Minimum application rate is 5.5 milliliters per liter (3 oz. per 1000 cubic inches) of engine displacement.

12. Also, use a sprayer to apply a mixture of 50% VCI oil and 50% engine oil on the flywheel, ring gear teeth and starter pinion. Install the covers to keep the vapors in.

13. Remove the fuel nozzles and install 30 milliliters (1 oz) of 50% VCI oil and 50% engine oil in each cylinder. Test (using calibrating oil) then install fuel nozzles and tighten all fittings to the correct torque. Use an engine turning tool to turn the engine over slowly two complete revolutions in the direction of normal rotation, to put oil on the cylinder walls.

14. Remove the fuel from the secondary fuel filter housing or change the spin-on fuel filter element to get out any dirt and water. Clean the primary fuel filter, fill with calibration oil and operate the priming pump. This will get clean oil to the secondary fuel filter and engine, and help to prevent "sticky" fuel pump nozzles during extended storage. Calibrating oil is available from your Caterpillar dealer in two sizes, 208 liters (55 gallons) or 19 liters (5 gallons). Open the fuel tank drain valve and remove any water or dirt from the inside of the fuel tank.

The fuel must be treated with a Biocide, which prevents bacteria and fungi from contaminating diesel fuel that contains some water. Microbial contamination can cause severe fuel system blockage, filter plugging, fuel pump sticking and corrosion.

Additional information as to ordering and use of diesel fuel Biocide and a list of suppliers outside the U.S.A. are available from:

Amalgamated Coal & Petroleum
Specialists, Inc.
C.P.S. Associates
9214 Ernst Road
Fort Wayne, Indiana 46809
Telephone (219) 747-7080

Methyl Cellosolve will help assimilate water in the fuel and prevent freezing problems.

Fill the fuel tank with the treated fuel.

Seal all openings to the tank to prevent evaporation of the fuel.

15. Withdraw a sample of coolant and check it for clarity (rust) and freezing point. If it contains suspended particles or does not provide freeze protection to at least −23°C (−10°F), the coolant should be replaced. Completely drain the cooling system, if needed. The cooling system must be thoroughly flushed and chemically cleaned.

16. Refill the cooling system with a coolant solution that is 50% water and 50% ethylene glycol. Install a new precharge coolant conditioner element (if equipped with coolant conditioner elements). A 3% to 6% concentration of coolant conditioner does not have to be added, if the cooling system is filled with coolant solution to the top of the filler neck. Attach a tag indicating what has been done.

NOTE: Do not use coolant conditioner elements or liquid coolant conditioner with Dowtherm 209 Full-Fill coolant.

Procedure for Operation After Storage

1. Remove all outside protective covers, and any tape or grease which were used for protection.

2. Drain the VCI oil and engine oil mixture from the engine, if the oil has been in the engine for more than one year, or if the engine was left drained before adding the VCI mixture. If storage was short term, the engine can be operated with a 3% to 4% VCI mixture in the engine.

3. Tighten the fan and alternator belts, connect the batteries and check the oil and coolant level.

4. Use an engine turning tool to turn the engine two complete revolutions in the direction of normal rotation, to make sure there are not hydraulic locks or resistance.

5. Before starting the engine, remove the valve cover or covers and put a large amount of engine oil on the valve mechanism to prevent damage to the valves.

Engine Storage

6. To get immediate lubrication and prevent damage to the engine in the first seconds after starting, it is necessary to pressure lubricate the engine. (See "Procedure for Pressure Lubrication" below.) Prime the engine with clean diesel fuel before starting.

7. Crank engine with fuel off until oil pressure is observed.

8. On the first day of operation, check the complete engine several times for leaks and correct operation.

9. See Form SEBU5338, Cold Weather Operation Guide, if the engine is removed from storage in temperatures less than −23°C (−10°F).

10. After start-up, add cooling system conditioner as needed.

Pressure Lubrication Introduction

It is very important for an engine to have adequate (needed) lubrication during the first seconds of operation. A dry start (without needed lubrication) of an engine can cause bearing damage. An engine generally has enough oil on the parts for lubrication during engine start-up.

However, this lubrication may not be enough or may be lost if the engine has been in storage for any length of time. To prevent the possibility of a dry start and bearing damage during the first seconds of operation, pressure lubrication of the engine is necessary (fill the main oil passages with oil under pressure).

Sources of clean oil under pressure, such as a service shop central oil supply, can be used for pressure lubrication.

Procedure for Pressure Lubrication

1. Connect the oil supply to the main oil passage of the engine.

2. Fill the crankcase with the correct oil. The amount of oil used in the pressure lubrication procedure must be subtracted from the Refill Capacity Chart given in the Operation and Maintenance Guide.

NOTE: Use a minimum of 30% of the engine oil capacity. It may be necessary to fill the tank several times.

Initial Operation After Engine Storage

1. Following engine storage, only an operational check at the first start is necessary before operation.

2. The purpose of this first operational check is to be sure that the pressures and temperatures in the cooling, fuel and lubrication systems are correct, and any leaks are corrected.

3. To be sure of a safe, uniform check at first operation, use the following procedure:

a. Turn the engine at cranking speed with the throttle in fuel OFF position until oil pressure is present.

b. Operate the engine for 5 minutes at low idle speed until the coolant temperature is 66°C (150°F) or higher.

Maintenance Recommendations

Cooling System

NOTICE

Never add coolant to an overheated engine; allow the engine to cool first.

Check the specific gravity of the antifreeze solution frequently in cold weather to ensure adequate protection.

If the engine is to be stored in, or shipped to, an area with below freezing temperatures; the cooling system must be protected against freezing to the lowest expected outside temperature.

All water is corrosive at engine operating temperature. The cooling system should be protected with conditioner at all times regardless of the concentration of antifreeze. This can be done by either using Caterpillar coolant conditioner elements, or by maintaining a 3% to 6% concentration of liquid Caterpillar cooling system conditioner, or equivalent.

To prevent over inhibiting the cooling system, never use both liquid cooling system conditioner and coolant conditioner elements at the same time.

Do not use Caterpillar cooling system conditioner or coolant conditioner elements with Dowtherm 209 Full-Fill coolant. Follow the instructions provided with the Dowtherm 209 Full-Fill coolant.

Cooling System Conditioner Liquid

Maintain a 3% to 6% concentration of liquid Caterpillar cooling system conditioner, or equivalent. Add the correct amount of cooling system conditioner at every oil change interval. Use 0.24 liters (1/2 pint) conditioner per 38 liters (10 U. S. gallons) of cooling system capacity. On new, rebuilt or remanufactured engines and when changing coolant, use 0.95 liters (1 quart) of conditioner per 30 liters (8 U. S.gallons) of cooling system capacity.

Maintenance Recommendations

Coolant Conditioner Elements

For engines equipped with coolant conditioner elements, install a new maintenance element at every oil change interval. Use a precharge element only when filling the system on new, rebuilt or remanufactured engines, or changing coolant. Your Caterpillar dealer can provide you with the correct coolant conditioner element.

General

Coolant should be drained and replaced every 2400 service hours or 2 years, when Caterpillar cooling system conditioner, or equivalent, is added, as recommended.

Premix antifreeze solution to provide protection to the lowest expected outside temperature. Pure undiluted antifreeze will freeze at −23°C (−10°F).

A mixture of 50% ethylene glycol and 50% water will protect the coolant from freezing down to a temperature of −37°C (−34°F).

Use clean water that is low in scale forming mineral. Do not use softened water.

Filling at over 20 liters (5 U.S. gallons) per minute can cause air pockets in the cooling system.

After draining and refilling the cooling system, start and operate the engine with the fill cap off until the coolant level stabilizes. Add 3% to 6% liquid coolant conditioner or install a precharge coolant conditioner element.

Operate with a thermostat in the cooling system year-round. Overheating will occur without a thermostat.

Fuel System

NOTICE

Fill the fuel tank at the end of each day of operation to drive out moist air and to prevent condensation. Do not fill the tank to the top. Fuel expands as it gets warm and may overflow.

Do not fill the fuel filters with fuel before installing them. Contaminated fuel will cause accelerated wear to the fuel system parts.

After changing the fuel filters, bleed the fuel system to remove air bubbles from the system.

Drain water and sediment from the water separator daily and the fuel storage tank weekly, and before the tank is refilled. This will help prevent water or sediment from being pumped from the storage tank into the engine fuel tank.

Use only fuel as recommended in the "Coolant, Fuel and Lubricant Specifications" section of this guide.

Air Intake System

An air cleaner service indicator may be mounted on the air cleaner. A colored piston showing in the window indicates the need for servicing the air cleaner. Replace the filter element at least once a year.

Inspect the air intake system hoses, elbows and gaskets for cracks or damage, replace as needed. Check for loose clamps, tighten as needed.

Scheduled Oil Sampling (S-O-S)

Use Scheduled Oil Sampling (S-O-S) to monitor the condition and maintenance requirements of your engine. Each oil sample should be taken when the oil is hot and well mixed, to ensure that the sample is representative of the oil in the compartment.

S•O•S Interval Chart	
Compartment	**Interval**
Engine Oil	At Oil Change(1)

(1)See page 29.

Consult your Caterpillar dealer for complete information and assistance in establishing a Scheduled Oil Sampling program for your engine.

Electrical System

Engines installed without an engine-to-frame ground strap can be damaged by electrical discharge.

To prevent electrical discharge damage, check to make sure the engine's electrical system has an engine-to-frame ground strap. For engines which have the alternator connected to an engine component, the ground strap must connect that component to the frame.

NOTICE

Some engines have starter-to-frame ground straps. But, many of these starters are not electrically grounded to the engine. They have electrical insulation systems. For this reason, the starter-to-frame ground strap may not be an acceptable ground. Use a separate engine-to-frame ground strap.

When boost starting the engine, follow the instructions in the "Starting From An External Source" in the "Starting the Engine" section to properly start the engine.

Your engine may have a 12 or 24 Volt starting system. Use only the same voltage for boost starting. The use of a higher voltage or a welder will damage the electrical system.

Coolant, Fuel and Lubricant Specifications

Coolant Specifications

NOTICE

Use a mixture of water, antifreeze and cooling system conditioner. Pure, undiluted antifreeze will freeze at -23°C (-10°F).

Always add cooling system conditioner to water, or install a coolant conditioner element (if equipped). Never use water only.

To prevent overinhibiting the cooling system, never use both liquid cooling system conditioner and a coolant conditioner element (if equipped) at the same time.

Do not use Caterpillar cooling system conditioner or coolant conditioner elements with Dowtherm 209 Full-Fill coolant. Follow the instructions provided with the Dowtherm 209 Full-Fill coolant.

Refer to "Know Your Cooling System," Form SEBD0518, for more detailed specifications and instructions on water and cooling system conditioner sampling and testing.

Water

Acceptable water for use in the ethylene glycol-type antifreeze and water mixture is shown in the chart below:

Acceptable Water		
Water Content	**50% Antifreeze 50% Water**	**Without Antifreeze**
Chlorides	100 ppm or less	50 ppm or less
Sulfates	100 ppm or less	50 ppm or less
Hardness as $CaCO_3$	200 ppm or less	100 ppm or less
Dissolved Solids	500 ppm or less	250 ppm or less
pH	6.5 or higher	6.5 or higher

ppm = parts per million

Coolant, Fuel and Lubricant Specifications

Antifreeze

Use ethylene glycol-type antifreeze. Use the correct amount, mixed with water, to provide freeze protection to the lowest expected outside temperature.

Cooling System Conditioner (Liquid)

Use Caterpillar cooling system conditioner or equivalent. Add the correct amount of cooling system conditioner at every oil change interval to maintain a 3% to 6% concentration. Conditioner can be purchased from your Caterpillar dealer.

Coolant Conditioner Elements (If Equipped)

Coolant conditioner elements should be used to maintain a 3% to 6% concentration of conditioner. Install a new maintenance element at every oil change interval. Use a precharge element when filling the complete system or changing coolant. Your Caterpillar dealer can provide you with the correct coolant conditioner element.

Fuel Specifications and Information

Types of Fuel

Caterpillar engines have the ability to burn a wide variety of fuels. These fuels are divided into two general groups, preferred and permissible.

The preferred fuels provide maximum engine service life and performance. They are distillate fuels. They are commonly called diesel fuel, furnace oil, gas oil or kerosene.

The permissible fuels are crude oils or blended fuels. Use of these fuels can result in higher maintenance costs and reduced engine service life.

Refer to "Fuels for Caterpillar Diesel Engines," Form SEHS7067, for a detailed summary of preferred and permissible fuels and their specifications.

Refer to S.A.E. J313 Diesel Fuels for information about better quality fuels, such as ignition quality, gravity/density, viscosity, cloud point, sulfur content, etc.

Fuel Sulfur Content

The percentage of sulfur in the fuel will affect the engine oil recommendations. If the fuel has over 0.5% sulfur content, the CD/SE or CD/SF engine oil must have a TBN of 20 times the percentage of fuel sulfur (TBN as measured by the ASTM D-2896 method).

Fuel sulfur is chemically changed during combustion to form sulfuric acid. The acid chemically attacks metal surfaces and causes corrosive wear. Higher engine oil TBN values are essential to minimize corrosive wear.

Periodically request fuel sulfur content information from your fuel supplier. Fuel sulfur content can change with each bulk delivery.

Fuel Cetane Requirement

The minimum fuel cetane number recommended for the direct injection engine is 40.

Fuel Cloud Point

Fuel waxing can plug the fuel filters in cold weather. The fuel cloud point must be below the temperature of the surrounding air to prevent filter waxing and power loss. Fuel heating attachments are available from your Caterpillar dealer to minimize fuel filter waxing.

Engine Specifications

Lubricant Specifications

The abbreviations listed below follow S.A.E. J754 nomenclature. The classifications follow S.A.E. J183 classifications. The MIL specifications are U.S.A. Military Specifications. These definitions will be of assistance in purchasing lubricants. The recommended oil viscosities are found on the "Recommended Lubricant Viscosities" chart.

The prefix "SPC" is a general abbreviation used by Caterpillar to identify special oils such as synthetic or semi-synthetic oils.

Engine Oils

Use oils that meet the Engine Service Classification CD/SE or CD/SF (MIL-L-2104D).

Consult the "EMA Lubricating Oils Data Book," Form SEBU5939, for a listing of CD/SE and CD/SF oil brands.

The percentage of sulfur in the fuel will affect the engine oil recommendations. If the fuel has over 0.5% sulfur content, the CD/SE or CD/SF engine oil must have a TBN of 20 times the percentage of fuel sulfur (TBN as measured by the ASTM D-2896 method).

Higher TBN values are essential to retard the corrosive damage to metal engine parts.

Your oil supplier should be able to furnish the correct oils.

Lubricating Grease (MPG)

Use Multipurpose-type Grease (MPG). Multipurpose-type grease which contains 3% to 5% molybdenum disulfide (MPGM) is preferred. NLGI No. 2 Grade is suitable for most temperatures. Use NLGI No. 1 or No. 0 Grade for extremely low temperatures.

Engine Specifications	
Number of Cylinders	8
Bore	114 mm (4.5 in.)
Stroke	127 mm (5.0 in.)
Displacement	10.4 liters (636 cu. in.)
Firing Order	1-2-7-3-4-5-6-8
Rotation (viewed from flywheel)	Counterclockwise

Recommended Lubricant Viscosities

For Temperature Ranges °F and°C*					
Compartment or System	Oil Viscosities	Degrees F		Degrees C	
		Minimum**	Maximum***	Minimum**	Maximum***
CD/SE, CD/SF	SAE 5W-20 (SPC)	-22	+50	-30	+10
	SAE 5W-20	-13	+50	-25	+10
	SAE 10W	-4	+50	-20	+10
	SAE 10W-30	-4	+104	-20	+40
	SAE 15W-40	+5	+122	-15	+50
	SAE 30	+32	+104	0	+40
	SAE 40	+41	+122	+5	+50

*When operating below -30°C (-22°F) refer to the Cold Weather Recommendation Operation and Maintenance Guide, Form SEBU5898, available from your Caterpillar dealer.

**Ambient starting temperature.

***Ambient operating temperature.

Refill Capacities - (Approximate)

Compartment or System	U.S. Quarts	Liters	Imperial Quarts
ENGINE CRANKCASE including FILTERS[1]			
Serial No. 90N1-44127 [2]	12[2] or 14	11.5[2] or 13	10[2] or 11.5
Serial No. 90N44128-Up	14	13	11.5
Serial No. 3Z1-Up	20	19	16.5
Serial No. 29A225-Up	18	17	15
Serial No. 30A210-Up [3]	18[3]	17[3]	15[3]
Serial No. 30A210-Up [4]	20[4]	19[4]	16.5[4]
Clutch Rear Bearing	1	.9	.8
COOLING SYSTEM			
Engine Only	26	24.5	21.5
Standard Radiator	38.8	37.5	32.5
High Capacity Radiator	40	38	33.5

[1]Additional oil is required with the use of auxiliary filters. Make sure to add enough oil to fill the auxiliary oil circuit.

