

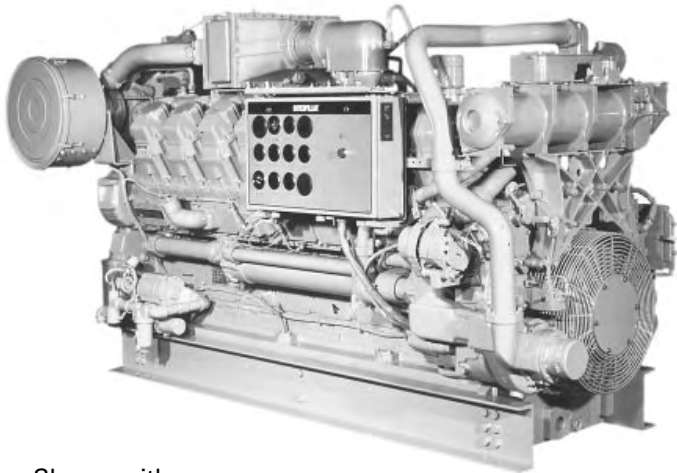


Gas Industrial Engine

G3516

660-1340 hp

Standard and Low Emission



Shown with Optional Equipment

SPECIFICATIONS

V-16, 4-Stroke-Cycle, Spark Ignited

Bore—in (mm)	6.7 (170)
Stroke—in (mm)	7.5 (190)
Displacement—cu in (L).....	4211 (69.0)
Compression Ratio	
STD	9:1
LE	8:1
Aspiration	Naturally Aspirated or Turbocharged-Aftercooled
Lube Oil Capacity — gal (L)	
STD*	153 (580)
STD**	171 (646)
LE	106 (402)
Jacket Water System — gal (L)	
Capacity w/o Radiator	53 (205)

* Oil fill capacity with 21 elements

**Oil fill capacity without elements



FEATURES

■ DIESEL STRENGTH

All Caterpillar® gas engines are built on diesel frames which means greater service life. Caterpillar gas engines inherit more from their diesel counterparts than just strength. They are backed by the same support system recognized as one of the most sophisticated and dependable in the world.

■ APPLICATION FLEXIBILITY

Broad operating speed range and ability to burn a wide spectrum of gaseous fuels.

■ LOW EMISSIONS

Low emission engines are capable of NO(x) levels as low as 2.0 grams/hp-hr. Lower emissions may be achievable for selected applications. Consult your Caterpillar dealer.

■ CATERPILLAR® GAS ENGINES

Represent the latest technology in engine design. Engines are offered in both naturally aspirated and turbocharged/aftercooled configurations.

TA is offered as standard and low emission. These different configurations offer:

- High energy ignition systems for consistent firing
- High efficient combustion chamber for complete burning of the fuel.
- Modern component design such as deep cup, oil gallery piston.

■ ELECTRONIC IGNITION SYSTEM WITH DETONATION SENSITIVE TIMING

The Caterpillar electronic ignition system provides optimized spark timing for all operating conditions. Timing is automatically controlled to maintain continuous detonation protection.

STANDARD EQUIPMENT

Air cleaners single stage, dry, with service indicator	intake manifold temp (TA only) pressure (LE) service meter
Breather, crankcase	exhaust
Carburetor natural gas	pyrometer (LE)
Cooler lubricating oil	Lifting eyes
Filter lubricating oil, RH	Manifold, exhaust watercooled
Flywheel housing SAE No. 00	Pumps, gear driven aftercooler water (TA only) jacket water
Governor Woodward	Rails, mounting, 10 in. Regulator, gas pressure
Ignition system Altronic III	SAE standard rotation
Instrument panel, RH 8 gauge panel (STD) 12 gauge panel (LE) oil pressure coolant temperature oil pressure differential	Thermostats and housing Torsional vibration damper

OPTIONAL EQUIPMENT

Cooling systems high temp (LE only)
Exhaust fittings
Muffler
Power takeoffs
Starting systems
Tachometer
Low BTU arrangements
Landfill arrangements
Air head for 3161
CSA ignition
Air-to-air aftercooler connection

CONTINUOUS RATINGS (BHP)

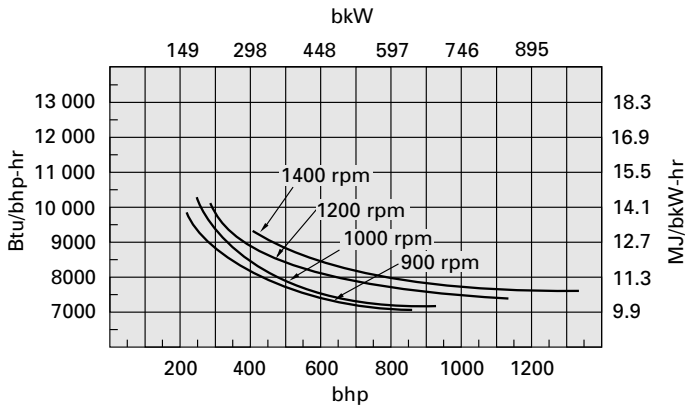
Aspiration	1400 rpm	1300 rpm	1200 rpm	1100 rpm	1000 rpm	900 rpm
LE-90	1340	1245	1150	1050	955	860
LE-130	1265	1175	1085	995	900	810
STD TA-90	–	–	1085	995	905	815
STD TA-130	–	–	1050	960	875	785
STD NA	–	–	660	605	585	525

PHYSICAL FACTORS

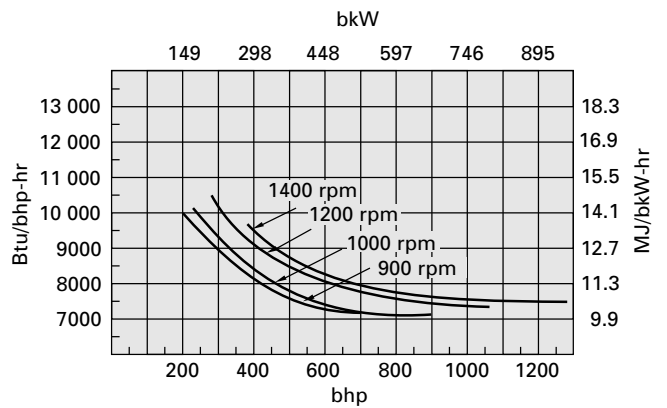
	Height in (mm)	Width in (mm)	Length in (mm)	Weight lb (kg)
LE	73.2 (1859)	67.1 (1703)	131 (3327)	17 670 (8022)
STD TA	73.2 (1859)	67.1 (1703)	131 (3327)	17 470 (7931)
STD NA	75.2 (1911)	61.6 (1564)	126.4 (3211)	16 400 (7446)