[2]These engines originally had an 11.5 liters (12 U.S. quarts) capacity. The dipsticks on these engines should be re-marked for 13 liters (14 U.S. quarts) capacity. Consult your Caterpillar engine dealer for procedure.

[3]Turbocharged engines WITHOUT piston cooling jets should use these refill capacities. These engines will have an engine oil cooler that is approximately 254 mm (10" long).

[4]Turbocharged engines WITH piston cooling jets should use these refill capacities. These engines will have an engine oil cooler that is approximately 356 mm (14" long).

NOTE: For remanufactured engines, use the Reference Serial No. (Ref. Ser. No.) to determine the crankcase refill capacity. Remanufactured engines with Ref. Ser. No. 90N1-44127, have the correct dipstick markings for 13 liters (14 U.S. quarts) capacity.

Oil and Filter Change Interval (Service Hours of Engine Operation)

Crankcase Refill Capacity Including Filters (U.S. Quarts)	Minimum API Oil Classification When Diesel Fuel Sulfur Content is 0.5% or Less
	CD/SE or CD/SF[1]
18 and 20 quarts (Turbocharged Engines)	300 Service Hours
18 quarts (Non-Turbocharged Engines)	300 Service Hours
14 quarts (Non-Turbocharged Engines)	200 Service Hours

[1]If fuel contains more than 0.5% sulfur use only Cd/SE or CD/SF oil with a TBN of 20 times the percentage of fuel sulfur.

Coolant Conditioner

Cooling system coolant conditioner is necessary to prevent cylinder wall pitting. Most antifreeze solutions DO NOT contain sufficient coolant conditioners. See topics "Cooling System," "Coolant, Fuel and Lubricant Specifications" and "Maintenance Recommendations" for precharge and maintenance recommendations and procedures.

Lubrication and Preventive Maintenance Schedule

NOTE: Performance of this Lubrication and Maintenance schedule is the owner's responsibility.

Item	Service	Lube.	Page
Daily			
Walk-Around Inspection	Inspect engine.		31
Engine Crankcase	Measure oil level. (Engine Stopped)	**CD/SE, CD/SF,**	31
Cooling System	Check coolant level – inspect.		32
Fuel Tank	Drain water and sediment.		32
Air Cleaner	Check air cleaner indicator.		32
Clutch Adjustment	Check adjustment.		33
Water Separator	Drain water and sediment – inspect.		33
First Oil Change Interval Only – New, Rebuilt or Remanufactured Engines			
Engine Valve Lash **NOTE:** Check and adjust at first oil change interval, then every 1200 service hours or one year.	Check and adjust valve lash at the first scheduled oil change interval, due to initial wear and seating of valve train components.		35
Every 100 Service Hours or Two Weeks, Whichever Occurs First			
Clutch Control Lever	Lubricate 2 fittings.	**MPG**	36
Pilot Bearing (Standard and Heavy Duty)	Lubricate 1 fitting.	**MPG**	36
Flywheel Clutch (Standard) (Heavy Duty)	Lubricate 1 fitting. Maintain oil at proper level.	**MPG CD**	37
Oil and Filter Change Interval Every _____ Service Hours or Three Months Whichever Occurs First **NOTE:** Make sure to fill in the number of service hours in the blank space above for the oil and filter change interval. This interval in service hours is determined by the crankcase capacity and the API classification of oil used. Refer to the two charts on preceding page.			
Engine Crankcase	Change oil and filters.	**CD/SE, CD/SF,**	38
Cooling System	Add conditioner or replace element. Clean radiator fins – inspect.		40
Fuel Filters	Replace.		41
Air Cleaner	Clean or replace elements, more often if needed.		43
Batteries	Clean – check electrolyte level.		46
Alternator, Fan and Accessory Drive Belts	Check – adjust.		47
Every 1200 Service Hours or One Year, Whichever Occurs First			
Engine Valve Lash	Check and adjust.		48
Flywheel Clutch (Heavy Duty)	Change oil.	**CD**	48
Water Separator	Replace element.		49
PCV Valve	Check diaphragms. Replace if necessary.		49
Thermostats	Replace thermostats, gaskets and seals.		50
Turbocharger (If Equipped)	Check – repair or replace if necessary.		51
Vibration Damper	Check – replace if necessary.		51
Engine Protective Devices (If Equipped)	Check by authorized personnel only.		51
Every 2400 Service Hours or Two Years, Whichever Occurs First			
Cooling System	Clean, add conditioner precharge.		52
Coolant and PCV Hoses	Replace.		53
Fuel Injection Nozzles	Test – replace if necessary.		54
Governor	Check full load speed (set point) and low idle rpm.		58
Every 4000 Service Hours			
Generator Bearing	Lubricate.	**MPG**	59
When Required			
Voltage Regulator and Generator	Clean and inspect, check space heaters, winding resistance checks.		60

PM1

PM2

PM3

NOTE: Items identified by PM-1, PM-2 and PM-3 are organized for a Preventive Maintenance Program.

Walk-Around Inspection

Inspect Engine

1. Make sure lines are properly clamped and tight. Check for loose fittings or leaks.

2. All guards must be in place. Repair or replace missing or damaged guards.

3. Disconnect any battery chargers that are not protected against the starter current drain. Check condition of batteries and the level of electrolyte.

4. Check for coolant, fuel or oil leaks on or below engine.

5. Drain water from the water separator daily before starting the engine.

6. Check condition of all belts. Replace if necessary.

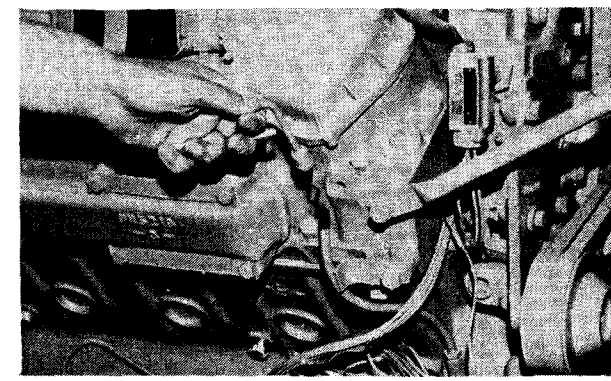
7. Check condition of gauges. Replace if cracked or if gauges can not be calibrated to zero ("0").

Engine Crankcase (Engine Stopped)

Measure Oil Level (Engine Stopped)

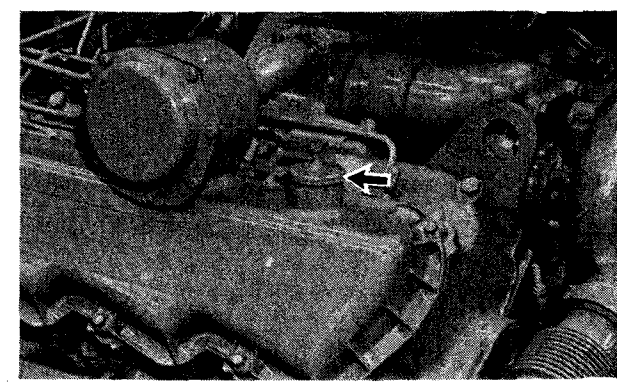
⚠ WARNING

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



1. Measure the oil level.

2. Maintain the oil level between the FULL and ADD marks on the dipstick. Do not fill the crankcase above the FULL mark.



3. Add oil if necessary.

Cooling System

Check Coolant Level — Inspect

⚠ WARNING

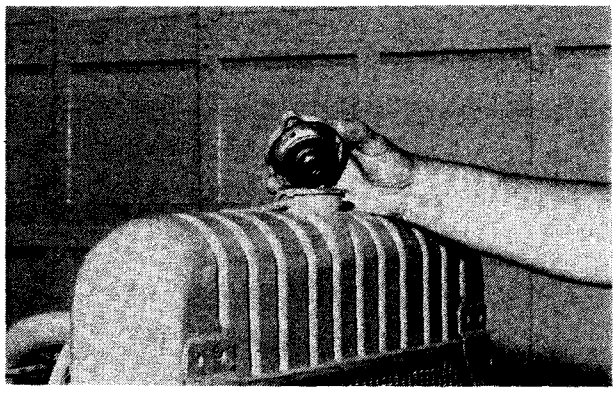
At operating temperature, the engine coolant is hot and under pressure.

Steam can cause personal injury.

Check the coolant level only after the engine has been stopped and the filler cap is cool enough to touch with your bare hand.

Remove the filler cap slowly to relieve pressure.

Cooling system conditioner contains alkali. Avoid contact with the skin and eyes to prevent personal injury.



1. Check the coolant level with the engine stopped and cold.

2. Remove the filler cap slowly to relieve any pressure.

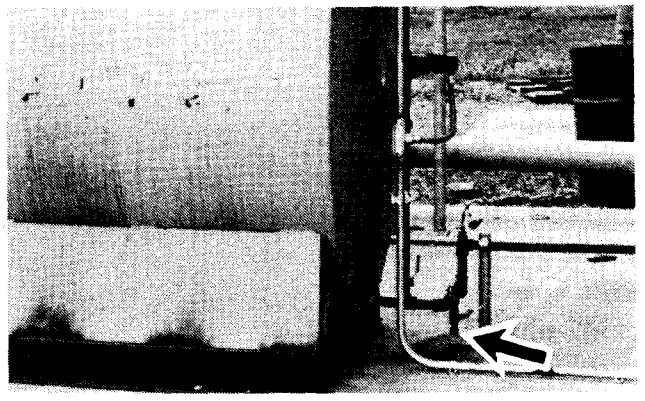
3. Maintain the coolant level within 13 mm (1/2 inch) below the bottom of the fill pipe or to the proper level on the sight glass, if so equipped.

4. Inspect the filler cap. Replace it if damaged. Install the filler cap.

5. Inspect and clean the radiator fins.

Fuel Tank

Drain Water and Sediment



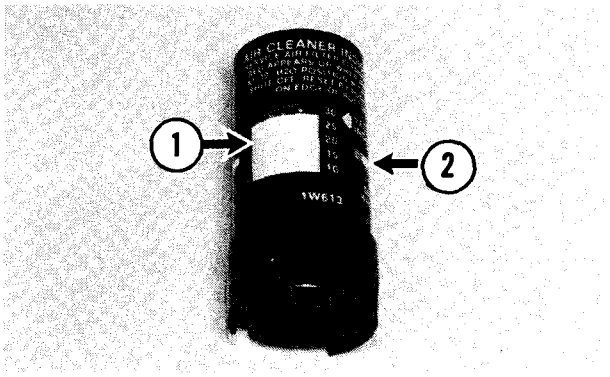
Drain water and sediment.

Air Cleaner

Check Air Cleaner Indicator

NOTICE

Service the air cleaners with the engine stopped.



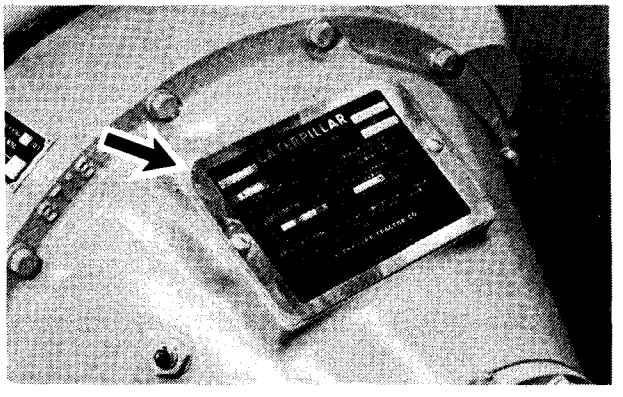
Change the air cleaner elements when the indicator diaphragm ① enters the red zone ②.

NOTE: Refer to the "Air Cleaner" section under "Oil and Filter Change Interval" for procedure to change the air cleaner elements.

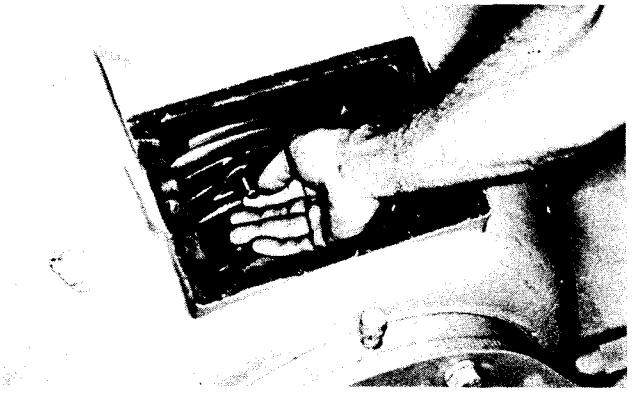
Clutch Adjustment

Check Adjustment

The clutch should engage with a hard push and a distinct snap. If the engagement is "soft," adjust the clutch.



1. Stop the engine and remove the clutch inspection cover.



2. Turn the clutch until the lock pin, engaged in the locking ring, is visible.

3. Pull the lock pin out and rotate the locking ring clockwise until the lock pin engages the next notch.

4. Test the clutch adjustment. If still too "soft," rotate the ring to the next notch. If the adjustment is too tight, turn the ring back one notch.

5. Install the cover.

Water Separator

Drain Water and Sediment

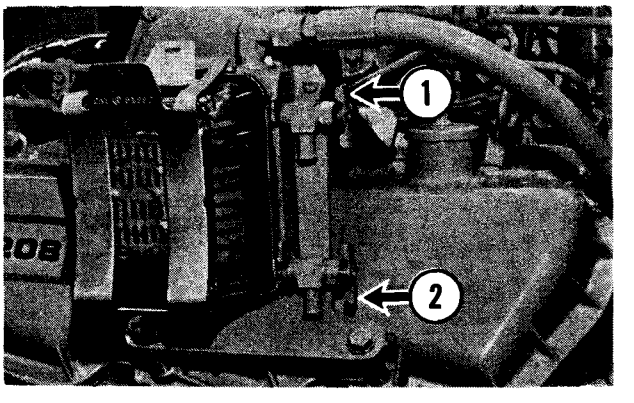
⚠ WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire.

Turn the start switch OFF when changing fuel filters or water separator elements. Drain the fuel from the water separator into a container before removing the water separator retaining clamp.

NOTICE

The engine should never be allowed to run with the water level in the separator more than 1/2 full or engine damage may result.



1. Drain water from the separator daily before starting the engine.

2. Close the fuel supply line, if equipped.

3. Open vent valve ① and drain valve ②. Allow the water to drain.

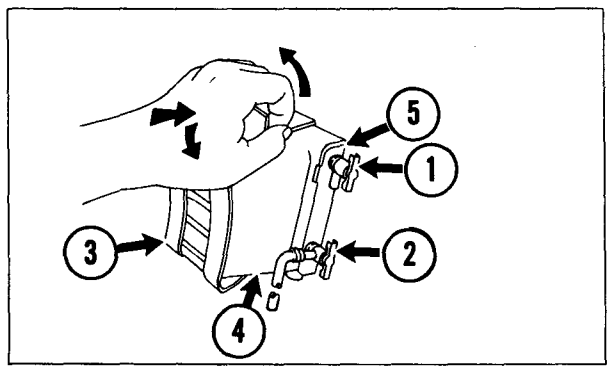
4. Close vent valve ①, drain valve ② and open the fuel supply valve, if equipped.

Replacing

NOTE: The water separator is not a filter. It separates water from the fuel.

Change element anytime the water separator becomes contaminated enough that water level cannot be seen through the transparent cover.

1. Close the fuel supply valve, if equipped.

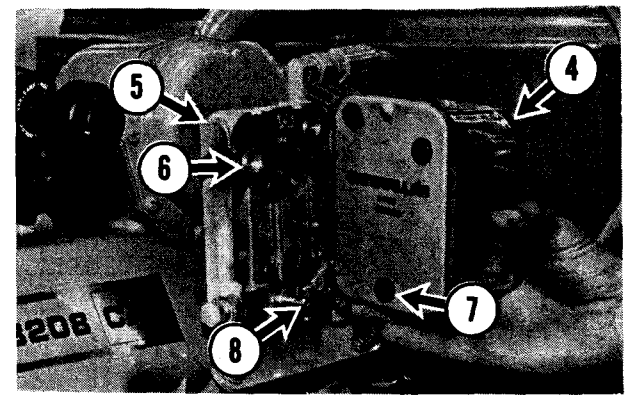


2. Remove all dirt from the separator and surrounding area.

3. Open vent valve ① and drain valve ②. Allow water to drain. Close valves ① and ②.

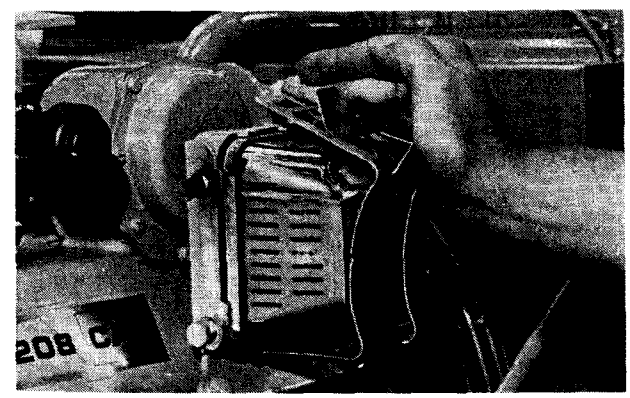
4. To remove the water separator element, depress the extended tab ③ with the heel of the hand. Then lift the slotted tab from the locking slot, at the top of the base, with the fingers. Remove the clamp.

5. Remove element ④ from base ⑤ and discard it.



6. Clean the three sealing surfaces ⑥ on base ⑤ before installing a new element.

7. Align outlet hole ⑦ and roll pin ⑧ and push new element ④ into position on the base.



8. The clamp must be installed with the hand and finger tabs in the UP position.

9. Engage lower tab of clamp in slot at bottom of separator base. While depressing clamp, with heel of hand, push upper tab into locking slot at top of base.

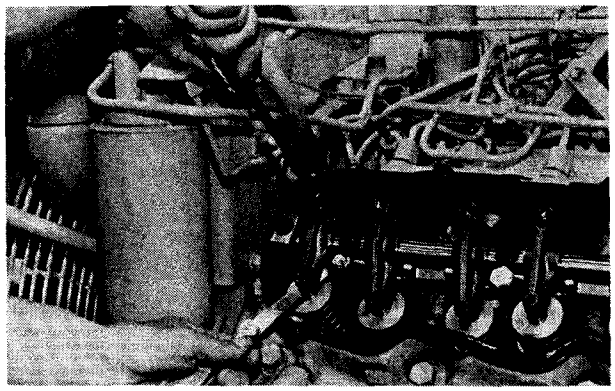
10. Open the fuel supply valve, if equipped.

11. Prime the fuel system. See "Priming the System" under item "Fuel Filters."

12. Start the engine and check for fuel leaks.

Engine Valve Lash

Check and Adjust

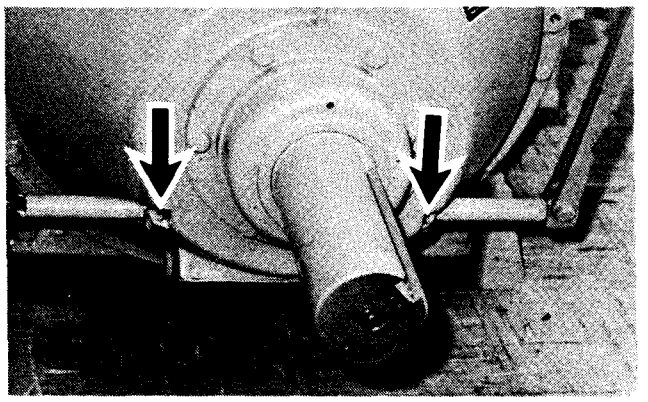


Initial valve lash adjustment on new, rebuilt or remanufactured engines is recommended at the first scheduled oil change interval, due to initial wear and seating of valve train components.

For the procedure, see topic, "Engine Valve Lash" in "Every 1200 Service Hours or 1 Year, Whichever Occurs First."

Clutch Control Lever

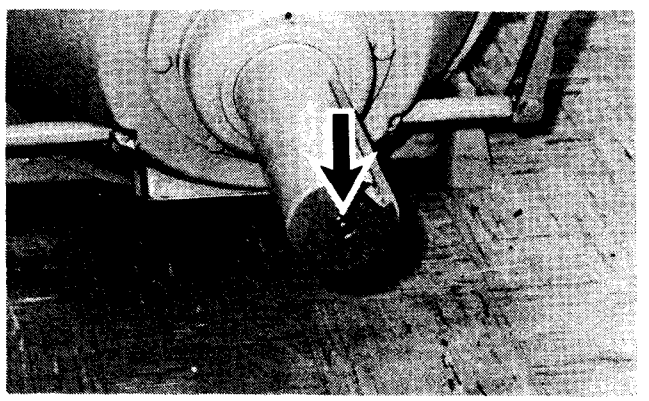
Lubricate Fittings



1. Lubricate 2 fittings; 1 fitting on each side of the clutch housing.

Pilot Bearing (Standard Clutch)

Lubricate Fitting

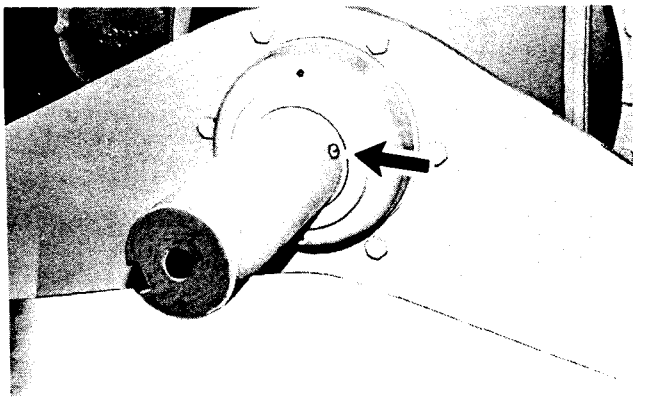


Lubricate 1 fitting at the end of shaft.

NOTE: Some clutches are furnished with a prelubricated pilot bearing, therefore no lubrication will be required.

Pilot Bearing (Heavy Duty Clutch)

Lubricate Fitting



1. Remove plug from main shaft.

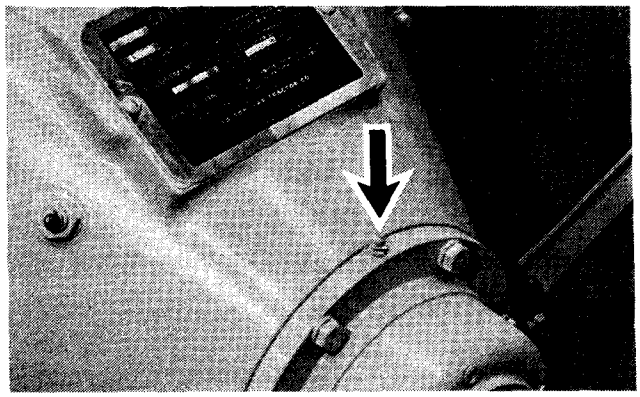
2. Insert grease fitting and lubricate bearing.

3. Remove grease fitting and install plug.

NOTE: Some clutches are furnished with a prelubricated pilot bearing, therefore no lubrication will be required.

Flywheel Clutch (Standard)

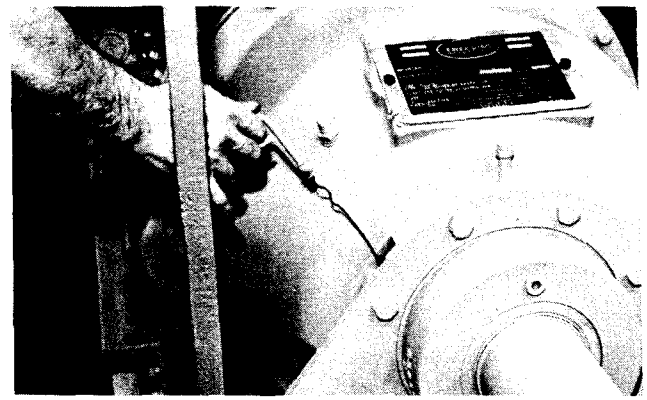
Lubricate Fitting



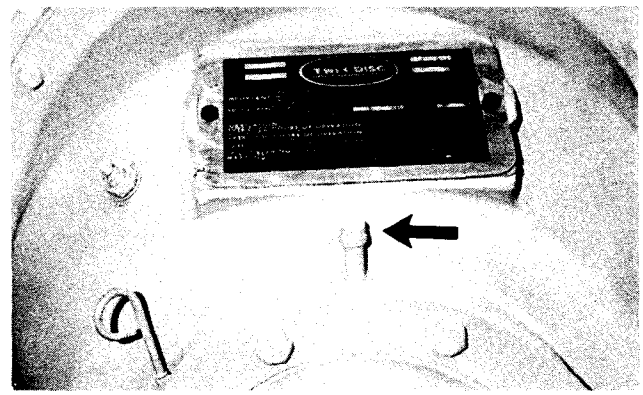
Lubricate 1 fitting on top-rear of housing.

Flywheel Clutch (Heavy Duty)

Maintain Oil Level at Proper Level



1. With the engine stopped, check the oil level. Maintain oil between the ADD and FULL marks on the dipstick.



2. Add oil if necessary. Do not overfill.

Oil and Filter Change Interval - Every _____ Service Hours or Three Months, Whichever Occurs First

Engine Crankcase

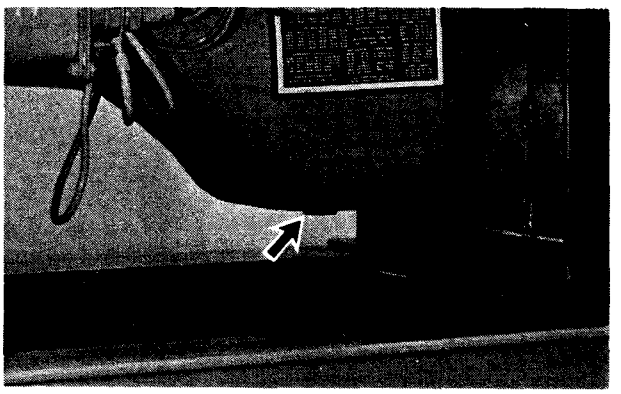
Change Oil and Filters

The percentage of sulfur in the fuel will affect the engine oil recommendations. If the fuel has over 0.5% sulfur content, the CD/SE or CD/SF engine oil must have a TBN of 20 times the percentage of fuel sulfur (TBN as measured by the ASTM D-2896 method). Your oil supplier should be able to furnish the correct oils.

⚠ WARNING

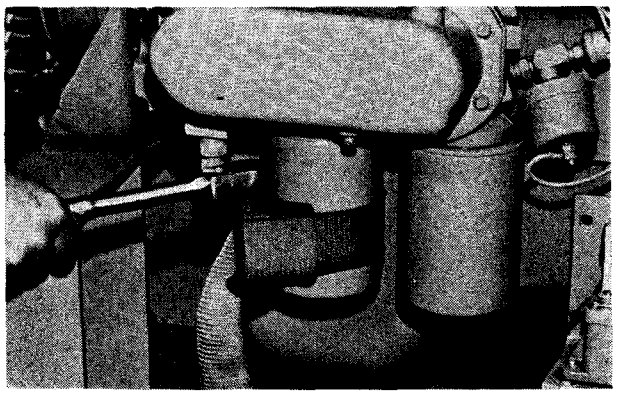
Hot oil and components can cause personal injury. Do not allow hot oil or components to contact skin.

Drain the crankcase with the oil warm and the engine stopped.

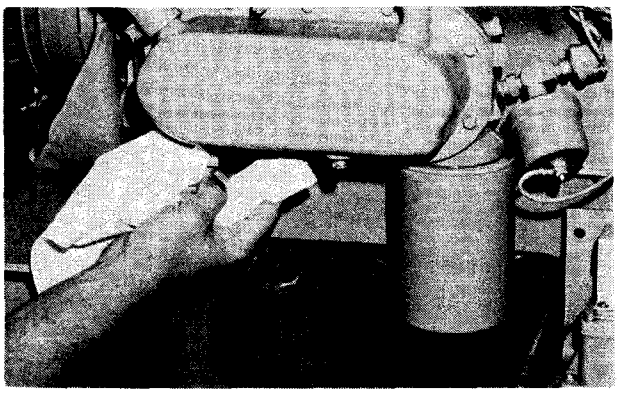


1. Remove the crankcase drain plug and allow the oil to drain.

2. Install the crankcase drain plug and tighten it to 70 ± 14 N·m (50 ± 10 lb ft).



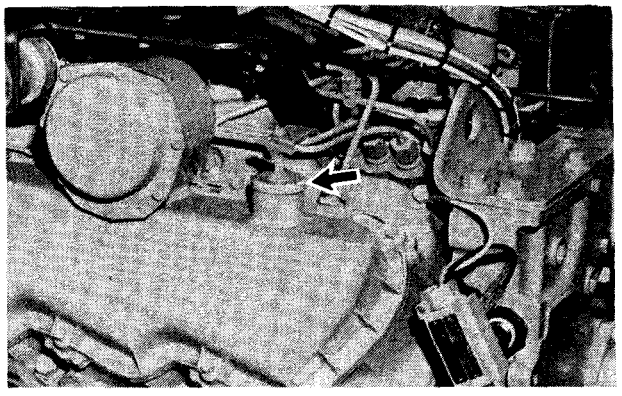
3. Remove and discard the oil filters.



4. Wipe the sealing surface of the filter element mounting base. Make sure all of the old gaskets are removed.

5. Apply a small amount of clean engine oil to the new filter element gaskets.

6. Install the new filter elements by hand until the gasket contacts the base. Tighten the filters 3/4 of a turn more with a filter wrench. Do not overtighten.

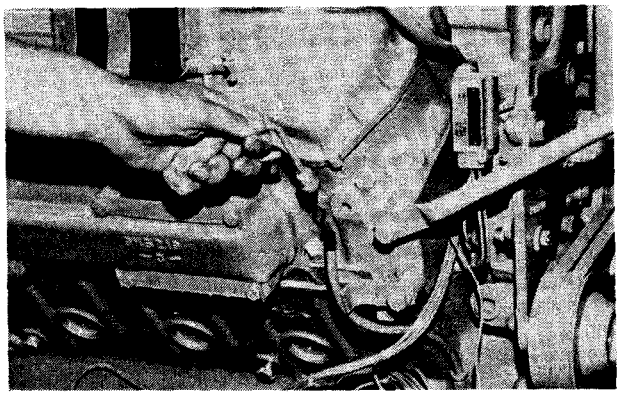


7. Fill the crankcase. See "Refill Capacities."

NOTICE

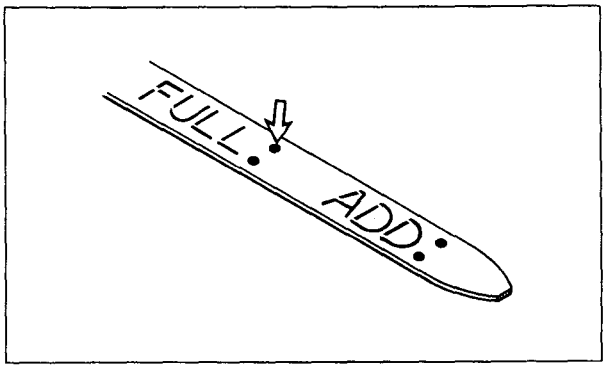
If equipped with auxiliary oil filters, extra oil must be added when filling the crankcase.

If the extra oil is not added, the auxiliary oil filter will take priority and the engine may starve for oil.



8. Before starting the engine, check the oil level. The oil level should be at or above the FULL mark on the dipstick.

9. Start and run the engine at low idle for two minutes. Inspect for oil leaks. Stop the engine.



10. Wait 10 minutes to allow the oil to drain back into the crankcase. Check the oil level. Maintain the oil level to the FULL mark on the dipstick.

Cooling System

Add Conditioner or Replace Element

⚠ WARNING

At operating temperature, the engine coolant is hot and under pressure.

Steam can cause personal injury.

Check the coolant level only after the engine has been stopped and the filler cap is cool enough to touch with your bare hand.

Remove the filler cap slowly to relieve pressure.

Cooling system conditioner contains alkali. Avoid contact with the skin and eyes to prevent personal injury.

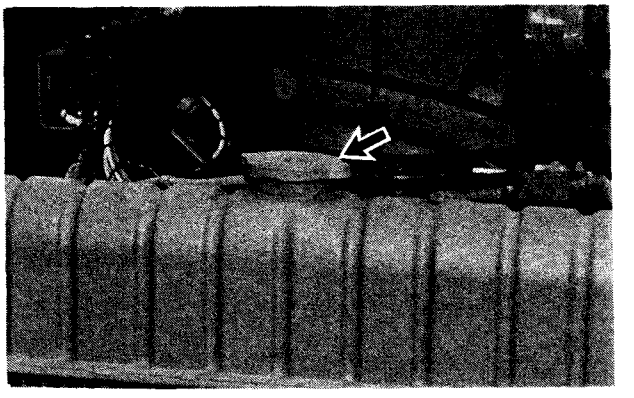
NOTICE

All water is corrosive at engine operating temperature. Use Caterpillar liquid cooling system conditioner or Caterpillar cooling system conditioner element to treat either plain water or ethylene glycol antifreeze solution.

Never use both the liquid cooling system conditioner and the conditioner element at the same time.

NOTE: See "Know Your Cooling System" Form SEBD0518 and your Caterpillar dealer for more detailed specifications.