FUEL CONSUMPTION

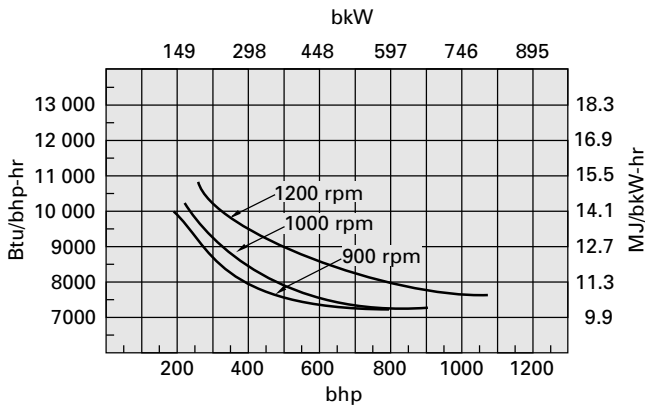
LE-90



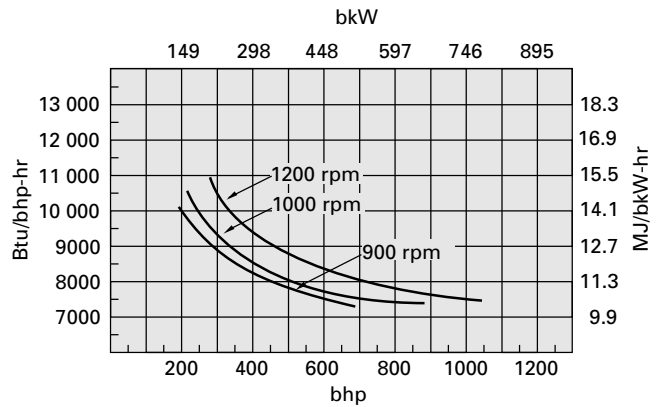
LE-130



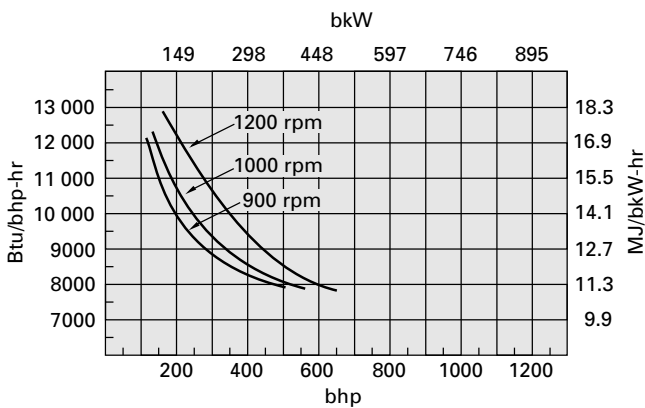
STD TA-90



STD TA-130

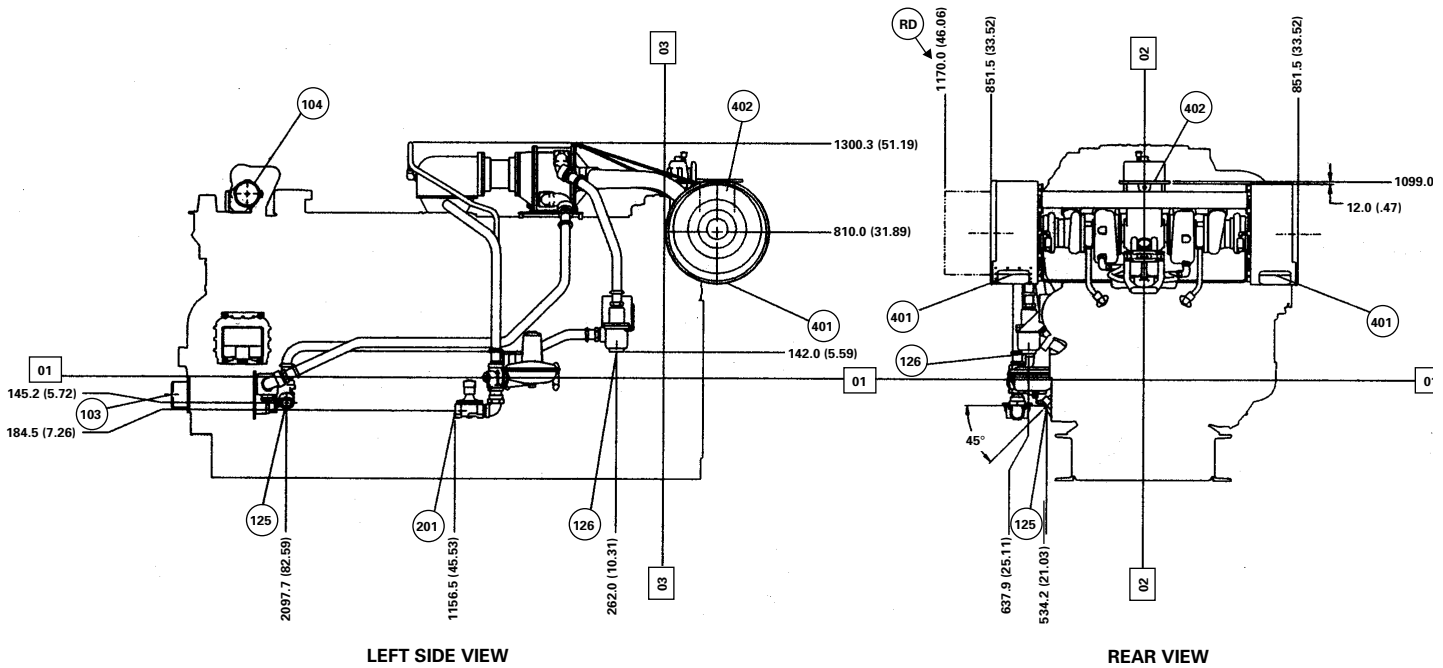


STD NA



LE refers to low emission engine configuration.
 STD refers to standard engine configuration.
 90 refers to aftercooler water inlet temperature in 90° F (32° C).
 130 refers to aftercooler water inlet temperature in 130° F (54° C).
 All data is based on standard conditions. 77° F (25° C) 500 ft Alt.
 These ratings do not allow for overload capability.

GAS INDUSTRIAL ENGINE PHYSICAL FACTORS



- | | | |
|---------------------------------------|-------------------------------------|----------------------------|
| 01 Centerline of Crankshaft | 104 Jacket Water Outlet | 401 Air Inlet |
| 02 Centerline of Engine | 125 Aftercooler water inlet | 402 Exhaust |
| 03 Rear face of Cylinder Block | 126 Aftercooler water outlet | RD Removal Distance |
| 103 Jacket Water Inlet | 201 Fuel Inlet | |

See general dimension drawing 114-6637 for additional Electronic Ignition System (E.I.S.) engine detail and NA information.

For magneto ignition system engines see general dimension drawing 7W4452.

Note: General configuration not to be used for installation.

CONDITIONS AND DEFINITIONS

Ratings are based on SAE J1349 standard conditions of 29.61 in Hg (100 kPa) and 77° F (25° C). These ratings also apply at ISO3046, DIN6271, and BS5514 standard conditions of 29.61 in Hg (100 kPa), 81° F (27° C); and API 7B-11C standard conditions of 29.38 in Hg (99 kPa), 85° F (29° C).

Ratings are based on dry natural gas having a low heat value of 905 btu/ft³ (35.54 MJ/N m³). Variations in altitude, temperature, and gas composition from standard conditions may require a reduction in engine horsepower.

Turbocharged-aftercooled ratings apply to 5000 ft (1525 m) and 77° F (25° C). **Naturally aspirated** engines apply to 500 ft (150 m) and 77° F (25° C). For applications which exceed these limits, consult your Caterpillar dealer.

Additional ratings may be available for specific customer requirements. Consult your Caterpillar representative for details.

Operation and Maintenance Manual

G3500 Engines

4WD1-Up (Engine)
5JD1-Up (Engine)
8LD1-Up (Engine)
9TG1-Up (Engine)
2TJ1-Up (Engine)
7NJ1-Up (Engine)
4EK1-Up (Engine)
6JW1-Up (Engine)
8PW1-Up (Engine)
9AW1-Up (Engine)
7SZ1-Up (Engine)
8BZ1-Up (Engine)
5ZZ1-Up (Engine)
8JZ1-Up (Engine)

Important Safety Information

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

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

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

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

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



The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

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

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

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

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



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

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

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Foreword

Literature Information

This manual contains safety, operation instructions, lubrication and maintenance information. This manual should be stored in or near the engine area in a literature holder or literature storage area. Read, study and keep it with the literature and engine information.

English is the primary language for all Caterpillar publications. The English used facilitates translation and consistency in electronic media delivery.

Some photographs or illustrations in this manual show details or attachments that may be different from your engine. 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 are not included in this manual. Whenever a question arises regarding your engine, or this manual, please consult with your Caterpillar dealer for the latest available information.

Safety

This safety section lists basic safety precautions. In addition, this section identifies hazardous, warning situations. Read and understand the basic precautions listed in the safety section before operating or performing lubrication, maintenance and repair on this product.

Operation

Operating techniques outlined in this manual are basic. They assist with developing the skills and techniques required to operate the engine more efficiently and economically. Skill and techniques develop as the operator gains knowledge of the engine and its capabilities.

The operation section is a reference for operators. Photographs and illustrations guide the operator through procedures of inspecting, starting, operating and stopping the engine. This section also includes a discussion of electronic diagnostic information.

Maintenance

The maintenance section is a guide to engine care. The illustrated, step-by-step instructions are grouped by service hours and/or calendar time maintenance intervals. Items in the maintenance schedule are referenced to detailed instructions that follow.

Use service hours to determine intervals. Calendar intervals shown (daily, annually, etc) may be used instead of service meter intervals if they provide more convenient schedules and approximate the indicated service meter reading.

Recommended service should always be performed at the service hour interval. The actual operating environment of the engine also governs the maintenance schedule. Therefore, under extremely severe, dusty, wet or freezing cold operating conditions, more frequent lubrication and maintenance than is specified in the maintenance schedule may be necessary.

The maintenance schedule items are organized for a preventive maintenance management program. If the preventive maintenance program is followed, a periodic tune-up is not required. The implementation of a preventive maintenance management program should minimize operating costs through cost avoidances resulting from reductions in unscheduled downtime and failures.

Maintenance Intervals

Perform maintenance on items at multiples of the original requirement. Each level and/or individual items in each level should be shifted ahead or back depending upon your specific maintenance practices, operation and application. We recommend that the maintenance schedules be reproduced and displayed near the engine as a convenient reminder. We also recommend that a maintenance record be maintained as part of the engine's permanent record.

See the section in the Operation and Maintenance Manual, "Maintenance Records" for information regarding documents that are generally accepted as proof of maintenance or repair. Your authorized Caterpillar dealer can assist you in adjusting your maintenance schedule to meet the needs of your operating environment.

California Proposition 65 Warning

Battery posts, terminals and related accessories contain lead and lead compounds. Wash hands after handling.