Liquid Conditioner

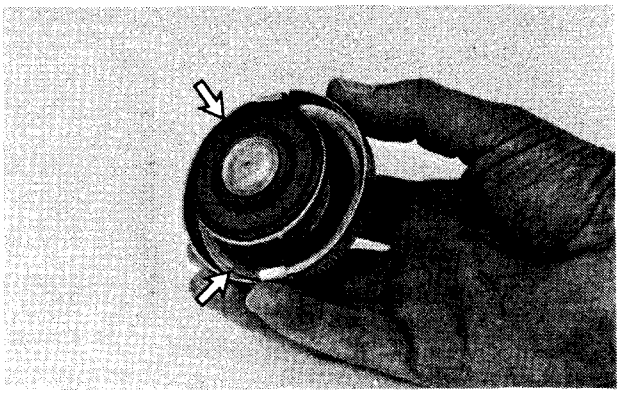


1. Loosen the filler cap slowly to relieve pressure and remove the cap.

2. It may be necessary to drain enough coolant from the radiator to allow for the addition of the liquid cooling system conditioner.

3. Add 0.24 liters (1/2 pint) of Caterpillar liquid cooling system conditioner for every 38 liters (10 U.S. gallons) of cooling system capacity.

NOTE: On new, rebuilt or remanufactured engines only or when changing the coolant, add enough liquid conditioner for a 3% to 6% concentration of conditioner. Add 0.95 liters (1 quart) for every 30 liters (8 U.S. gallons) of cooling system capacity.



4. Inspect the filler cap gaskets. Replace the cap if the gaskets are damaged. Install the filler cap.

Conditioner Element (If Equipped)

1. Close the coolant conditioner element inlet and outlet valves.

2. Remove and discard the conditioner element.

3. Clean the element mounting base. Make sure all of the old gasket is removed.

4. Coat the gasket of a new maintenance conditioner element with a thin film of engine oil. Install the new conditioner element.

NOTE: On a new, rebuilt or remanufactured engine, use a precharge conditioner element for original fill of the cooling system.

5. Open the inlet and outlet valves.

6. Remove the filler cap.

7. Start the engine and check for leaks. Allow the coolant level to stabilize.

8. Add coolant if necessary to bring the coolant to within 13 mm (1/2 inch) below the bottom of the fill pipe or to the proper level on the sight glass, if so equipped.

9. Inspect the filler cap. Replace the cap if the gasket is damaged. Install the cap.

Fuel Filters

Replace

⚠ WARNING

Fuel leaked or spilled onto hot surfaces or electrical components can cause a fire.

Turn the disconnect switch OFF or disconnect the battery when changing fuel filters.

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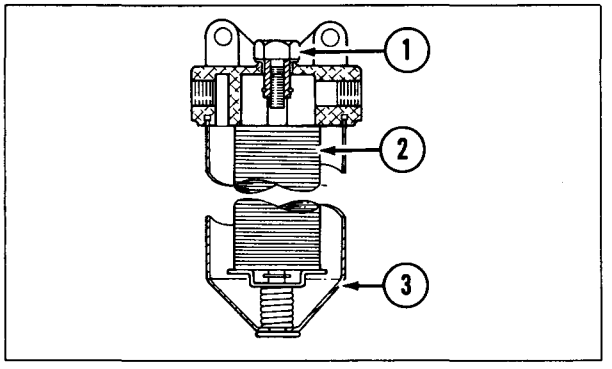
1. Stop the engine.

2. Shut off the fuel tank supply valve.

Primary Filter (If Equipped)



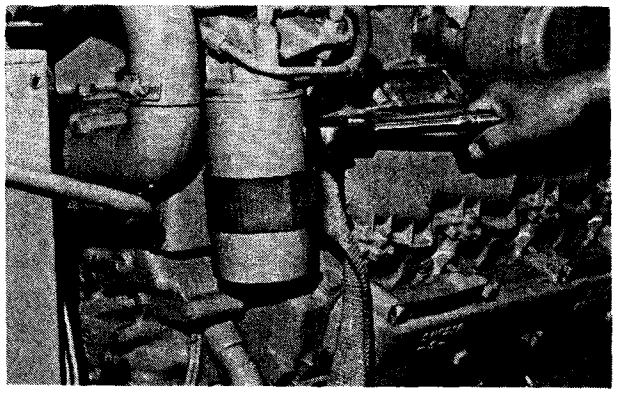
1. Loosen bolt ① on the filter housing and remove filter case ③.

2. Remove element ② and wash it in clean, nonflammable solvent.

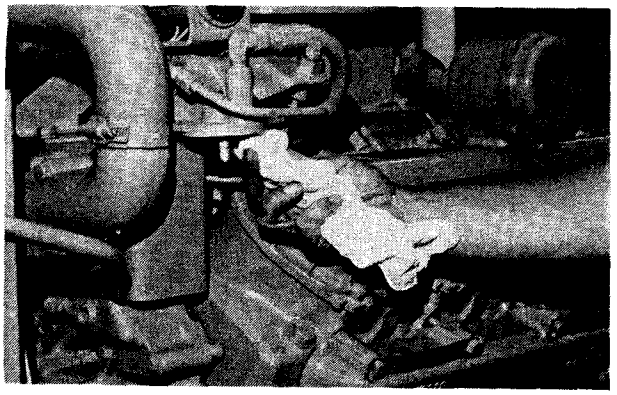
3. Install element ② and case ③. Tighten bolt ①.

Oil and Filter Change Interval - Every _____ Service Hours or Three Months, Whichever Occurs First

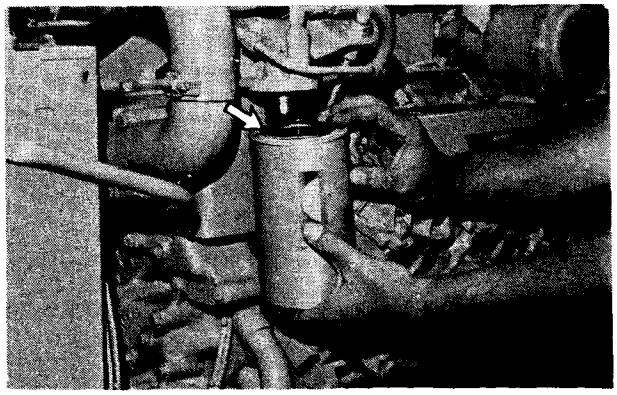
Final Fuel Filter



1. Remove and discard the fuel filter element.



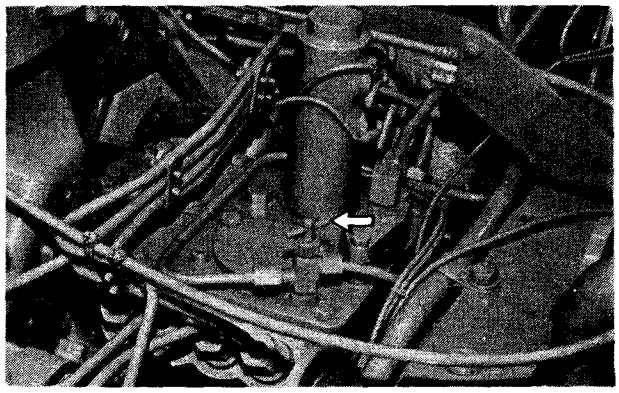
2. Clean the gasket sealing surface of the filter base. Make sure all of the old gasket is removed.



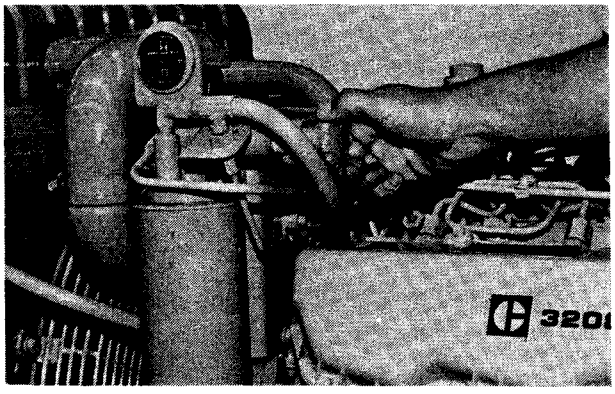
3. Apply clean diesel fuel to the fuel filter gasket.

4. Install the filter and tighten by hand until the filter gasket contacts the base. Tighten the filter 1/2 to 3/4 turn more with a filter wrench.

Priming the System



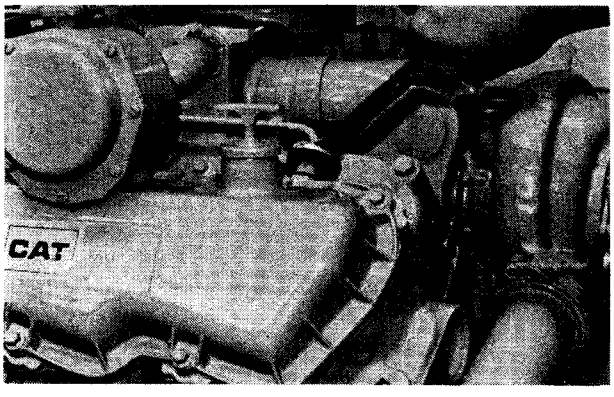
1. Open the vent valve on the fuel injection pump housing and turn on the fuel tank supply valve.



2. Unlock and operate the priming pump plunger until the flow of fuel from the vent valve is continuous and free of bubbles.

3. Close the vent valve and lock the priming pump plunger.

4. Start the engine. If the engine will not start, continues to misfire or smoke, further bleeding is necessary.



5. Loosen the fuel line nuts at the cylinder head.

6. Crank the engine until fuel flows free of air bubbles.

7. Tighten the fuel line nuts to 40 ± 7 N·m (30 ± 5 lb ft).

Air Cleaner

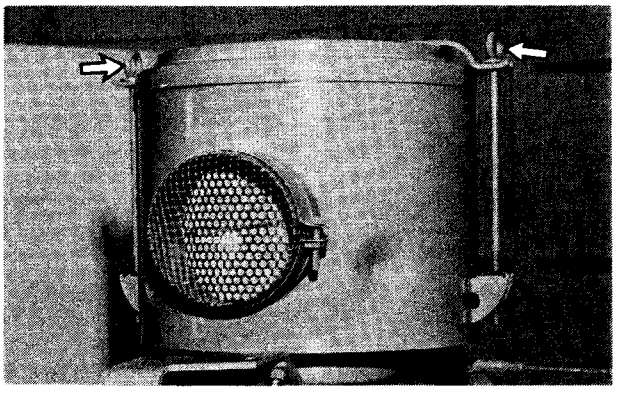
Clean or Replace Element

A service indicator may be mounted on the engine. A colored piston showing in the window indicates the need for servicing the air cleaner. Replace the filter element at least once a year.

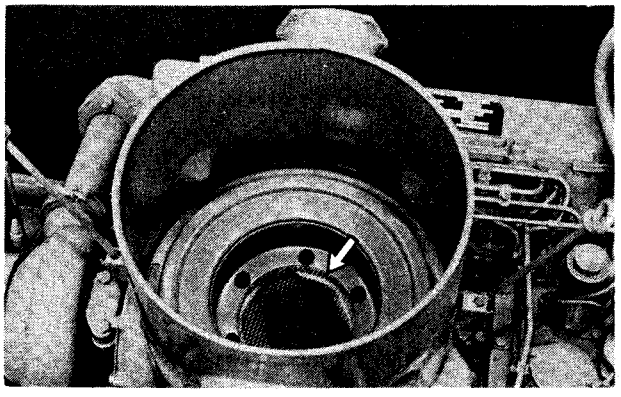
NOTICE

Never service the air cleaner with the engine running.

Changing Air Cleaner Elements

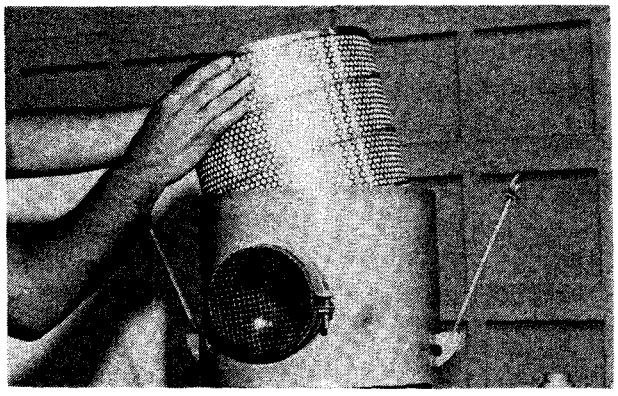


1. Loosen the rod assembly, remove the cover and element.



2. Cover the air inlet opening with tape to keep dirt out.

3. Clean the inside of the cover.



4. Remove the tape covering the inlet opening. Install either a new or cleaned filter element with the larger gasket on top.

5. Install the air cleaner cover and tighten the rod assembly.

6. Reset the service indicator by pushing on the piston plunger.

Cleaning Air Cleaner Elements

⚠ WARNING

Pressure air can cause personal injury.

When using pressure air for cleaning, wear a protective face shield, protective clothing and protective shoes.

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

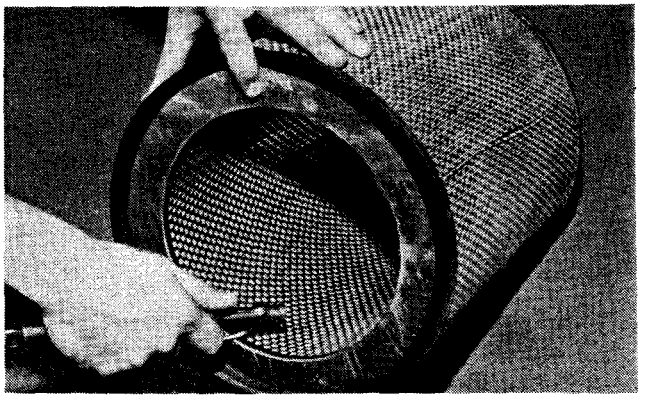
NOTICE

Do not clean filter elements by bumping or tapping.

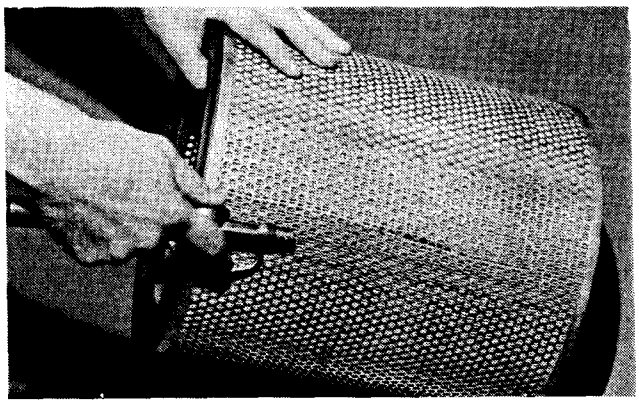
Do not use filter elements with damaged pleats, gaskets or seals.

NOTE: Air cleaner filter elements can be cleaned with either air, water or detergent. Have spare elements on hand to use while cleaning used elements.

Pressure Air — 205 kPa (30 psi) Maximum Pressure

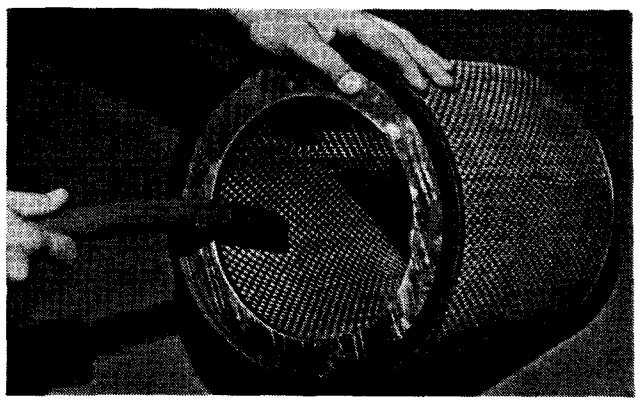


1. Direct air inside of the element along the length of the pleats.

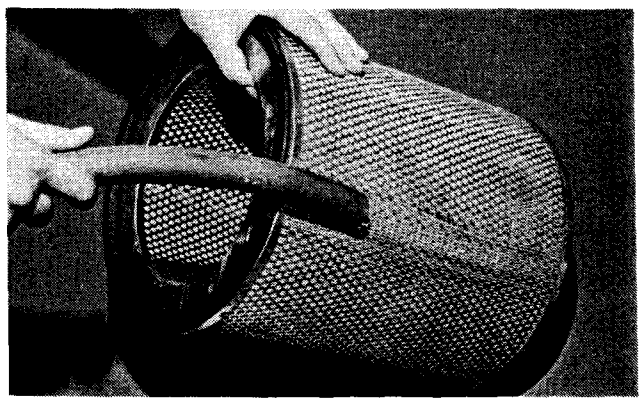


2. Direct air on the outside of the element along the length of the pleats. Direct air on the inside along the pleats. Inspect the element for any rips, tears or damage.

Pressure Water — 280 kPa (40 psi) Maximum Pressure

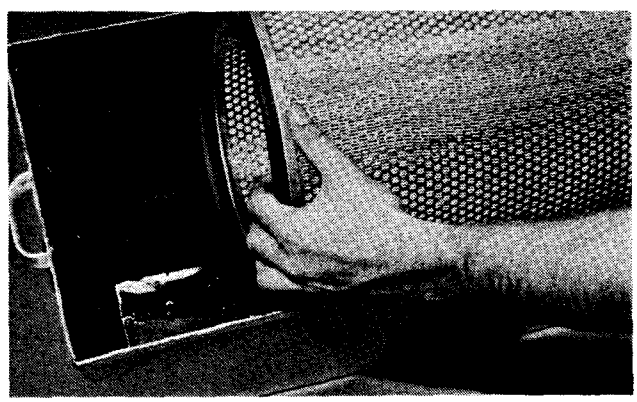


1. Direct water on the inside of the element, along the length of the pleats.



2. Direct water on the outside of the element along the length of the pleats. Air dry thoroughly before using and inspect the element.

Detergent



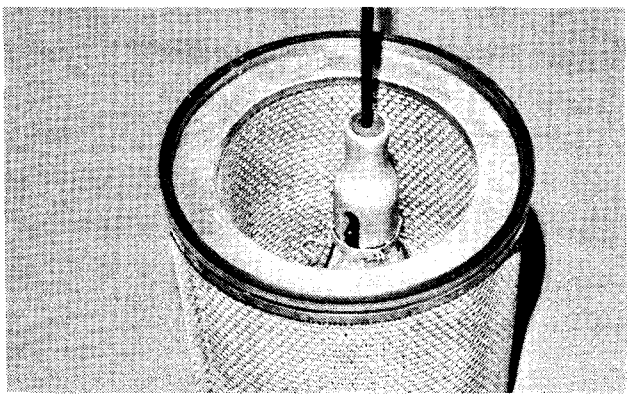
1. Wash the element in warm water and nonsudsing detergent.

2. Rinse the element with clean water. See instruction for cleaning with water.

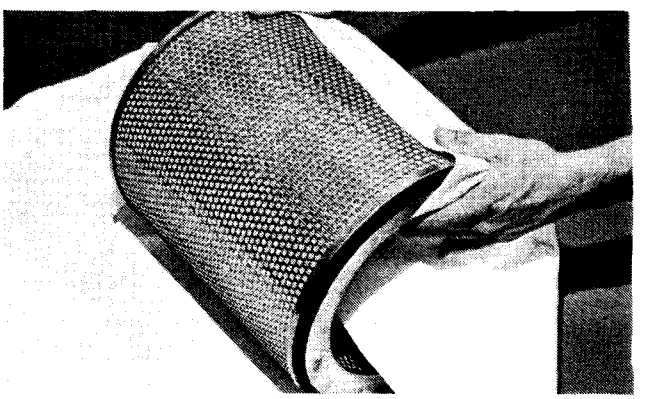
3. Air dry it thoroughly before using and inspect the element.

Oil and Filter Change Interval - Every _____ Service Hours or Three Months, Whichever Occurs First

Inspecting Element



1. Insert a light inside of the cleaned and dry element. Inspect it for rips and tears. Discard the element if damaged.



2. Wrap and store good cleaned elements in a clean, dry place.

Batteries

Clean — Check Electrolyte Level

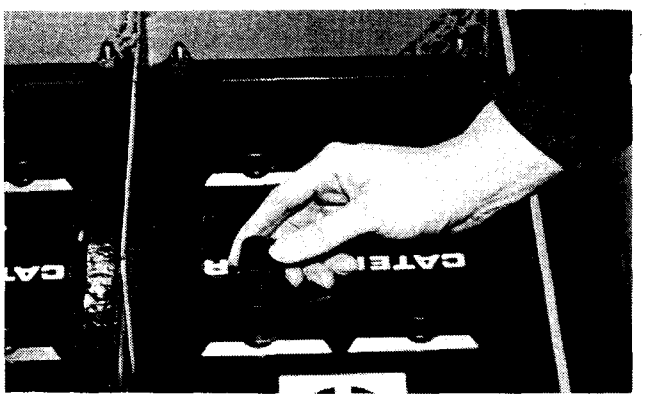
⚠ WARNING

Batteries give off flammable fumes that can explode.

Do not smoke when observing the battery electrolyte levels.

Electrolyte is an acid and can cause personal injury if it contacts skin or eyes.

Always wear protective glasses when working with batteries.



1. Clean the top of the batteries.

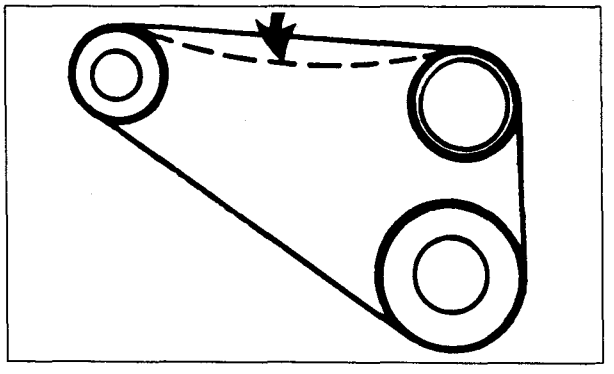
2. Remove the filler caps. Maintain the electrolyte level to the bottom of the filler openings. If an addition of water is necessary, use distilled water. If not available, use clean water, low in minerals. Do not use artificially softened water.

At proper charging rate, batteries should not require more than 30 cc (1 ounce) of water per cell per week.

3. Install filler caps.

Alternator, Fan and Accessory Drive Belts

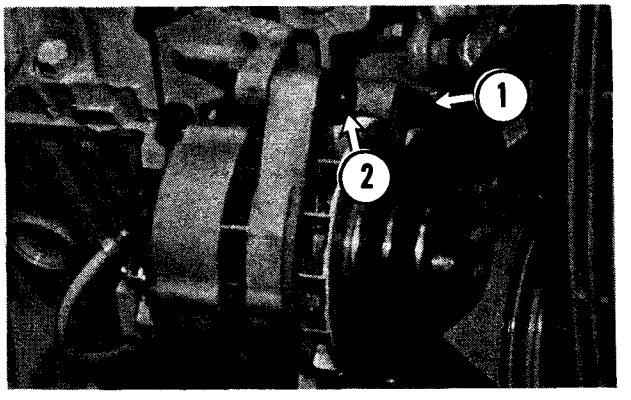
Inspect — Adjust



1. Inspect the condition and adjustment of the belts.

2. To check the belt tension, apply 110 N (25 lbs) of force midway between the pulleys. Correctly adjusted belts will deflect 13 to 19 mm (1/2 to 3/4 inch).

To Adjust



1. To adjust the alternator drive belt, loosen mounting bolt ① and the adjusting bracket bolt ②.

2. Move the alternator in or out as required to obtain the correct adjustment.

3. Tighten bolts ① and ②.

4. If new belts are installed, check belt adjustment again after 30 minutes of engine operation.

Engine Valve Lash

Measure Valve Lash (Clearance)

NOTE: Initial valve lash adjustment on new, rebuilt or remanufactured engines only, is recommended at the first scheduled oil change interval, due to initial wear and seating of valve train components.

⚠ WARNING

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

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

NOTICE

Measure the valve lash with the engine stopped. To obtain an accurate measurement, allow at least 20 minutes for the valves to cool to engine cylinder head and block temperature.

If the valve clearance is within ± 0.08 mm (.003 in) of the nominal clearance given, adjustment is not required. If the clearance is not within these limits, set the clearance as given in the chart.

Valve Clearance Setting	
Intake	0.38 mm (.015 in)
Exhaust	0.64 mm (.025 in)

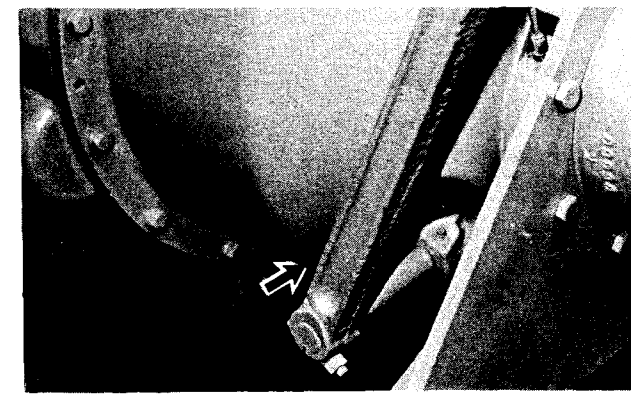
Refer to the Service Manual or your Caterpillar dealer for the complete valve adjustment procedure.

Flywheel Clutch (Heavy Duty)

Change Oil

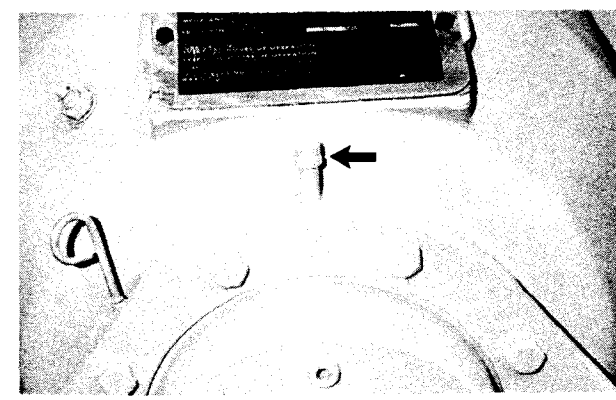
⚠ WARNING

Hot oil or components can cause personal injury if they contact skin. Use caution when draining oil or changing filters.



1. Remove the drain plug located on lower left side of the shaft bearing reservoir. Allow the oil to drain.

2. Install drain plug.



3. Add oil. See "Refill Capacities."

4. Check oil level. Level should be to FULL mark on dipstick.

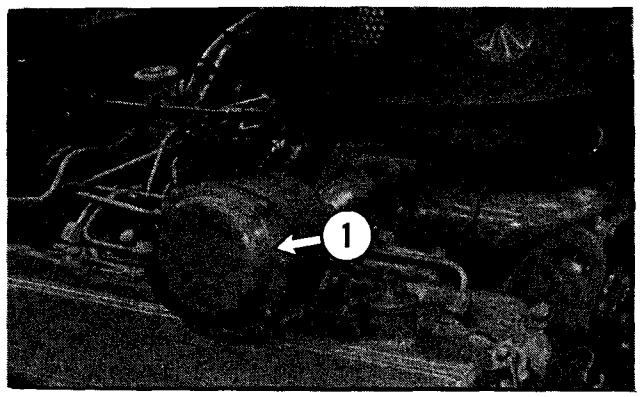
Water Separator

Replace Element

It is recommended that the water separator element be replaced at this Preventive Maintenance interval. Refer to Water Separator in the Daily Preventive Maintenance section of this guide for the proper procedure.

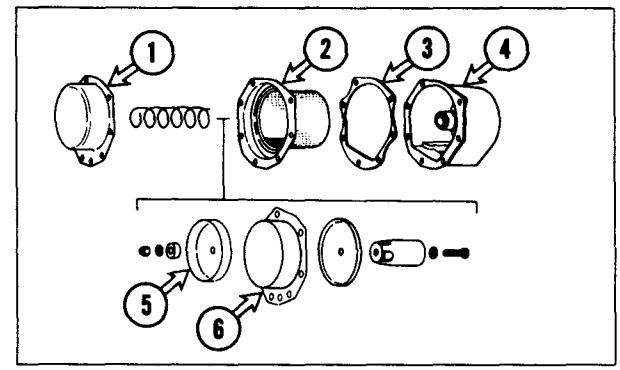
PCV Valve

Check Diaphragms - Replace If Necessary



1. Clean the outside of the PCV valve(s) and the area around it. Inspect PCV hoses for deterioration or damage, replace if necessary.

2. Remove the screws and washers that hold cover ① in place.



3. Remove cover ① and the spring.

4. Remove the diaphragm assembly, inner sleeve ② and gasket ③ from housing ④.

5. Disassemble the diaphragm assembly.

6. Clean and inspect all parts. Replace any part that is worn or damaged. Always install a new gasket and diaphragm when the PCV valve is disassembled.

7. Assemble the diaphragm assembly using a new diaphragm ⑥.

8. To prevent diaphragm ⑥ from distorting and tearing during assembly, coat both flange sides of the diaphragm with gasket cement. Install it with the side marked "piston face" towards piston ⑤.

9. Coat new gasket ③ with gasket cement and install it against the rear face of inner sleeve ②.

10. Install the diaphragm assembly in housing ④.

11. Install the spring and cover ① with the washers and screws that hold cover ① in place.

Thermostats

Replace Thermostats, Gaskets and Seals

⚠ WARNING

At operating temperature, the engine coolant is hot and under pressure.

Steam can cause personal injury.

Check the coolant level only after the engine has been stopped and the filler cap is cool enough to touch with your bare hand.

Remove the filler cap slowly to relieve pressure.

Cooling system conditioner contains alkali. Avoid contact with the skin and eyes to prevent personal injury.

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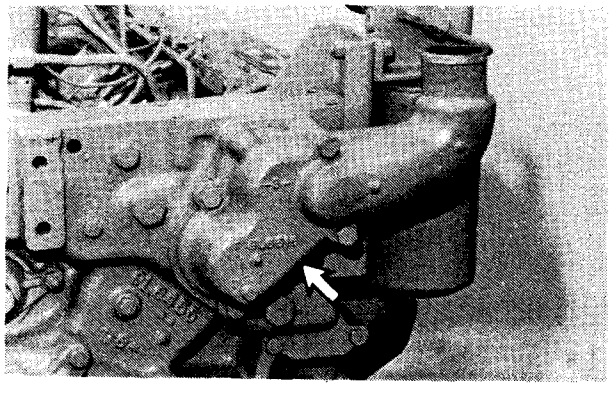
1. Loosen the filler cap slowly to relieve any pressure and remove the cap.

2. Drain the coolant from the cooling system to a level below the thermostat housing.

3. Loosen the hose clamps and remove the radiator hose from the thermostat housing.

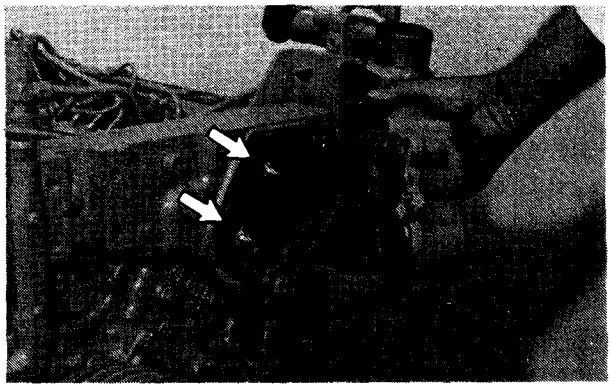


4. Remove the thermostat housing from the engine block.

5. Remove the thermostats and gasket from the engine block. Remove thermostat and seal from thermostat housing

6. Replace thermostats and gasket.

NOTE: The thermostats should begin opening (bench test in atmospheric pressure) at approximately 80°C to 84°C (176°F to 183°F). The thermostats should be fully open at approximately 90°C to 94°C (194°F to 201°F).



7. Install new thermostats in the engine block.

NOTE: Former thermostats may be reused, if they meet test specifications above and are not damaged or have excessive buildup of deposits.

8. Install a new gasket and the thermostat housing on the engine block.

9. Install the radiator hose and tighten the hose clamps.

10. Add coolant to the cooling system to bring it to the proper level.

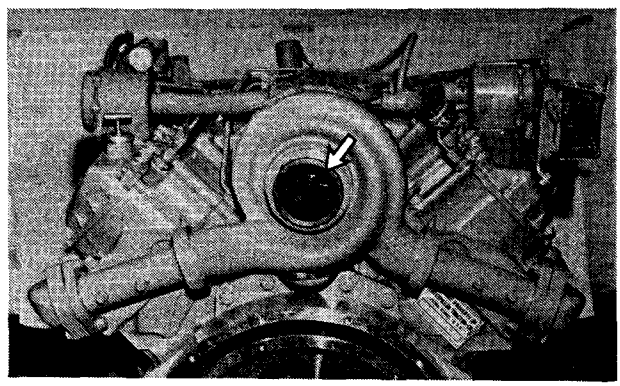
11. Start the engine and inspect for leaks and proper operating temperature.

Turbocharger (If Equipped)

Check — Repair or Replace If Necessary

1. Remove the exhaust outlet piping from the turbocharger.

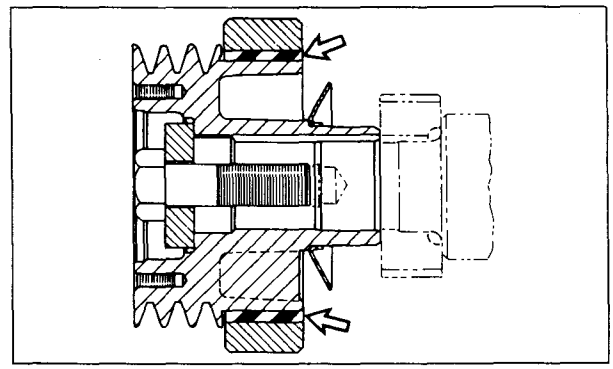
2. Turn the turbine and compressor wheel by hand. The assembly should turn freely.