Overhaul

Major engine overhaul details are not covered in the Operation and Maintenance Manual except for the interval and the maintenance items in that interval. Major repairs are best left to trained personnel or an authorized Caterpillar dealer. Your Caterpillar dealer offers a variety of options regarding overhaul programs. If you experience a major engine failure, there are also numerous after failure overhaul options available from your Caterpillar dealer. Consult with your dealer for information regarding these options.

Safety Section

Safety Signs and Labels

i01058484

SMCS Code: 1000; 7405

There may be several specific safety signs on your engine. The exact location and a description of the signs are reviewed in this section. Please become familiar with all of the signs.

Ensure that all of the signs are legible. Clean the signs or replace the signs if the words cannot be read or if the illustrations are not visible. Use a cloth, water, and soap for cleaning the signs. Do not use solvents, gasoline, or other harsh chemicals. Solvents, gasoline, or harsh chemicals could loosen the adhesive that secures the signs. The signs that are loosened could drop off of the engine.

Replace any sign that is damaged or missing. If a sign is attached to a part of the engine that is replaced, install a new sign on the replacement part. Your Caterpillar dealer can provide new signs.

WARNING

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

The safety signs that may be attached on the engine are illustrated and described below.

Coupling

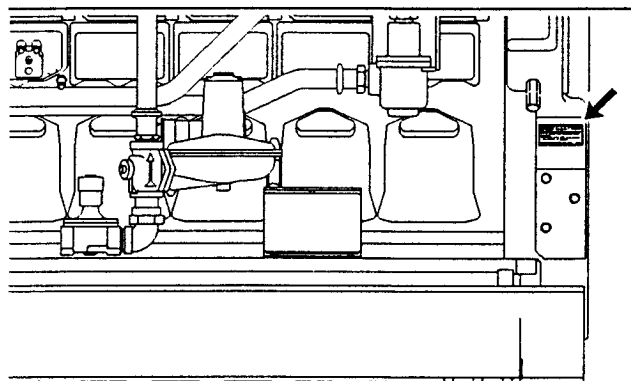
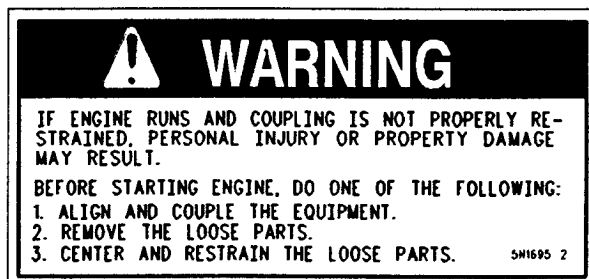


Illustration 1

g00305685

The warning label for the coupling is located on the sides of the flywheel housing.



g00305692

WARNING

If engine runs and coupling is not properly restrained, personal injury or property damage may result.

Before starting engine, do one of the following:

- 1. Align and couple the equipment.**
- 2. Remove the loose parts.**
- 3. Center and restrain the loose parts.**

Crankcase Covers

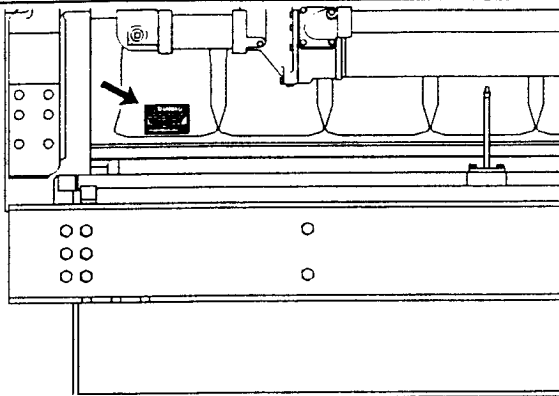


Illustration 2

g00305845

The warning label for the crankcase covers is located on the crankcase covers.

Electrical Distribution (Generator)

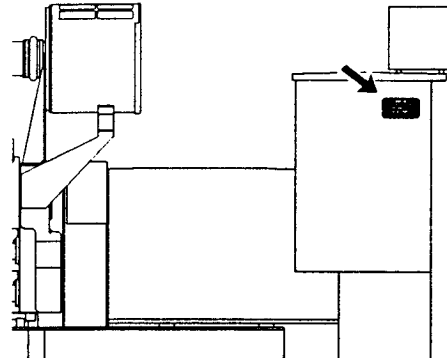


Illustration 3

g00305862

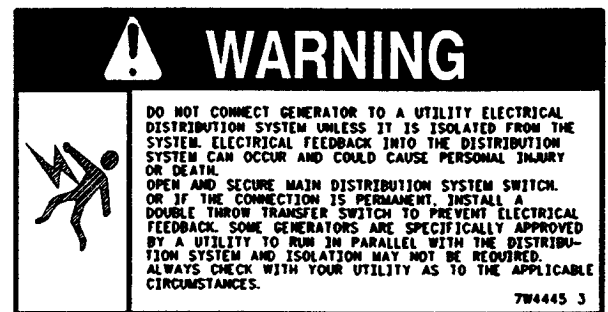
The warning label for electrical distribution (generator) is located on the covers of the generator.



g00123185



Flash fire may result in personal injury, if crankcase covers are removed within fifteen minutes after emergency shut down. Do not restart engine until cause for shutdown has been corrected.



g00296980



Do not connect generator to a utility electrical distribution system unless it is isolated from the system. Electrical feedback into the distribution system can occur and could cause personal injury or death.

Open and secure main distribution system switch, or if the connection is permanent, install a double throw transfer switch to prevent electrical feedback. Some generators are specifically approved by a utility to run in parallel with the distribution system and isolation may not be required. Always check with your utility as to the applicable circumstances.

Electrical Shock

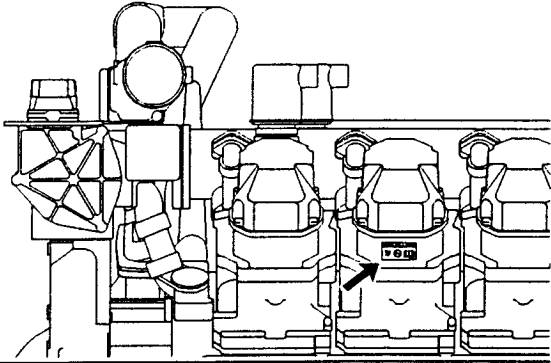
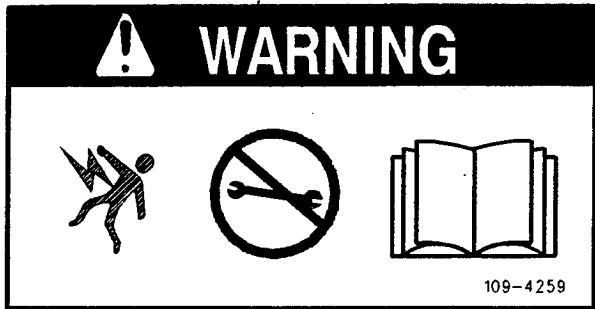


Illustration 4

g00305887

The warning label for electrical shock is located on the valve covers.



g00305892

Ignition systems can cause electrical shocks. Avoid contacting the ignition system components and the wiring.

Do not operate or work on the engine unless the instruction and warnings in the Operation and Maintenance Manual are understood. Failure to follow the instructions or failure to heed the warnings could result in injury or death. Proper care is your responsibility.

Emergency Stop

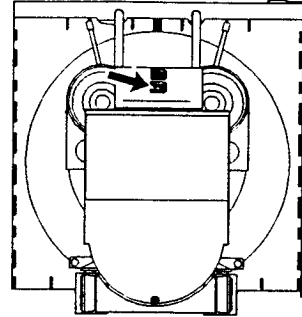
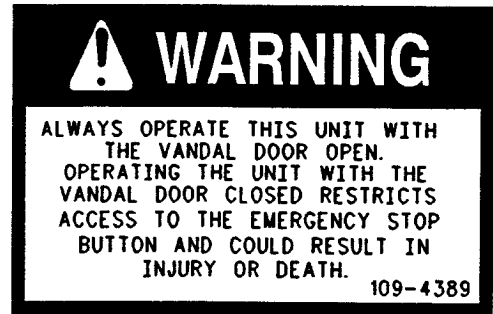


Illustration 5

g00305895

The warning label for emergency stop is located on the outside of the door of the control panel.



g00305896



Always operate this unit with the vandal door open. Operating the unit with the vandal door closed restricts access to the emergency stop button and could result in injury or death.

Engine Lifting

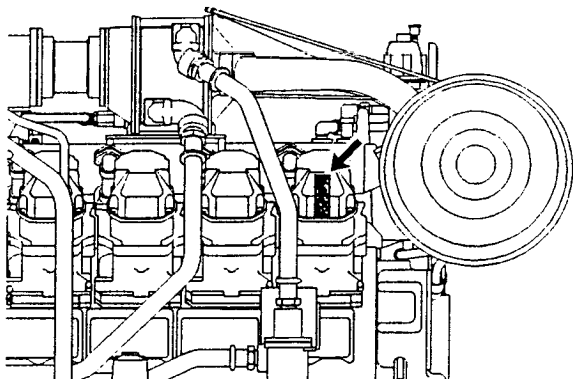


Illustration 6

g00305967

The warning label for engine lifting is located on the valve covers.