3. If the assembly does not turn freely, refer to the Service Manual or consult your Caterpillar dealer.

Vibration Damper

Check



1. Inspect for separation of the rubber ring, between the inner hub and the outer ring.

2. Replace the vibration damper if there is separation or damage to the rubber ring.

Engine Protective Devices (If Equipped)

Check By Authorized Personnel Only

It is important that the shut-off switches be in good working order because they operate only in time of a mechanical emergency, it is impossible to tell if they are in good working order through normal operation.

Have them checked at regular intervals by your Caterpillar dealer.

Cooling System

Clean and Change

⚠ WARNING

At operating temperature, the engine coolant is hot and under pressure.

Steam can cause personal injury.

Check the coolant level only after the engine has been stopped and the filler cap is cool enough to touch with your bare hand.

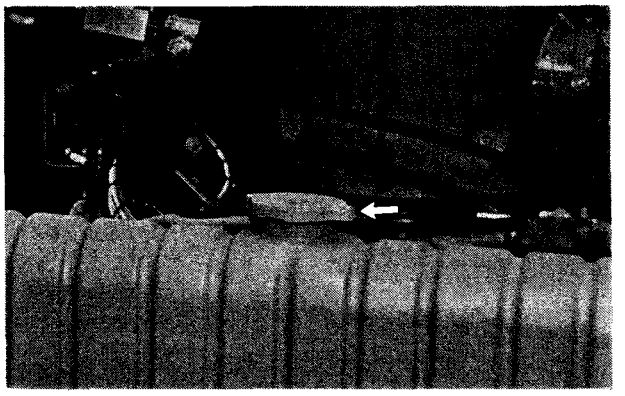
Remove the filler cap slowly to relieve pressure.

Cooling system conditioner contains alkali. Avoid contact with the skin and eyes to prevent personal injury.

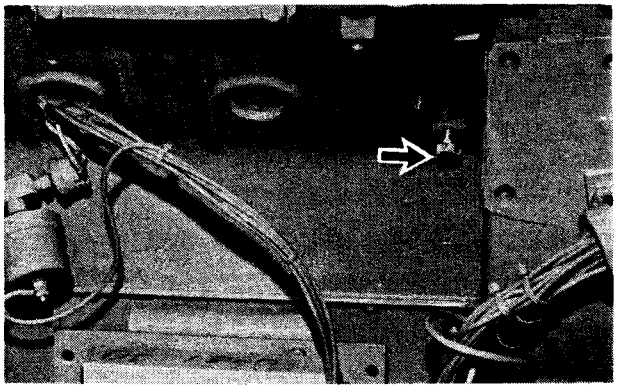
NOTICE

If the engine is to be stored in, or shipped to an area with below freezing temperatures, the cooling system must be either protected to the lowest expected outside temperature or drained completely to prevent damage.

Do not use Caterpillar cooling system conditioner or coolant conditioner elements with Dowtherm 209 Full-Fill coolant. Follow recommendations provided with Dowtherm 209 Full-Fill coolant.



1. Loosen the filler cap slowly to relieve any pressure and remove the cap.



2. Remove the cooling system drain plugs or open the drain valve and allow the coolant to drain.

3. Install the drain plugs or close the drain valve.

4. Fill the cooling system with a cleaning solution. Use a commercially available cleaner or 1 kg (2 lb) sodium bisulphate per 40 liters (10 U.S. gallons) water.

5. Start and run the engine 1/2 hour. Stop the engine and drain the cleaning solution.

6. Flush the system, with engine stopped, with water until the draining water is clear.

7. Install or close the drain valve. Fill the system with a commercially available neutralizer or 250 g (1/2 lb) sodium carbonate per 40 liters (10 U. S. gallons) water.

8. Start the engine and run it for 10 minutes. Stop the engine and drain the neutralizing solution.

9. Flush the system with clean water until draining water is clear. Replace thermostats. See page 50.

10. Mix a solution of acceptable water, antifreeze and cooling system conditioner or if equipped with a coolant conditioner element, install a precharge element. Add 0.95 liters (1 quart) of Caterpillar cooling system conditioner per 30 liters (8 U.S. gallons) of cooling system capacity (for a 3% to 6% concentration).

NOTICE

If the engine is equipped with a Caterpillar coolant conditioner element, to prevent over inhibiting do not use both the liquid cooling system conditioner and the coolant conditioner element at the same time.

11. Fill the cooling system with the coolant solution at 20 liters (5 U.S. gallons) per minute or less to avoid air locks.

12. Start and run the engine with the filler cap removed. Allow the coolant to warm and the level to stabilize.

13. Add coolant if necessary to bring the coolant level to the bottom of the fill pipe or to the correct level on the sight glass.

14. Check the condition of the filler cap gasket. Replace it if damaged. Install the filler cap.

Coolant and PCV Hoses

Replace

⚠ WARNING

At operating temperature, the engine coolant is hot and under pressure.

Steam can cause personal injury.

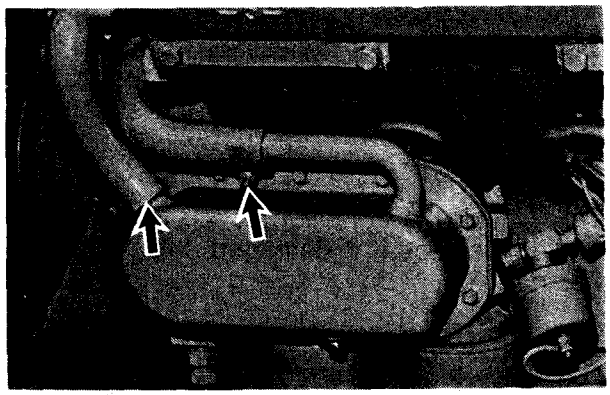
Check the coolant level only after the engine has been stopped and the filler cap is cool enough to touch with your bare hand.

Remove the filler cap slowly to relieve pressure.

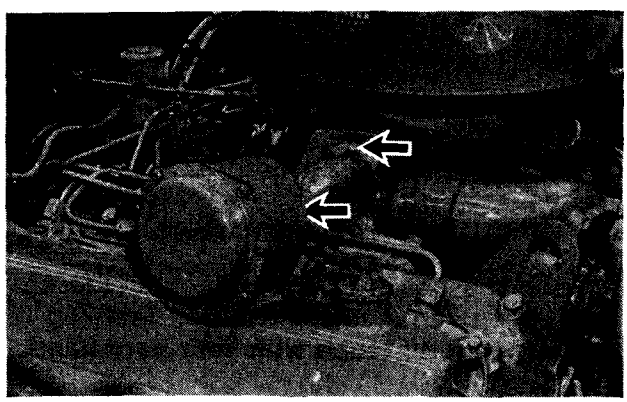
Cooling system conditioner contains alkali. Avoid contact with the skin and eyes to prevent personal injury.

1. Loosen the filler cap slowly to relieve any pressure and remove the cap.

2. Drain the coolant from the cooling system to a level below the oil cooler.



3. Loosen the hose clamps and remove the oil cooler hoses and discard.



4. Loosen the hose clamps and remove the hoses from PCV valves on both sides of the engine.

5. Install all new coolant and PCV hoses and tighten the clamps.

6. Add the coolant to the cooling system.

7. Start and run the engine with the filler cap off. Allow the coolant to warm and stabilize.

8. Add coolant if necessary to bring the coolant level to the proper level. Install the filler cap.

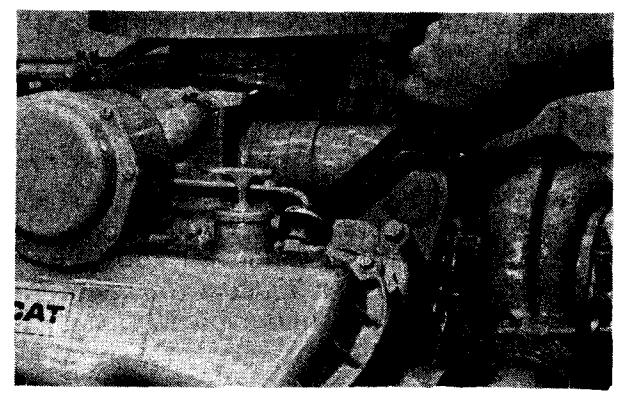
9. Check for coolant leaks at the oil cooler connections. Stop the engine.

Fuel Injection Nozzles

Test — Replace If Necessary

Whenever the engine performs in such a manner that a fuel injection nozzle is suspected of causing irregular running, smoking or knocking, isolate each fuel injection nozzle, one at a time, to determine the malfunctioning nozzle.

NOTE: For complete fuel injection nozzle testing and cleaning, consult your authorized Caterpillar engine dealer.



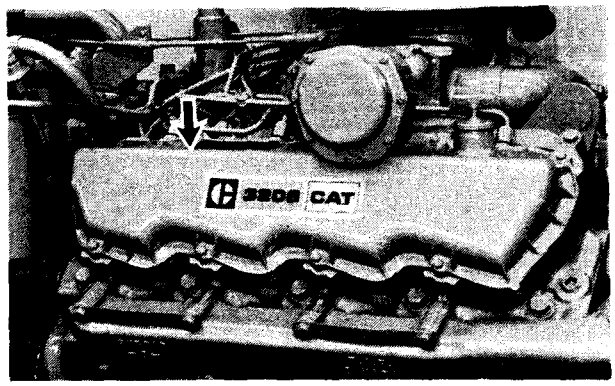
1. Loosen the fuel injection line nut at the cylinder head, one at a time, with the engine running. Be sure to tighten each fuel line nut after the test, before the next fuel line nut is loosened.

2. When a cylinder is found where the loosened fuel line nut does not make a difference in engine performance or smoking, have that cylinder injection nozzle tested.

To Remove Injection Nozzles

1. Clean the area around the valve cover.

2. Loosen the hose clamp and disconnect the hose from the PCV valve(s).



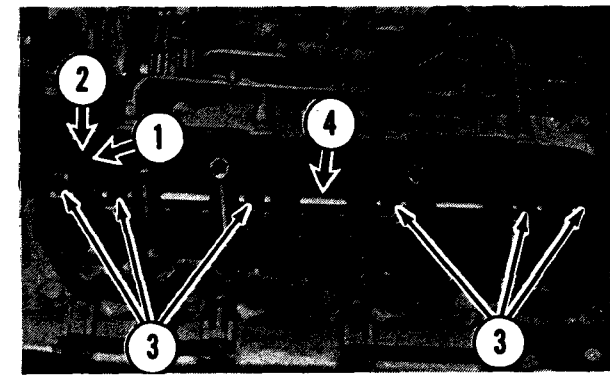
3. Remove the valve cover.

NOTE: On later engines it is NOT NECESSARY to loosen the valve adjusting locknuts or to remove the rocker arm assemblies (steps 4 and 5). These later engines have a different type of nozzle with the fuel line routed OVER the rocker arm assembly. These nozzles may be removed without disturbing the valve mechanism. DO NOT REMOVE the fuel line from these nozzles.

Engines with these new nozzles also have new fuel injection lines with a larger inside diameter. They can be identified by the notched nuts on the fuel injection lines.

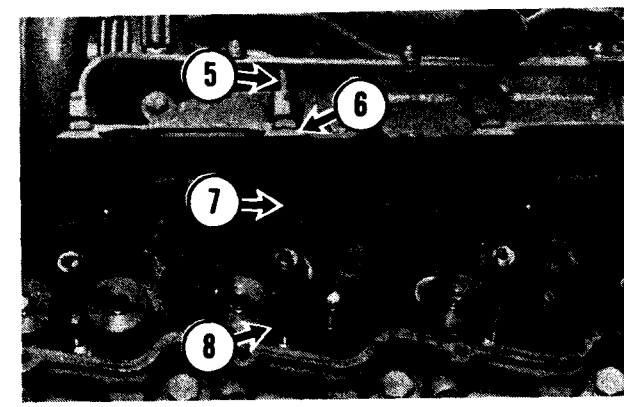
The new nozzles and fuel injection lines were effective with 90N65055, 29A789, 3Z3472 (except Sperry-New Holland TR95 Combine which was effective with 3Z3923), and 30A1176 (except engine arrangement 7W8603 which does not use the new nozzles and lines).

The new nozzles require a 6V6976 Puller Group for nozzle removal. Nozzle and fuel line are removed and tested as an assembly. To remove nozzle and fuel line assembly proceed to step 6.



4. Loosen the valve adjusting screw locknuts ①. Turn adjusting screw ② counterclockwise until there is some clearance between the push rod end and the adjusting screw ②. Remove six bolts ③.

5. Remove rocker arm assembly ④.



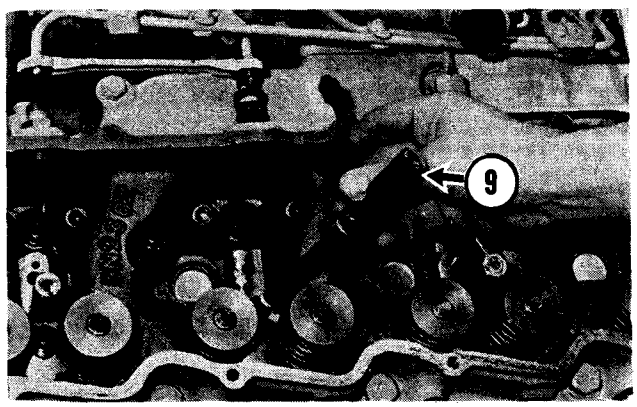
6. Thoroughly clean the area around each fuel line connection. Disconnect fuel line ⑤ from adapter ⑥.

7. Disconnect injection nozzle line ⑦ from adapter ⑥. Slide adapter ⑥ out of the cylinder head.

8. Remove clamp ⑧ and the spacer that holds the fuel injection nozzle in place.

NOTICE

Never use force to remove the fuel injection nozzles. Turn and pull the fuel injection nozzles straight out by hand. Never pry with a screwdriver or similar tool. Use 6V4061 Nozzle Pulling Group for difficult to remove nozzles.



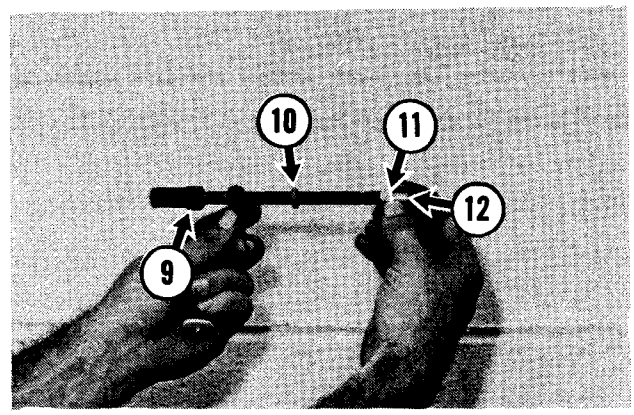
9. Remove fuel injection nozzles (9) from the cylinder head.

10. Have fuel injection nozzles (9) tested by an authorized Caterpillar engine dealer.

To Install Injection Nozzles

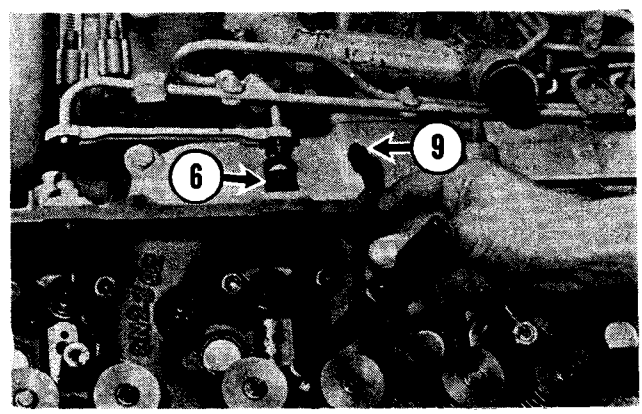
NOTICE

Never install an injector that has been dropped without first testing it. Examine the tip to be sure it is not broken or cracked. Using the Caterpillar 6V3020, 20X scope, provides a close examination of the nozzle tip and orifices.



1. Install a new seal washer (10) and carbon dam (11) with 6V4979 Carbon Seal Tool (12) on fuel injection nozzle (9).

2. Make sure the bore in the cylinder head and the fuel inlet fittings are clean.

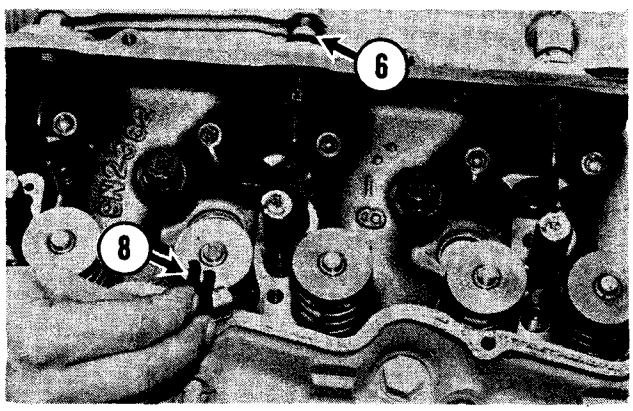


3. Install new O-ring seals on adapter (6) and fuel injection nozzle (9).

NOTICE

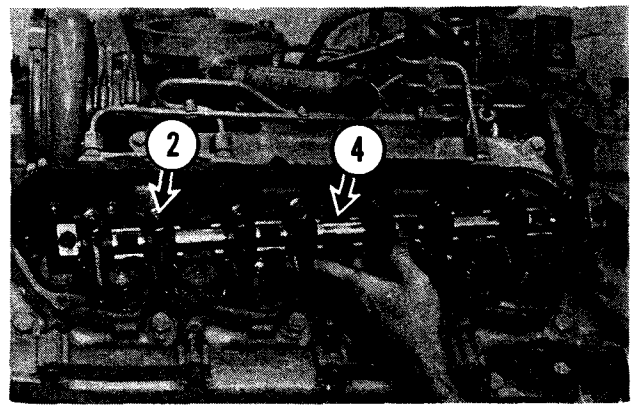
Do not bend the injector inlet line when installing injector into the cylinder head. Bending of the inlet line creates tension on the injector and can cause binding of the needle in the guide and can result in injector failure.

4. Install fuel injection nozzle ⑨ in the cylinder head. Turn and push the nozzle into its correct position. Never put lubricant on the nozzle or bore in the cylinder head.



5. Install adapter ⑥ in the cylinder head. Connect the nozzle and fuel injection lines to the adapter. Tighten the fuel line nuts to 40 ± 7 N·m (30 ± 5 lb ft).

6. Install the spacer and clamp ⑧ that hold the fuel injection nozzle in place.



7. Put rocker arm assembly ④ into position. Make sure that valve adjusting screws ② are loose and do not bind with the push rods during installation.

8. Tighten the rocker shaft mounting bolts to 24 ± 7 N·m (18 ± 5 lb ft).

9. Adjust the valves, see item "Engine Valve Lash."

10. Purge the fuel lines of air.

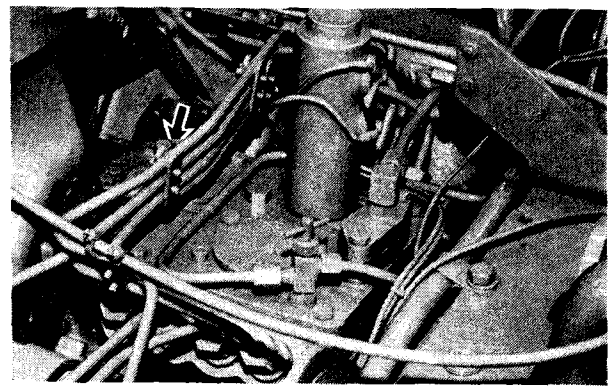
11. Start the engine and check for any fuel leaks. Stop the engine and correct any fuel leaks that may occur.

12. Install the valve cover and tighten the bolts in sequence to 14 ± 3 N·m (10 ± 2 lb ft).

13. Connect the hose to the PCV valve(s).

Governor

Check Full Load Speed (Set Point) and Low Idle RPM

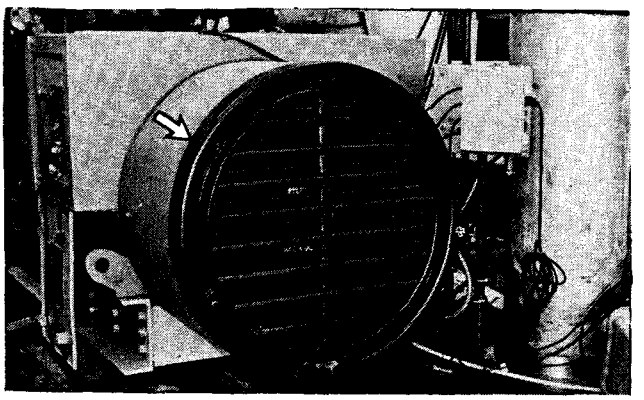


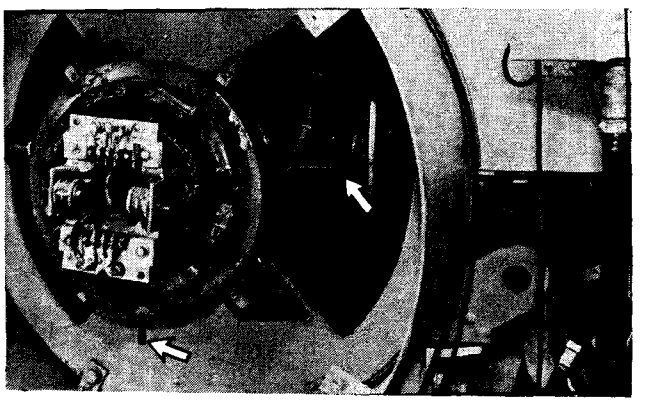
NOTICE

These adjustments are to be made only by an authorized Caterpillar engine dealer or a mechanic that has the correct training.

Generator Bearing

Lubricate





1. Remove the cowl cover from the rear of the generator housing.

2. Remove the right side and lower grease pipe plugs.

3. Install a grease fitting in the right side threaded grease pipe.

4. Lubricate all small frame generators with a grease gun using two (2) pumps of grease.

Use Multipurpose-type Grease (MPG). NLGI No. 2 Grade is suitable for most temperatures. Use NLGI No. 1 or 0 Grade for extremely low temperatures.

5. Install the lower plug. Wipe off excess grease.

6. Remove the fitting from the right side grease pipe.

7. Start the engine and allow the grease to expand.

8. Stop the engine. Install the plug in the right side grease pipe and wipe off excess grease.

9. Install the cowl cover.

Voltage Regulator and Generator

Clean and Inspect

⚠ WARNING

Before working inside the generator, make sure that the starter motor can not be activated by any automatic or manual signal.

When the engine-generator is operating, voltages up to 600V are present in these areas near or on the regulator:

1. the regulator terminal strip
2. the excitation transformer terminal strip (self-excited generator only)

Do not short these terminals to ground with any part of the body or any conductive material. Loss of life or injury could result from electrical shock or injury from molten metal.

An electrical shock can be received from the regulator capacitor (C1) when the engine-generator is not in operation. To avoid possible injury, discharge the stored charge using an 100 ohm resistor across C1 terminals.

NOTICE

Electronic components in the regulator can be damaged during generator operation if contact is made between the part and ground.

If moisture is allowed to remain in contact with an electrical winding, some of the moisture will eventually be absorbed. This will lower the resistance of the winding insulation. The insulation used on the windings of Caterpillar generators is moisture resistant, but constant exposure to moisture will gradually lower the insulation's resistance.

Dirt can make the problem worse because it can hold the moisture in contact with the insulation. Salt (from sea air) can also make the problem much worse. This is because salt tends to absorb moisture from the air. When the salt and moisture combine, they make a good electrical conductor.

Clean the voltage regulator and generator of dirt and debris. Use a brush to loosen accumulations of dirt and a vacuum system for removal. Use of compressed air is not recommended, because of moisture present in the form of condensate.

Carbon tracking on insulators can be caused by dirt or loose connections. These carbon paths must be cleaned or the insulators replaced. Failure to correct a carbon tracking problem will eventually result in a short in the electrical circuit.

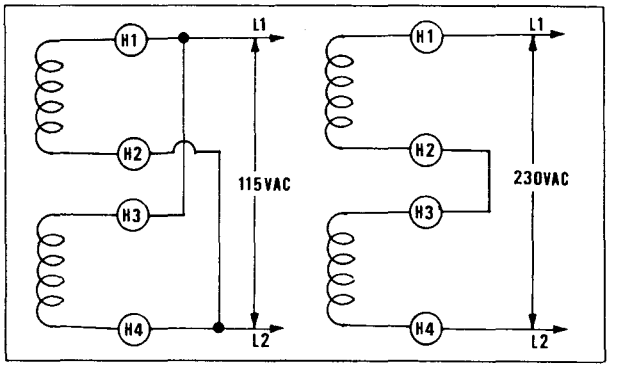
Visually check for loose or broken wires and connections. Check the wires and connections on the regulator assembly. Check that all circuit boards are fully plugged in their sockets. Check all wires and connections in the generator. Make any necessary repairs to the wiring as required. Refer to the "Electric Set Generator Service Manual" for testing and adjusting or disassembly and assembly procedures.

Space Heaters

The SR4 generator can operate in high humidity conditions without problems. However, problems can occur when the generator is idle and the surrounding air is warmer than the generator. Moisture can form on the windings and result in poor performance and even result in damage to the windings. Whenever the generator is not in use, insure that the space heaters are in operation.

An external source of either 115 or 230 (200 v at 50 Hz) volts A.C. is required to operate the space heaters.

Space Heater Connection to External Source H1, H2, H3, H4. Terminal Strip Terminals



If 115 VAC source is available, connect both heaters in parallel across the source (L1-L2). If 230 VAC source is available, connect both heaters in series across the source (L1-L2).

Recommended Periodic Insulation Resistance Checks

Use a megohmmeter to check generator winding insulation resistance periodically. The frequency of the megohmmeter test is determined by the generator's environment and by previous megohmmeter test indications.

Megohmmeter test every 6 months if the generator is installed in an enclosed area with relatively low humidity and minimal temperature variations.

Megohmmeter test every 3 months if the generator is not protected from the elements by an enclosed area.

Megohmmeter test every week and use space heaters if the generator is exposed to a sea water environment or if the surrounding conditions are very humid (relative humidity above 75%) or if a recent megohmmeter test reading was less than 3megohms. In applications where salt and high hunidity are present, space heaters must be operated whenever the generator is not operating under load. This is the only way to maintain megohmmeter test readings above 1 megohm.

Refer to the Testing and Adjusting section of the "Electric Set Generator Service Manual" for the proper procedure to test the windings.

Preventive Maintenance Recommendations for Standby Generator Sets

Information relating to maintenance procedures is included in this engine guide. Further information is available in the Service Manual, or consult your Caterpillar dealer.

Standby Generators

Standby generator sets may not be needed very often, but when they are, it is usually under emergency conditions. Maintenance of these standby units is very important. They must always be in excellent operating condition, ready to work under load at any time. It is recommended that the following Preventive Maintenance Program be established.

⚠ WARNING

The stop-manual-automatic switch on the cranking panel must be set at "stop" position when performing maintenance or repair work on a standby generator set. This prevents the unit from starting if a power failure or voltage drop should occur while working on the unit. Failure to comply could result in personal injury or death.

Make any necessary repairs with the engine stopped and the starting system disabled.

Maintain a log or a record keeping system to document all gauge readings, problems, repairs and maintenance performed on the equipment.

Space Heaters

Moisture is a natural enemy of generators and all electrical equipment. Every effort must be made to keep the generator as dry as posible. Space heaters should be operated inside the generator when it is not in use to maintain the integrity of the generator windings.

Preventive Maintenance for Standby Generator Set Engines To Be Performed By An Authorized Operator

Item	Service
Weekly: Before Starting the Engine	
Walk-Around Inspection	Check the engine, radiator and generator for debris, foreign objects, loose or broken fittings, guards and components. Repair as necessary.
Belts	Inspect for worn, broken or loose belts (alternator, fan, drive, etc.).
Cooling System	Maintain proper coolant level.
Block Heater	Check for proper operation. Maintain 32°C (90°F) coolant temperature in the block at all times.
Air Cleaner Indicator	Check the indicator. Change the air cleaner elements when the indicator diaphragm remains locked.
Engine Crankcase	Check the oil level. Maintain the oil level between the add and full marks on the engine stopped side of the dipstick.
Governor	Check and maintain the oil level (if required).
Fuel System	Check for leaks and drain water separator (if equipped). Keep fuel tank full. Check fuel filter indicator (if equipped).
Air System (If Equipped)	Drain condensate; check air pressure.
Batteries	Maintain electrolyte level, clean batteries if necessary, check for tight connections.
Gauges	Check the condition of all gauges. Repair or replace any broken gauge.
Battery Charger	Check for proper operation. Disconnect charger before starting the engine if it is not capable of handling a cranking load.
Weekly: With Engine Running	
Start the Engine	Run the engine for approximately five minutes while performing these checks. If required, the engine may be operated for as long as 30 minutes. The engine must be loaded if a period longer than 30 minutes is required.
Oil Pressure	Check for proper operating oil pressure. Refer to the Operation section of this guide for the correct pressure reading.
Fuel Pressure	Check for proper operating fuel pressure. Refer to the Operation section of this guide for the correct pressure reading.
Frequency (rpm) and Generated Voltage	Check and record readings. NOTE: The operating voltage of a cold (just started) generator will be slightly higher than the operating voltage of a generator that has been under load and warm. The full load voltage of a SR4 Generator will decrease a maximum of 1% when this generator stabilizes at 100°C (212°F). Most of the voltage decrease occurs in about 30 minutes. Generally, temperatures of generators stabilize within two hours.
Radiator Louvers	Check for proper operation (able to open and close freely).
Leaks and Noises	Check for leaks and unusual noises. NOTE: Engine must be stopped before making necessary repairs.
Weekly: After Stopping the Engine	
Automatic Switches (If Equipped)	Check that all switches are in proper position for automatic start.
Fuel Level	Check the fuel level; refill when below three-fourths full.
Battery Charger	Connect if charger had previously been disconnected. Record charging amperage reading.
Malfunctions	Report any malfunction and make necessary repairs.

Preventive Maintenance For Standby Generator Set Engines To Be Performed By An Authorized Mechanic

Item	Service
Yearly: Before Starting the Engine	
Walk-Around Inspection	Check the engine, radiator, and generator for debris, foreign objects, loose or broken fittings, guards and components. Repair as necessary.
Cooling System	Check for leaks. Add coolant conditioner (if required).
Fuel System	Drain water and sediment from tank. Change fuel filters.
Air Cleaner Element	Inspect; clean or replace.
Governor	Check and maintain oil level (if required).
Engine Crankcase	Check oil level. Maintain oil level between the add and full marks on the engine stopped side of the dipstick.
Engine Crankcase Breather	Clean.
Valve Lash	Check, adjust if necessary. Refer to the engine Service Manual for proper procedure and settings.
Linkages	Check and adjust all linkages, if necessary. Lubricate all linkage fittings.
Alarms and Shutdown Devices	Check; test for proper operation.
Batteries	Check electrolyte level, clean terminals and connections.
Engine	Wipe down; clean as needed.
Generator NOTE: Refer to the generator Service Manual for information relating to use of the megohmmeter and low resistance readings.	Lubricate bearing; vacuum clean and check wiring of the regulator, exciter and stator. Check generator windings with megohmmeter and record readings for reference. Check operation of space heaters.
Yearly: With Engine Running	
Start the Engine	Check all gauges, oil pressure, fuel pressure, rpm (frequency), generated voltage and engine jacket water temperature, for correct readings.
Radiator Louvers	Check for proper operation (able to open and close freely).
Leaks and Noises	Check for leaks and unusual noises. NOTE: Engine must be stopped before making necessary repairs.
Load Test	Load the engine to minimum of 30% of rated load. Operate at this level for minimum of two hours.
Gauge Readings	After approximately one hour record the readings of all gauges: oil pressure, fuel pressure, oil level, rpm (frequency), generated voltage, service meter, engine jacket water temperature, exhaust temperature (if equipped) and manifold vacuum (if equipped).
Yearly: After Stopping the Engine	
Repair or Adjust	Make any repairs or adjustments to the engine and generator set as necessary.
Engine Crankcase	Change oil; take sample for analysis. Change filters, cut old filter open and inspect for foreign material.
Fuel Level	Record the fuel tank level. Fill if below three-fourths full.
Battery Charger	Record charging amperage reading.
Automatic Switches (If Equipped)	Check that all switches are in proper position for automatic start.

Preventive Maintenance For Standby Generator Set Engines To Be Performed By An Authorized Mechanic

Item	Service
Every Three Years: Before Starting the Engine	
Before Starting	Perform all Yearly Before Starting the Engine Preventive Maintenance procedures.
Cooling System	Drain, clean and flush the cooling system. Replace thermostat(s). Refill with coolant solution and conditioner.
Rubber Hoses and Belts	It is recommended that all hoses and belts be replaced at this time to minimize downtime and additional repair cost of component failures caused by these items.
Batteries	Replace all batteries at this interval.
Turbocharger	Inspect, repair or replace if necessary to minimize additional associated component failures.
Engine	Perform a complete engine adjustment and tune-up.
Every Three Years: With Engine Running	
Engine Running	Same as all Yearly With Engine Running Preventive Maintenance procedures.
Exhaust System	Check for leaks. Repair or replace defective components with engine stopped.
Every Three Years: After Stopping the Engine	
After Stopping	Same as all Yearly After Stopping the Engine Preventive Maintenance procedures.