Oil Filter

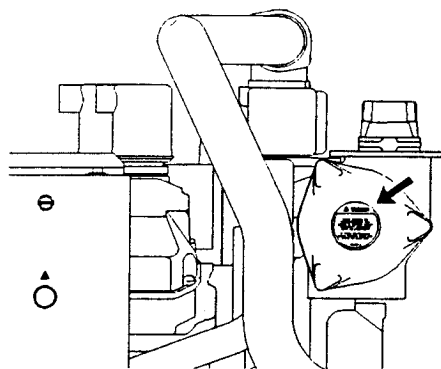
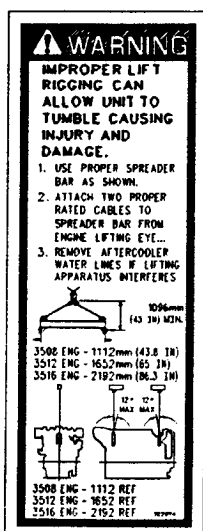


Illustration 7

g00306130

The warning label for the oil filter is located on the cover of the oil filter.

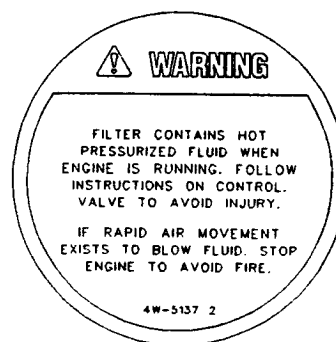


g00306083

WARNING

Improper lift rigging can allow unit to tumble causing injury and damage.

If improper equipment is used to lift the engine, injury and damage can occur. Use cables that are properly rated for the weight. Use a spreader bar and attach the cables according to the information on the warning label.



g00306243

WARNING

Filter contains hot pressurized fluid when engine is running. Follow instructions on control valve to avoid injury if rapid air movement exists to blow fluid. Stop engine to avoid fire.

Operation

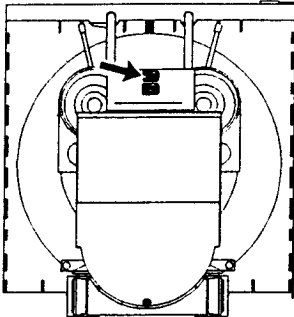
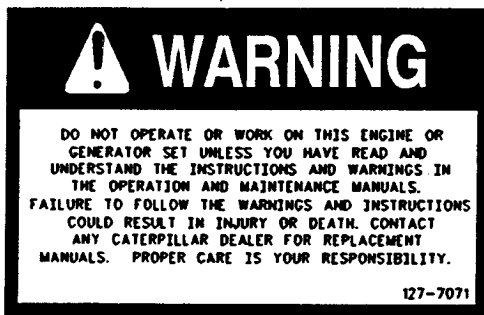


Illustration 8

g00306263

The warning label for operation is located on the outside of the door of the control panel.



g00306265

Prelube Pump

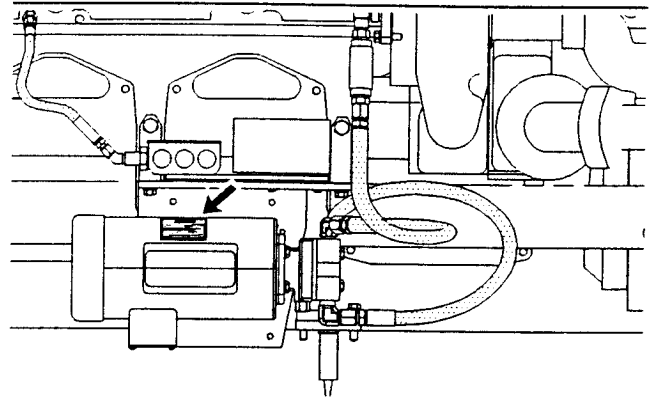
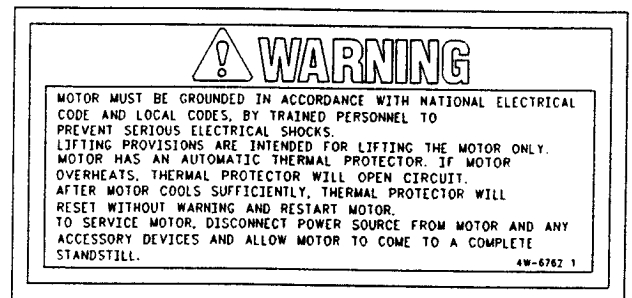


Illustration 9

g00306383

The warning label for the pre-lube pump is located on the pre-lube pump.



g00306385



Do not operate or work on this engine or generator set unless you have read and understand the instructions and warnings in the Operation and Maintenance Manuals.

Failure to follow the warnings and instructions could result in injury or death. Contact any Caterpillar dealer for replacement manuals. Proper care is your responsibility.



Motor must be grounded in accordance with national electrical code and local codes, by trained personnel to prevent serious electrical shocks.

Lifting provisions are intended for lifting the motor only.

Motor has an automatic reset thermal protector. If motor overheats, thermal protector will open motor circuit.

After motor cools sufficiently, thermal protector will reset without warning and restart motor.

To service motor, disconnect power source from motor and any accessory devices and allow motor to come to a complete standstill.

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General Hazard Information

SMCS Code: 1000; 7405

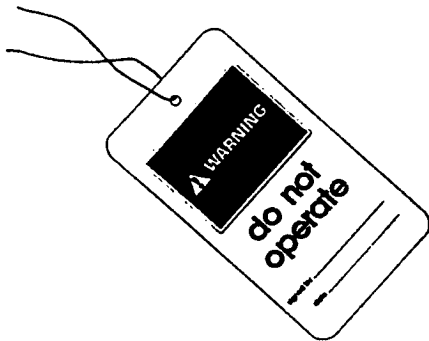


Illustration 10

g00104545

Attach a "Do Not Operate" warning tag or a similar warning tag to the start switch or to the controls before the engine is serviced or before the engine is repaired. These warning tags (Special Instruction, SEHS7332) are available from your Caterpillar dealer. Attach the warning tags to the engine and to each operator control station. When it is appropriate, disconnect the starting controls.

Do not allow unauthorized personnel on the engine, or around the engine when the engine is being serviced.

Engine exhaust contains products of combustion which may be harmful to your health. Always start the engine and operate the engine in a well ventilated area. If the engine is in an enclosed area, vent the engine exhaust to the outside.

Cautiously remove the following parts. To help prevent spraying or splashing of pressurized fluids, hold a rag over the part that is being removed.

- Filler caps
- Grease fittings
- Pressure taps
- Breathers
- Drain plugs

Use caution when cover plates are removed. Gradually loosen, but do not remove the last two bolts or nuts that are located at opposite ends of the cover plate or the device. Before removing the last two bolts or nuts, pry the cover loose in order to relieve any spring pressure or other pressure.

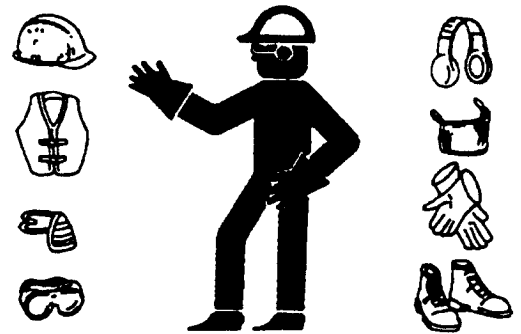


Illustration 11

g00702020

- Wear a hard hat, protective glasses, and other protective equipment, as required.
- When work is performed around an engine that is operating, wear protective devices for ears in order to help prevent damage to hearing.
- Do not wear loose clothing or jewelry that can snag on controls or on other parts of the engine.
- Ensure that all protective guards and all covers are secured in place on the engine.
- Never put maintenance fluids into glass containers. Glass containers can break.
- Use all cleaning solutions with care.
- Report all necessary repairs.

Unless other instructions are provided, perform the maintenance under the following conditions:

- The engine is stopped. Ensure that the engine cannot be started.
- Disconnect the batteries when maintenance is performed or when the electrical system is serviced. Disconnect the battery ground leads. Tape the leads in order to help prevent sparks.
- Do not attempt any repairs that are not understood. Use the proper tools. Replace any equipment that is damaged or repair the equipment.

California Proposition 65 Warning

Some engine exhaust constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

Pressure Air and Water

Pressurized air and/or water can cause debris and/or hot water to be blown out. This could result in personal injury.

When pressure air and/or pressure water is used for cleaning, wear protective clothing, protective shoes, and eye protection. Eye protection includes goggles or a protective face shield.

The maximum air pressure for cleaning purposes must be below 205 kPa (30 psi). The maximum water pressure for cleaning purposes must be below 275 kPa (40 psi).

Fluid Penetration

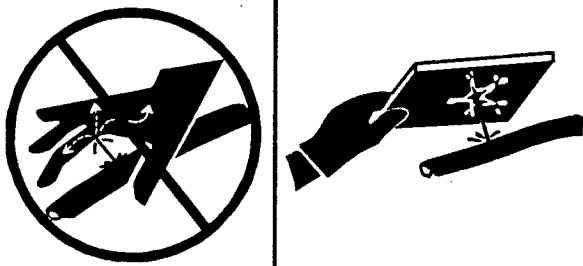


Illustration 12

g00687600

Always use a board or cardboard when you check for a leak. Leaking fluid that is under pressure can penetrate body tissue. Fluid penetration can cause serious injury and possible death. A pin hole leak can cause severe injury. If fluid is injected into your skin, you must get treatment immediately. Seek treatment from a doctor that is familiar with this type of injury.

Containing Fluid Spillage

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

Refer to Special Publication, NENG2500, "Tools and Shop Products Guide" for the following items:

- Tools that are suitable for collecting fluids and equipment that is suitable for collecting fluids
- Tools that are suitable for containing fluids and equipment that is suitable for containing fluids

Obey all local regulations for the disposal of liquids.

Asbestos Information

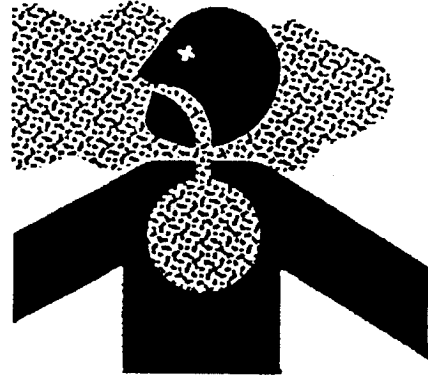


Illustration 13

g00702022

Caterpillar equipment and replacement parts that are shipped from Caterpillar are asbestos free. Caterpillar recommends the use of only genuine Caterpillar replacement parts. Use the following guidelines when you handle any replacement parts that contain asbestos or when you handle asbestos debris.

Use caution. Avoid inhaling dust that might be generated when you handle components that contain asbestos fibers. Inhaling this dust can be hazardous to your health. The components that may contain asbestos fibers are brake pads, brake bands, lining material, clutch plates, and some gaskets. The asbestos that is used in these components is usually bound in a resin or sealed in some way. Normal handling is not hazardous unless airborne dust that contains asbestos is generated.

If dust that may contain asbestos is present, there are several guidelines that should be followed:

- Never use compressed air for cleaning.
- Avoid brushing materials that contain asbestos.
- Avoid grinding materials that contain asbestos.
- Use a wet method in order to clean up asbestos materials.
- A vacuum cleaner that is equipped with a high efficiency particulate air filter (HEPA) can also be used.
- Use exhaust ventilation on permanent machining jobs.
- Wear an approved respirator if there is no other way to control the dust.

- Comply with applicable rules and regulations for the work place. In the United States, use Occupational Safety and Health Administration (OSHA) requirements. These OSHA requirements can be found in "29 CFR 1910.1001".
- Obey environmental regulations for the disposal of asbestos.
- Stay away from areas that might have asbestos particles in the air.

Dispose of Waste Properly

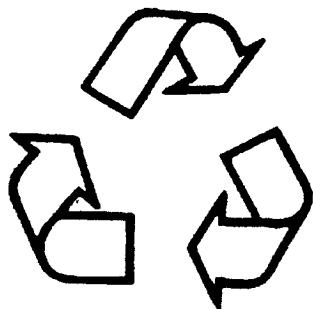


Illustration 14

g00706404

Improperly disposing of waste can threaten the environment. Potentially harmful fluids should be disposed of according to local regulations.

Always use leakproof containers when you drain fluids. Do not pour waste onto the ground, down a drain, or into any source of water.

i01480768

Burn Prevention

SMCS Code: 1000; 7405

Do not touch any part of an operating engine. Allow the engine to cool before any maintenance is performed on the engine. Relieve all pressure in the air system, in the hydraulic system, in the lubrication system, in the fuel system, or in the cooling system before any lines, fittings or related items are disconnected.

Coolant

When the engine is at operating temperature, the engine coolant is hot. The coolant is also under pressure. The radiator and all lines to the heaters or to the engine contain hot coolant.

Any contact with hot coolant or with steam can cause severe burns. Allow cooling system components to cool before the cooling system is drained.

Check the coolant level after the engine has stopped and the engine has been allowed to cool.

Ensure that the filler cap is cool before removing the filler cap. The filler cap must be cool enough to touch with a bare hand. Remove the filler cap slowly in order to relieve pressure.

Cooling system conditioner contains alkali. Alkali can cause personal injury. Do not allow alkali to contact the skin, the eyes, or the mouth.

Oils

Hot oil and hot lubricating components can cause personal injury. Do not allow hot oil to contact the skin. Also, do not allow hot components to contact the skin.

Batteries

Electrolyte is an acid. Electrolyte can cause personal injury. Do not allow electrolyte to contact the skin or the eyes. Always wear protective glasses for servicing batteries. Wash hands after touching the batteries and connectors. Use of gloves is recommended.

i01027886

Fire Prevention and Explosion Prevention

SMCS Code: 1000; 7405

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

Fire may result from lubricating oil or from fuel that is sprayed on hot surfaces. Fire may cause personal injury and property damage. Inspect all lines and tubes for wear or for deterioration. The lines must be properly routed. The lines must have adequate support and secure clamps. Tighten all connections to the recommended torque. Leaks can cause fires.

Determine whether the engine will be operated in an environment that allows combustible gases to be drawn in through the air inlet system. These gases could cause the engine to overspeed. This could result in bodily injury, property damage, or damage to the engine.

If the application involves the presence of combustible gases, consult your Caterpillar dealer in order to obtain additional information concerning suitable protection devices.

Leaking fuel or fuel that is spilled onto hot surfaces or onto electrical components can cause a fire.

All fuels, most lubricants, and some coolant mixtures are flammable. Diesel fuel is flammable. Gasoline is flammable. The mixture of diesel fumes and gasoline fumes is extremely explosive.

Do not smoke while the engine is refueled. Do not smoke in the refueling area.

Store all fuels and all lubricants in properly marked containers. Store the protective containers in a safe place.

Do not smoke in battery charging areas. Batteries give off flammable fumes which can explode.

Do not smoke in areas that contain flammable material.

Store oily rags and other flammable material in protective containers.

Do not weld on pipes or tubes that contain flammable fluids. Do not flame cut pipes or tubes that contain flammable fluids. Before pipes or tubes are welded or flame cut, clean the inside and clean the outside of the pipes or tubes thoroughly with nonflammable solvent.

Do not allow flammable materials to accumulate on the engine.

Do not expose the engine to flames.

Exhaust shields (if equipped) protect hot exhaust components from oil or fuel spray in case of a line, a tube, or a seal failure. Exhaust shields must be installed correctly.

Dispose of oil according to local regulations. Oil filters and fuel filters must be properly installed. The housing covers must be tightened to the proper torque when the housing covers are reinstalled.

Batteries must be kept clean. The covers (if equipped) must be kept on the cells. Use the recommended cables, connections, and battery box covers when the engine is operated.

Check the electrical wires daily for wires that are loose or frayed. Before the engine is operated, tighten all loose electrical wires. Repair all frayed electrical wires.

Wiring must be kept in good condition. Wires must be properly routed and securely attached. Routinely inspect the wiring for wear or for deterioration. Loose wiring, unattached wiring, or unnecessary wiring must be eliminated. All wires and all cables must be of the recommended gauge. Do not use a wire or a cable that is smaller than the recommended gauge. The wires and cables must be connected to a fuse or to a circuit breaker, as required. Do not bypass fuses and/or circuit breakers. Arcing or sparking could cause a fire. Secure connections, recommended wiring, and properly maintained battery cables will help prevent arcing or sparking.

Fire Extinguisher

Ensure that fire extinguishers are available. Be familiar with the operation of the fire extinguishers. Inspect the fire extinguishers and service the fire extinguishers regularly. Service the fire extinguisher according to the recommendations on the instruction plate.

i01359666

Crushing Prevention and Cutting Prevention

SMCS Code: 1000; 7405

Support the component properly when work beneath the component is performed.

Unless other maintenance instructions are provided, never attempt adjustments while the engine is running.

Stay clear of all rotating parts and of all moving parts. Leave the guards in place until maintenance is performed. After the maintenance is performed, reinstall the guards.

Keep objects away from moving fan blades. The fan blades will throw objects or cut objects.

When objects are struck, wear protective glasses in order to avoid injury to the eyes.

Chips or other debris may fly off objects when objects are struck. Before objects are struck, ensure that no one will be injured by flying debris.

i01372247

Mounting and Dismounting

SMCS Code: 1000; 7405

Inspect the steps, the handholds, and the work area before mounting the engine. Keep these items clean and keep these items in good repair.

Mount the engine and dismount the engine only at locations that have steps and/or handholds. Do not climb on the engine, and do not jump off the engine.