Troubleshooting

On the following pages there is a list of possible problems. To correct a problem, make reference to the CAUSE and CORRECTION.

If problems are encountered, they should be corrected promptly to maintain engine operation.

This list of problems, causes, and corrections, will only give an indication of where a possible problem can be, and what repairs may be needed.

Remember that a problem is not normally caused only by one part, but by the relation of one part with other parts.

This list can not give all possible problems and corrections. The serviceman must find the problem and its source, then make the necessary repairs.

Your Caterpillar dealer is equipped with the necessary tools and personnel to provide assistance when necessary.

Troubleshooting Index

1. **Engine Will Not Turn When Start Switch Is On**
2. **Engine Will Not Start**
3. **Starting Motor Does Not Turn**
4. **Air Starting Motor Turns Slowly**
5. **Alternator Gives No Charge**
6. **Alternator Charge Rate Is Not Regular**
7. **Alternator Has Noise**
8. **Misfiring Or Running Rough**
9. **Not Enough Power**
10. **Stall At Low RPM**
11. **Sudden Changes In RPM**
12. **Loud Combustion Noise**
13. **Valve Train Noise**
14. **Loud Valve Train Noise**
15. **Too Much Valve Lash**
16. **Little Or No Valve Clearance**
17. **Valve Spring Lock Is Free**
18. **Noise In Engine**
19. **Too Much Vibration**
20. **Too Much White Or Blue Smoke**
21. **Oil At The Exhaust**
22. **Too Much Lubrication Oil Used**
23. **Too Much Black Or Gray Smoke**
24. **Fuel Consumption Too High**
25. **Low Oil Pressure**
26. **Coolant In Oil**
27. **Oil In Cooling System**
28. **Coolant Is Too Hot**
29. **Engine Has Early Wear**
30. **Exhaust Temperature Is Too High**

1. Engine Will Not Turn When Start Switch Is On

Cause	Correction
Battery has low output.	Make reference to Item 3.
Wiring or switches are damaged.	Make reference to Item 3.
Starting motor solenoid is damaged.	Make reference to Item 3.
Starting motor is damaged.	Make reference to Item 3.
Oil pressure switch for prelubrication pump is damaged.	Make a replacement of damaged switch.
Prelubrication oil pump is damaged.	Repair or replace pump components as needed.
Inside problem prevents engine crankshaft from turning.	If the crankshaft can not be turned after disconnecting the driven equipment, remove the fuel injectors and check for fluid in the cylinders while turning the crankshaft. If fluid in the cylinders is not the problem, the engine must be disassembled to check for other inside problems. Some of these inside problems are bearing or piston seizure.

2. Engine Will Not Start

Cause	Correction
Slow cranking speed.	Make reference to Items 3, 4 and 5.
Dirty fuel filter.	Install new fuel filter.
Dirty or broken fuel lines.	Clean or install new fuel lines as necessary.
Fuel pressure is low.	At starting rpm, the minimum fuel pressure from fuel transfer pump must be 20 kPa (3 psi). If fuel pressure is less than 20 kPa (3 psi) change the fuel filter element. Look for air in the fuel system. If fuel pressure is still low, check the fuel control valve and the fuel transfer pump for correct operation.
No fuel to cylinders.	Put fuel in tank. "Prime" (remove the air and/or low quality fuel from the fuel system).

2. Engine Will Not Start (cont'd)

Cause	Correction
Bad quality fuel.	Remove the fuel from the fuel tank. Install a new fuel filter element. Put a good grade of clean fuel in the fuel tank.
Wrong fuel injection timing.	Make adjustment to timing.

3. Starting Motor Does Not Turn

Cause	Correction
Battery has low output.	Check condition of battery. Charge battery or make replacement as necessary.
Wiring or switch is damaged.	Make repairs or replacements as necessary.
Starting motor solenoid is damaged.	Install a new solenoid.
Starting motor is damaged.	Make repair or replacement of starting motor.

4. Air Starting Motor Turns Slowly

Cause	Correction
Low supply air pressure.	Increase the supply air pressure.
Pressure regulator adjustment not correct.	Adjust the air pressure regulator.
Air lubricator not working correctly.	Clean, make an adjustment to, and fill air lubricator.

5. Alternator Gives No Charge

Cause	Correction
Loose drive belt for alternator.	Make an adjustment to correct tension on the drive belt.
Charging or ground return circuit or battery connections are damaged.	Inspect all cables and connections. Clean and tighten all connections. Make replacement of part with damage.
Brushes are damaged.	Install new brushes.
Rotor is damaged.	Install a new rotor.

6. Alternator Charge Rate Is Not Regular

Cause	Correction
Loose drive belt for alternator.	Make an adjustment to correct tension on the drive belt.
Charging or ground return circuit or battery connections are damaged.	Inspect all cables and connections. Clean and tighten all connections. Replace malfunctioning parts.
Alternator regulator malfunctions.	Make an adjustment or replacement of alternator regulator.

7. Alternator Has Noise

Cause	Correction
Drive belt for alternator is worn or cracked.	Install a new drive belt for the alternator.
Loose alternator drive pulley.	Check groove in pulley for key that holds pulley in place. If groove is worn, install a new pulley. Tighten pulley nut.
Drive belt and drive pulley for alternator are not in alignment.	Make an adjustment to put drive belt and drive pulley in correct alignment.
Worn alternator bearings.	Install new bearings in the alternator.

8. Misfiring Or Running Rough

Cause	Correction
Fuel pressure is low.	Make sure there is fuel in the fuel tank. Look for leaks or bad bends in the fuel line between fuel tank and fuel transfer pump. Look for air in the fuel system, sticking, binding or damaged fuel control valve. Check fuel pressure. The outlet pressure of the fuel transfer pump must be a minimum of 140 kPa (20 psi) at full load speed. If fuel pressure is lower than the above pressure, install a new fuel filter element. If fuel pressure is still low, check the fuel transfer pump.
Air in fuel system.	Find the air leak in the fuel system and correct it. If air is in the fuel system it will generally get in on the suction side of the fuel transfer pump.

8. Misfiring Or Running Rough (cont'd)

Cause	Correction
Leak or break in fuel line between fuel manifold and cylinder head.	Install a new fuel line.
Wrong valve clearance.	Make adjustment.
Wrong fuel injection timing.	Make adjustment to timing.

9. Not Enough Power

Cause	Correction
Bad quality fuel.	Remove the fuel from the fuel tank. Install a new fuel filter element. Put a good grade of clean fuel in the fuel tank.
Fuel pressure is low.	Make sure there is fuel in the fuel tank. Look for leaks or bad bends in the fuel line between fuel tank and fuel transfer pump. Look for air in the fuel system, sticking, binding or damaged fuel control valve. Check fuel pressure. The outlet pressure of the fuel transfer pump must be a minimum of 140 kPa (20 psi) at full load speed. If fuel pressure is lower than the above pressure, install a new fuel filter element. If fuel pressure is still low, check the fuel transfer pump.
Leaks in air inlet system.	Check the pressure in the air intake manifold. Look for restrictions in the air cleaner.
Governor linkage.	Make adjustment to get full travel of linkage. Install new parts for those that have damage.
Wrong valve clearance.	Make adjustment.
Wrong fuel injection timing.	Make adjustment to timing.
Power setting too low.	Make an adjustment of the power setting to specifications shown on the engine information plate.
Turbocharger has carbon deposit.	Inspect and repair turbocharger as necessary.

10. Stall At Low RPM

Cause	Correction
Fuel pressure is low.	Make sure there is fuel in the fuel tank. Look for leaks or bad bends in the fuel line between fuel tank and fuel transfer pump. Look for air in the fuel system, sticking, binding or damaged fuel control valve. Check fuel pressure. The outlet pressure of the fuel transfer pump must be a minimum of 140 kPa (20 psi) at full load speed. If fuel pressure is lower than the above pressure, install a new fuel filter element. If fuel pressure is still low, check the fuel transfer pump.
Idle rpm too low.	Make adjustment to governor so idle rpm is the same as given on the engine information plate.
Engine accessories.	Check engine accessories for damage and correct adjustment. If necessary, disconnect the accessories and test the engine.

11. Sudden Changes In RPM

Cause	Correction
Failure of governor or fuel injection pump.	Look for damaged or broken springs, linkage or other parts. Remove the governor. Check for free travel of the control linkages. Install new parts for those that have damage.

12. Loud Combustion Noise

Cause	Correction
Bad quality fuel.	Remove the fuel from the fuel tank. Install a new fuel filter element. Put a good grade of clean fuel in the fuel tank.
Wrong fuel injection timing.	Make adjustment to timing.

13. Valve Train Noise

Cause	Correction
Broken valve spring(s) or locks.	Install new parts where necessary. Broken locks can cause the valve to slide into the cylinder. This will cause much damage.
Not enough lubrication.	Check lubrication in valve compartment. There must be a strong flow of oil at engine high rpm, but only a small flow of oil at low rpm. Oil passages must be clean, especially those sending oil to the cylinder head.
Damage in bridge for valves.	Make a replacement of the bridge and make an adjustment as necessary.
Too much valve clearance.	Make correct adjustment.

14. Loud Valve Train Noise

Cause	Correction
Broken valve spring(s).	Make replacement of damaged parts.
Broken camshaft.	Make replacement of damaged parts. Clean engine thoroughly.

15. Too Much Valve Lash

Cause	Correction
Not enough lubrication.	Check lubrication in valve compartment. There must be a strong flow of oil at engine high rpm, but only a small flow at low rpm. Oil passages must be clean, especially those sending oil to the cylinder head.
Rocker arm worn at face that makes contact with bridge.	If there is too much wear, install new parts or rocker arms. Make adjustment of valve clearance.
End of valve stem worn.	If there is too much wear, install new valves. Make adjustment of valve clearance.
Worn push rods.	If there is too much wear, install new push rods. Make adjustment of valve clearance.

15. Too Much Valve Lash (cont'd)

Cause	Correction
Valve lifter worn.	If there is too much wear, install new valve lifters. Make adjusment of valve clearance.
Bridges for valves worn.	Make an adjustment or replacement as necessary.
Broken or worn valve lifters.	Clean engine thoroughly. Install new valve lifters. Check camshaft for wear. Check for free movement of valves or bent valve stem. Make adjustment of valve clearance.
Worn cams on camshaft.	Check valve clearance. Check for free movement of valves or bent valve stems. Install a new camshaft. Install new valve lifters. Make adjustment of valve clearance.

16. Little Or No Valve Clearance

Cause	Correction
Worn valve seat or face of valve.	Reconditioning of cylinder head is needed. Make adjustment of valve clearance.

17. Valve Spring Lock Is Free

Cause	Correction
Broken locks.	Broken locks can cause the valve to slide into the cylinder. This will cause much damage.
Broken valve spring(s).	Install new valve spring(s).
Broken valve.	Replace valve and other damaged parts.

18. Noise In Engine

Cause	Correction
Failure of bearing for connecting rod.	Inspect the bearing for the connecting rod and the bearing surface (journal) on the crankshaft. Install new parts where necessary.
Damaged gears.	Install new parts where necessary.
Defect in attachment.	Repair or install new components.

19. Too Much Vibration

Cause	Correction
Vibration damper or pulley is loose.	Check vibration damper and pulley for damage. Tighten bolts or nuts. If vibration damper or pulley bolt holes have damage or wear, replace with new parts.
Engine supports are loose, wrong, or have damage.	Tighten all mounting bolts. Install new components if necessary.
Driven equipment is not in alignment or is out of balance.	Check alignment and balance. Correct if needed.
Misfiring or running rough.	Make reference to Item 8.

20. Too Much White Or Blue Smoke

Cause	Correction
Too much lubrication oil in engine.	Remove extra oil. Find where extra oil comes from. Put correct amount of oil in engine.
Misfiring or running rough.	Make reference to Item 8.
Wrong fuel injection timing.	Make adjustment to timing.
Worn valve guides.	Recondition cylinder head.
Worn piston rings.	Install new piston rings.
Failure of turbocharger oil seal.	Check inlet manifold for oil and repair turbocharger if necessary.

21. Oil At The Exhaust

Cause	Correction
Too much oil in the valve compartment.	Be sure that there is a plug in the end of the rocker shaft.
Worn valve guides.	Reconditioning of the cylinder head is needed.
Worn piston rings.	Inspect and install new parts as needed.

22. Too Much Lubrication Oil Used

Cause	Correction
Too much lubrication oil in engine.	Remove extra oil. Find where extra oil comes from. Fill engine with oil to the FULL mark on the dipstick. Then, check oil level while engine is running. Do not put too much oil in engine.
Oil leaks.	Find all oil leaks. Make repairs as needed. Check for dirty oil breather.
Oil temperature is too high.	Check operation of oil cooler. Install new parts if necessary. Clean the core of the oil cooler.
Too much oil in the valve compartment.	Be sure that there is a plug in the end of the rocker shaft.
Worn valve guides.	Recondition the cylinder head.
Worn piston rings.	Inspect and install new parts as needed.

23. Too Much Black Or Gray Smoke

Cause	Correction
Not enough air for combustion.	Check air cleaner for restrictions.
Bad fuel injectors.	Install new fuel injectors.
Wrong fuel injection timing.	Make adjustments of timing.

24. Fuel Consumption Too High

Cause	Correction
Fuel system leaks.	Replacement of parts is needed at points of leakage.
Fuel and combustion noise (knock).	Make reference to Item 8 and Item 9.
Wrong fuel injection timing.	Make adjustment to timing.
Low tire pressures.	Check tires periodically and maintain the correct inflation pressure.

25. Low Oil Pressure

Cause	Correction
Dirty oil filter or oil cooler.	Check the operation of bypass valve for the filter. Install new oil filter element if needed. Clean or install new oil cooler core. Remove dirty oil from engine. Put clean oil in engine.
Diesel fuel in lubrication oil.	Find the place where diesel fuel gets into the lubrication oil. Make repairs as needed. Drain the lubrication oil that has diesel fuel in it. Install a new oil filter element. Fill the engine with clean oil.
Too much clearance between rocker arm shaft and rocker arms.	Check lubrication in valve compartments. Install new parts as necessary.
Oil pump suction pipe has damage.	Replace pipe.
Pressure regulating valve does not close.	Clean valve and housing. Install new parts as necessary.
Oil pump has damage.	Repair or replace oil pump.
Too much clearance between crankshaft and crankshaft bearings.	Inspect the bearings and make replacement if necessary.
Too much clearance between camshaft and camshaft bearings.	Install new camshaft and camshaft bearings if necessary.
Defect in oil pressure gauge.	Install new gauge.

26. Coolant In Oil

Cause	Correction
Failure of oil cooler core.	Install a new core for the oil cooler. Drain crankcase and refill with clean lubricant. Install new oil filter element.
Failure of cylinder head gasket.	Check cylinder liner projection. Install a new cylinder head gasket. Tighten the bolts holding the cylinder head.
Crack or damage in cylinder head.	Install a new cylinder head.
Crack or damage in cylinder block.	Install a new cylinder block.
Failure of liner seals.	Replace seals.

27. Oil In Cooling System

Cause	Correction
Defect in core of oil cooler.	Install a new core in the oil cooler.
Failure of cylinder head gasket.	Check cylinder liner projection. Replace head gasket.

28. Coolant Is Too Hot

Cause	Correction
Not enough coolant in system.	Add coolant to cooling system. Check for leaks.
Pressure relief valve has damage.	Check operation of pressure relief valve. Install a new pressure relief valve if necessary.
Combustion gases in coolant.	Find out where gases get into the cooling system. Make repairs as needed.
Water temperature regulators (thermosats) or temperature gauge have damage.	Check water temperature regulators for correct operation. Check temperature gauge operation. Install new parts as necessary.
Water pump has damage.	Make repairs to the water pump as necessary.
Too much load on the system.	Reduce the load.
Wrong fuel injection timing.	Make adjustment to timing.

29. Engine Has Early Wear

Cause	Correction
Dirt in lubrication oil.	Remove dirty lubrication oil. Install a new oil filter element. Put clean oil in the engine. Check oil filter bypass valve for a weak or broken spring.
Air inlet leaks.	Inspect all gaskets and connections. Make repairs if leaks are found.
Fuel leakage into lubrication oil.	This will cause high fuel consumption and low engine oil pressure. Make repairs if leaks are found. Install new parts where needed. Make reference to Items 24 and 25.

30. Exhaust Temperature Is Too High

Cause	Correction
Air inlet system has a leak.	Check pressure in the air intake manifold. Look for restrictions at the air cleaner. Correct any leaks.
Exhaust system has a leak.	Find cause of exhaust leak. Make repairs as necessary.
Air inlet or exhaust system has a restriction.	Remove restriction.
Wrong fuel injection timing.	Make an adjustment to the timing.