Face the engine in order to mount the engine or dismount the engine. Maintain a three-point contact with the steps and handholds. Use two feet and one hand or use one foot and two hands. Do not use any controls as handholds.

Do not stand on components which cannot support your weight. Use an adequate ladder or use a work platform. Secure the climbing equipment so that the equipment will not move.

Do not carry tools or supplies when you mount the engine or when you dismount the engine. Use a hand line to raise and lower tools or supplies.

i00702251

Ignition Systems

SMCS Code: 1550

Ignition systems can cause electrical shocks. Avoid contacting the ignition system components and wiring.

Do not attempt to remove the valve covers when the engine is operating. The transformers are grounded to the valve covers. Personal injury or death may result and the ignition system will be damaged if the valve covers are removed during engine operation. The engine will not operate without the valve covers.

i00659904

Before Starting Engine

SMCS Code: 1000

Inspect the engine for potential hazards.

Before starting the engine, ensure that no one is on, underneath, or close to the engine. Ensure that the area is free of personnel.

Ensure that the engine is equipped with a lighting system that is suitable for the conditions. Ensure that all lights work properly.

All protective guards and all protective covers must be installed if the engine must be started in order to perform service procedures. To help prevent an accident that is caused by parts in rotation, work around the parts carefully.

Do not bypass the automatic shutoff circuits. Do not disable the automatic shutoff circuits. The circuits are provided in order to help prevent personal injury. The circuits are also provided in order to help prevent engine damage.

On the initial start-up of a new engine or an engine that has been serviced, be prepared to stop the engine if an overspeed condition occurs. This may be accomplished by shutting off the fuel supply to the engine, or shutting off the ignition system.

See the Service Manual for repairs and for adjustments.

i00572000

Engine Starting

SMCS Code: 1000

If a warning tag is attached to the engine start switch or to the controls, DO NOT start the engine or move the controls. Consult with the person that attached the warning tag before the engine is started.

All protective guards and all protective covers must be installed if the engine must be started in order to perform service procedures. To help prevent an accident that is caused by parts in rotation, work around the parts carefully.

Start the engine from the operator's compartment or from the engine start switch.

Always start the engine according to the procedure that is described in the Operation and Maintenance Manual, "Engine Starting" topic in the Operation Section. Knowing the correct procedure will help to prevent major damage to the engine components. Knowing the procedure will also help to prevent personal injury.

To ensure that the jacket water heater (if equipped) and/or the lube oil heater (if equipped) is working properly, check the water temperature gauge and the oil temperature gauge during the heater operation.

Engine exhaust contains products of combustion which can be harmful to your health. Always start the engine and operate the engine in a well ventilated area. If the engine is started in an enclosed area, vent the engine exhaust to the outside.

i00659907

Engine Stopping

SMCS Code: 1000

To avoid overheating of the engine and accelerated wear of the engine components, stop the engine according to the instructions in this Operation and Maintenance Manual, "Engine Stopping" topic (Operation Section).

Use the Emergency Stop Button (if equipped) ONLY in an emergency situation. Do not use the Emergency Stop Button for normal engine stopping. After an emergency stop, DO NOT start the engine until the problem that caused the emergency stop has been corrected.

On the initial start-up of a new engine or an engine that has been serviced, make provisions to stop the engine if an overspeed occurs. This may be accomplished by shutting off the fuel supply to the engine, or shutting off the ignition system.

i00887114

Electrical System

SMCS Code: 1000; 1400

Never disconnect any charging unit circuit or battery circuit cable from the battery when the charging unit is operating. A spark can cause the combustible gases that are produced by some batteries to ignite.

Check the electrical wires daily for wires that are loose or frayed. Tighten all loose electrical wires before the engine is operated. Repair all frayed electrical wires before the engine is started.

Grounding Practices

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

Uncontrolled electrical circuit paths can result in damage to main bearings, to crankshaft journal surfaces, and to aluminum components. Uncontrolled electrical circuit paths can also cause electrical activity that may degrade the engine electronics and communications.

For the starting motor, do not attach the battery negative terminal to the engine block.

Use a ground strap to ground the case of all control panels to the engine block.

Ground the engine block with a ground strap that is furnished by the customer. Connect this ground strap to the ground plane.

Use a separate ground strap to ground the battery negative terminal for the control system to the ground plane.

Rubber couplings may connect the steel piping of the cooling system and the radiator. This causes the piping and the radiator to be electrically isolated. Ensure that the piping and the radiator is continuously grounded to the engine. Use ground straps that bypass the rubber couplings.

Ensure that all grounds are secure and free of corrosion.

Product Information Section

Model Views and Specifications

i01626872

Model View Illustrations

SMCS Code: 1000

The illustrations show various typical features of G3500 Engines. The illustrations do not show all of the options that are available.

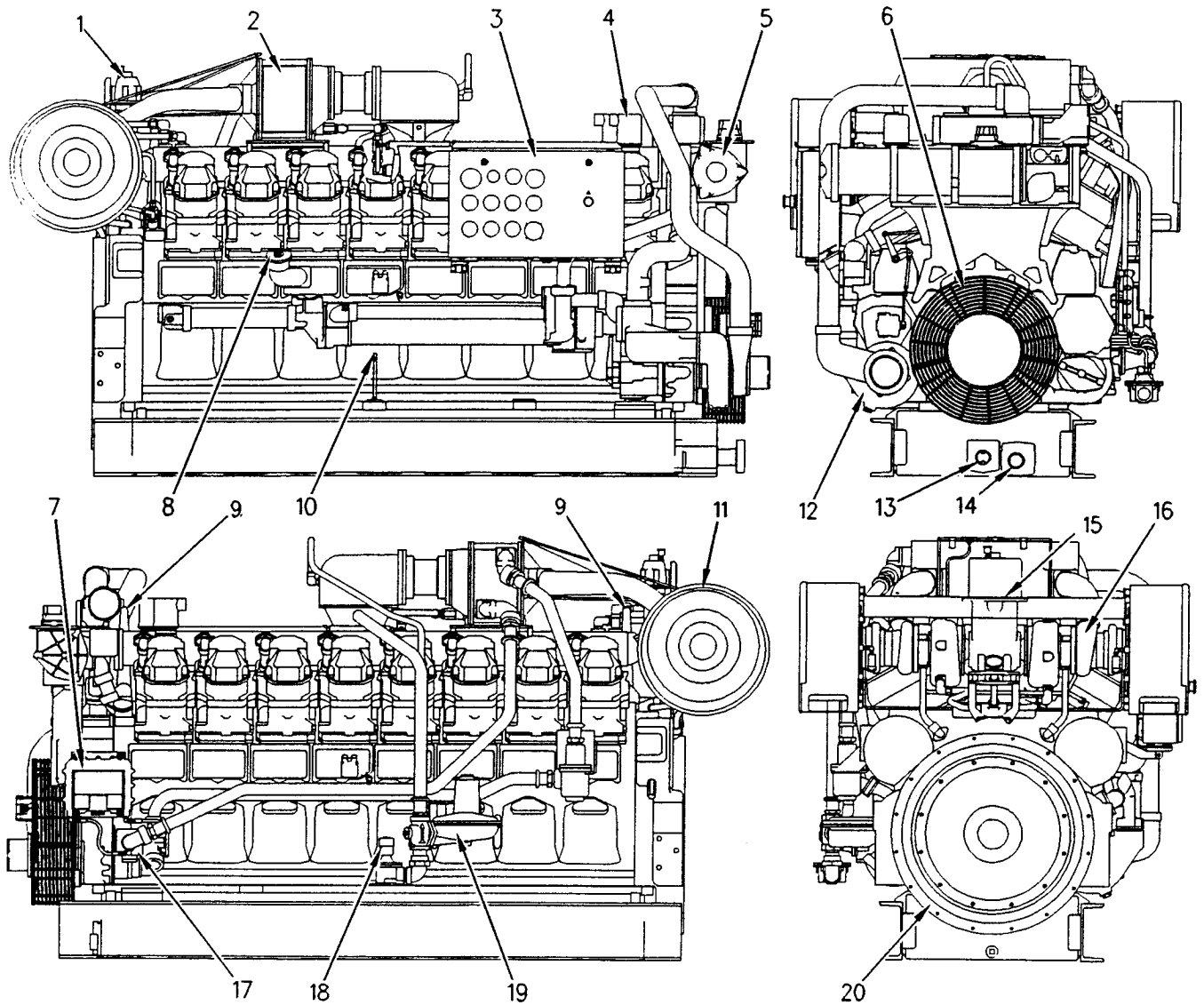


Illustration 15

g00842723

- | | | |
|---|---------------------------------|---------------------------|
| (1) Exhaust bypass | (8) Oil filler | (15) Exhaust |
| (2) Aftercooler | (9) Lifting eye | (16) Turbocharger |
| (3) Instrument panel | (10) Oil level gauge (dipstick) | (17) Auxiliary water pump |
| (4) Crankcase breather | (11) Air cleaner | (18) Gas shutoff valve |
| (5) Oil filter | (12) Jacket water pump | (19) Gas regulator |
| (6) Guard (crankshaft vibration damper) | (13) Oil screen | (20) Flywheel housing |
| (7) Engine control module (ECM) | (14) Oil drain | |

i01627027

Product Description

SMCS Code: 1000

The Caterpillar G3500 Engines were developed in order to provide gas engines for industrial applications and for generator set applications. The engines have the ability to burn a wide variety of gaseous fuels.

Fuel System

The engines can be equipped with a high pressure gas fuel system or a low pressure gas fuel system. Three different fuel systems are available:

- Low Emission (LE) with high pressure gas
- LE with low pressure gas
- Standard (stoichiometric) with high pressure gas

The LE engine with high pressure gas requires a gas pressure within a range of 207 to 310 kPa (30 to 45 psi). The air/fuel ratio is adjusted so that there is excess oxygen in the engine exhaust. This reduces the NO_x emissions.

The LE engine with low pressure gas requires a gas pressure within a range of 10 to 34 kPa (1.5 to 5 psi).

The LE engines with NO_x ratings of two grams have a nominal air/fuel ratio that results in approximately eight percent of free oxygen in the exhaust. The LE engines are turbocharged and aftercooled.

The Standard engines require gas pressure within a range of 138 to 172 kPa (20 to 25 psi). The nominal air/fuel ratio results in approximately two percent of free oxygen in the exhaust. The Standard engines are available with natural aspiration or turbocharged with aftercooling.

The engines can be equipped with a dual fuel system in one of the following configurations:

- A carburetor for high pressure gas and a carburetor for low pressure gas
- Two parallel carburetors for low pressure gas

For low pressure gas engines, the carburetor is located between the air cleaner and the turbocharger. For high pressure gas engines, the carburetor is located after the aftercooler and above the throttle. A governor and an actuator controls the carburetor. The governor maintains the engine rpm. The two following types of carburetors are available:

- Fixed venturi
- Adjustable jet

The low pressure gas engines can use either the fixed venturi or the adjustable jet. Standard engines and LE engines with high pressure gas use the adjustable jet.

The turbocharged aftercooled engines are equipped with flame arrestors. The flame arrestors are installed at the entrance of each inlet port. The flame arrestors prevent the engine backfire. The Engine backfire can occur in the following circumstances:

- Malfunction of ignition
- Engine shutdown

The flame arrestors will extinguish the flame before the flame can ignite in the inlet manifold.

Ignition System

The engine is equipped with an Electronic Ignition System (EIS). The EIS provides dependable firing and low maintenance. The EIS provides precise control of the following factors:

- Spark voltage
- Spark duration
- Ignition timing

The EIS also provides diagnostic capability that enhances troubleshooting. The primary ignition wiring is routed internally through the engine.

The engines are equipped with protection from detonation (combustion knock). The detonation sensors are mounted on each side of the cylinder block. The ignition timing is retarded when excessive detonation is sensed. If detonation continues after full retardation, then the engine control module (ECM) shuts down the engine.

Lubrication System

The engine lubrication oil is supplied by a pump that is driven by a gear. The oil is cooled and the oil is filtered. A bypass valve provides unrestricted flow of lubrication oil to the engine parts if the oil filter elements become plugged. The bypass valve will open if the oil filter differential pressure reaches 276 kPa (40 psi).

Cooling System

The standard cooling system has a centrifugal pump that is driven by a gear. Four temperature regulators regulate the temperature of the coolant.

The turbocharged engine has a Separate Circuit Aftercooler (SCAC). The aftercooler is required to operate at one of the following three temperatures. The temperature depends on the engine rating and the application.

- 32 °C (90 °F)
- 54 °C (129 °F)
- 70 °C (158 °F)

Cogeneration uses energy from heat which would otherwise be wasted. In a cogeneration engine, the oil cooler is not in the jacket water circuit because the jacket water is too hot. The circuit for the oil cooler and the circuit for the aftercooler may be either a combined circuit or a separate circuit. In the combined system, the auxiliary pump circulates water through both the aftercooler and oil cooler cores. The combined system uses a thermostatic control to regulate the oil temperature. This prevents overcooling.

Jacket water for cogeneration can be supplied at temperatures up to 127 °C (260 °F max). The customer must supply a pump for circulating the heated jacket water. The temperature of the jacket water is controlled by the customer.

For engines that use landfill gas, the jacket water coolant temperature is maintained at approximately 110 °C (230 °F min). This temperature depends on the design of the cooling system and the ambient conditions. This temperature is required in order to prevent condensation of the water vapor that is in the fumes of the crankcase. Condensation of the water enables acids to form. Acids are more likely to form because landfill gas contains contaminants such as chlorides, fluorides, and halides. Acids will cause severe internal damage to the engine.

For engines that use landfill gas, the coolant that is supplied to the aftercooler is maintained at a temperature of 54 °C (129 °F). This prevents condensation of moisture in the inlet air piping.

Engine Service Life

Engine efficiency and maximum utilization of engine performance depend on adherence to proper operation and maintenance recommendations. This includes the use of recommended lubricants, fuels, and coolants.

For the engine maintenance that is required, refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule" in the Maintenance Section.

Specifications

SMCS Code: 1000

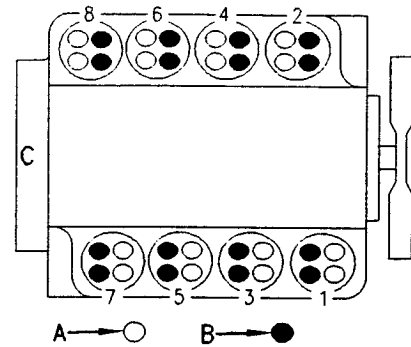


Illustration 16

g00845204

- (1 through 8) Cylinder numbers
- (A) Inlet valves
- (B) Exhaust valves
- (C) Flywheel

Table 1

G3508 Engine Specifications	
Rated rpm	1000 to 1800
Cylinders and arrangement	65 degree Vee 8
Bore	170 mm (6.7 inch)
Stroke	190 mm (7.5 inch)
Displacement	34.5 L (2105 cubic inch)
Compression ratio	7.5:1
	8:1
	11:1
	12.5:1
Aspiration	Naturally aspirated
	Turbocharged aftercooled Separate circuit aftercooling
Rotation (flywheel end)	Counterclockwise rotation is standard.
	Clockwise rotation is optional.
Inlet valve lash	0.51 mm (0.020 inch)
Exhaust valve lash	1.27 mm (0.050 inch)

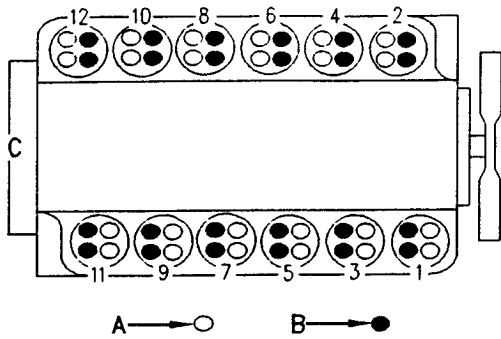


Illustration 17

g00845207

(1 through 12) Cylinder numbers
(A) Inlet valves
(B) Exhaust valves
(C) Flywheel

Table 2

G3512 Engine Specifications	
Rated rpm	1000 to 1800
Cylinders and arrangement	65 degree Vee 12
Bore	170 mm (6.7 inch)
Stroke	190 mm (7.5 inch)
Displacement	51.8 L (3158 cubic inch)
Compression ratio	7.5:1
	8:1
	11:1
	12.5:1
Aspiration	Naturally aspirated
	Turbocharged aftercooled Separate circuit aftercooling
Rotation (flywheel end)	Counterclockwise rotation is standard.
	Clockwise rotation is optional.
Inlet valve lash	0.51 mm (0.020 inch)
Exhaust valve lash	1.27 mm (0.050 inch)

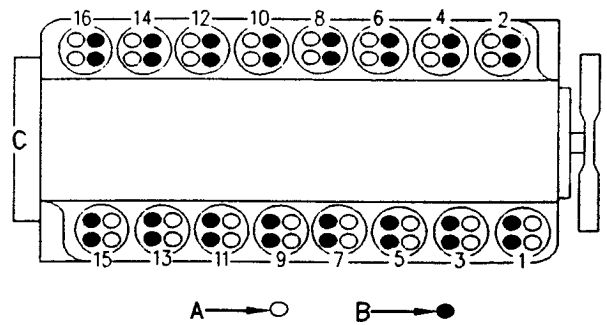


Illustration 18

g00845212

(1 through 16) Cylinder numbers
(A) Inlet valves
(B) Exhaust valves
(C) Flywheel

Table 3

G3516 Engine Specifications	
Rated rpm	1000 to 1800
Cylinders and arrangement	65 degree Vee 16
Bore	170 mm (6.7 inch)
Stroke	190 mm (7.5 inch)
Displacement	69 L (4210 cubic inch)
Compression ratio	7.5:1
	8:1
	11:1
	12.5:1
Aspiration	Naturally aspirated
	Turbocharged aftercooled Separate circuit aftercooling
Rotation (flywheel end)	Counterclockwise rotation is standard.
	Clockwise rotation is optional.
Inlet valve lash	0.51 mm (0.020 inch)
Exhaust valve lash	1.27 mm (0.050 inch)

Product Identification Information

i01627115

Plate Locations and Film Locations

SMCS Code: 1000

Engine Identification

Caterpillar engines are identified with serial numbers, with performance specification numbers, and with arrangement numbers. In some of the cases, modification numbers are used. These numbers are shown on the Serial Number Plate and the Information Plate that are mounted on the engine.

Caterpillar dealers need these numbers in order to determine the components that were included with the engine. This permits accurate identification of replacement part numbers.

Serial Number Plate

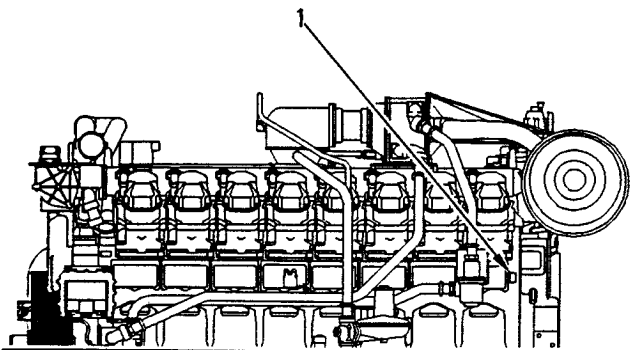


Illustration 19 g00842942

(1) Location of the Serial Number Plate

The Serial Number Plate is on the left side of the cylinder block near the rear of the engine.

ENGINE MODEL	
SERIAL NUMBER	
CATERPILLAR® CAT®	
ARRANGEMENT NUMBER	
(ALWAYS GIVE ALL NUMBERS) MADE IN U.S.A.	
3N-3790 12	

Illustration 20

g00123229

The following information is stamped on the Serial Number Plate: engine serial number, model, and arrangement number.

Information Plate

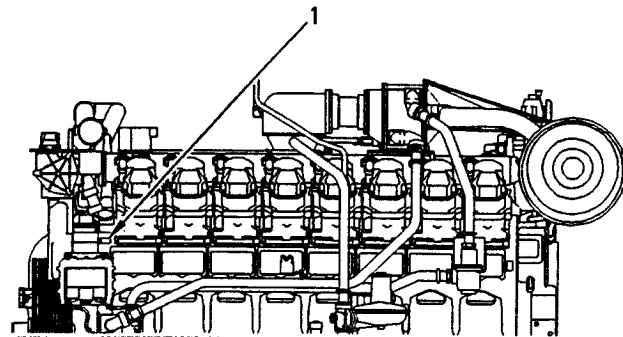


Illustration 21

g00842967

(1) Location of the Information Plate

The Information Plate is on the left side top surface of the cylinder block in front of the front cylinder head.

CAT®		
SER. NO.		
AR NO.	COMP. RATIO	TO 1
AFTERCOOLER DEG.C	TEMPERATURE DEG.F	IGNITION TIMING BTDC CONSULT FUEL USAGE GUIDE
POWER	kw	
FULL LOAD RPM		
159-8314		

Illustration 22

g00361974

The following information is stamped on the Information Plate: compression ratio, aftercooler temperature, power (kilowatts and horsepower), full load rpm, and other information.

i01452057

Reference Information

SMCS Code: 1000

Identification of the items in Table 4 may be needed in order to obtain parts and service. Some of the numbers are on the engine Serial Number Plate and/or Information Plate. Locate the information for your engine. Record the information on the appropriate space in Table 4. Make a copy of this list for a record. Retain the information for future reference.

The top level part numbers in the Parts Manual for the engine are listed with the engine arrangement number.

The packaging arrangement may also be called a pricing arrangement or a customer arrangement. This is the total package with attachments and options that are not included in the engine arrangement.

The performance specification can be used by your Caterpillar dealer with the Technical Marketing Information system. Before the engine leaves the factory, the engine performance is tested. Detailed performance data is recorded. The performance specification number can be used for obtaining the data.

Table 4

Reference Numbers	
Engine Model	
Serial Number	
Arrangement Number	
Packaging Arrangement	
Turbocharger	
Fuel Filter Element	
Lubrication Oil Filter Element	
Auxiliary Oil Filter Element	
Air Cleaner Element	
Fan Drive Belt	
Alternator Belt	
Capacity of the Lubrication System	
Capacity of the Cooling System	
Performance Specification Number	
Low Idle rpm	
High Idle rpm	
Full Load rpm	
Power Rating	

Operation Section

Engine Lifting and Storage

i01492427

Engine Lifting

SMCS Code: 1000; 1122

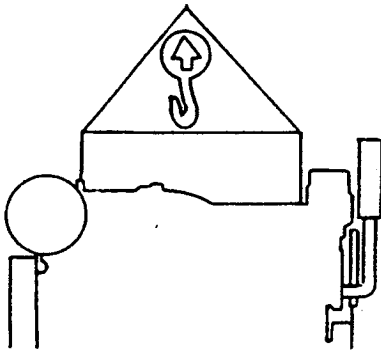


Illustration 23

g00103219

NOTICE

Never bend the eyebolts and the brackets. Only load the eyebolts and the brackets under tension. Remember that the capacity of an eyebolt is less as the angle between the supporting members and the object becomes less than 90 degrees.

When it is necessary to remove a component at an angle, only use a link bracket that is properly rated for the weight.

Use a hoist to remove heavy components. Use an adjustable lifting beam to lift the engine. All supporting members (chains and cables) should be parallel to each other. The chains and cables should be perpendicular to the top of the object that is being lifted.

Some removals require lifting fixtures in order to obtain proper balance and safety.

To remove the engine ONLY, use the lifting eyes that are on the engine.

Lifting eyes are designed and installed for the specific engine arrangement. Alterations to the lifting eyes and/or the engine make the lifting eyes and the lifting fixtures obsolete. If alterations are made, ensure that proper lifting devices are provided. Consult your Caterpillar dealer for information regarding fixtures for proper engine lifting.

Engine Lifting with a Generator

NOTICE

Do not use the engine lifting eyes to remove the engine and generator together.

A lifting plate is provided with the package generator set. Instructions for lifting the package generator set are stamped on the lifting plate.

Consult your Caterpillar dealer for information regarding proper fixtures and lifting devices.

Lifting packaged generator sets will not be level if you lift the unit with a single point lift. A counterweight can be added between the package frame rails whenever the application requires frequent relocation of the unit. For complete information about adding the counterweight, consult your Caterpillar dealer.

The single point lifting eye is secured from the factory before the enclosure is shipped. The correct orientation of the single point lifting eye will allow you to look through the eye when you stand at the side of the enclosure. The lifting eye may stretch when the package is lifted. This may cause the locking nuts to loosen. This could cause the lifting eye to swivel. Ensure that the lifting eye is correctly oriented on the packaged generator set. Ensure that the lifting eye is tightened to the correct torque before you lift the packaged generator set.

i00816700

Engine Storage

SMCS Code: 1000

If the engine will not be started for several weeks, the lubricating oil will drain from the cylinder walls and from the piston rings. Rust can form on the cylinder liner surface, which will increase engine wear which can reduce engine service life.

To help prevent excessive engine wear, use the following guidelines:

- Complete all of the lubrication recommendations that are listed in this Operation and Maintenance Manual, "Maintenance Interval Schedule" (Maintenance Section).
- If freezing temperatures are expected, check the cooling system for adequate protection against freezing. See this Operation and Maintenance Manual, "General Coolant Information" (Maintenance Section).

If an engine is out of operation and if use of the engine is not planned, special precautions should be made. If the engine will be stored for more than one month, a complete protection procedure is recommended.

Your Caterpillar dealer will have instructions for preparing the engine for extended storage periods.

For more detailed information on engine storage, see Special Instruction, SEHS9031, "Storage Procedure for Caterpillar Products".

Generator Storage

For information on generator storage, see the literature that is provided by the OEM of the generator. Consult your Caterpillar dealer for assistance.

Gauges and Indicators

i01663514

Gauges and Indicators

SMCS Code: 7450

Gauges provide indications of engine performance. Ensure that the gauges are in good working order. Determine the normal operating range by observing the gauges over a period of time.

Noticeable changes in gauge readings can indicate potential gauge or engine problems. Problems may also be indicated by gauge readings that change even if the readings are within specifications. Determine and correct the cause of any significant change in the readings. Consult your Caterpillar dealer for assistance.

Your engine may not have the same gauges or all of the gauges that are described below.

NOTICE

If no oil pressure is indicated, STOP the engine. The engine will be damaged from operating without oil pressure.



Engine Oil Pressure – This gauge indicates the pressure of the engine oil. This pressure will be highest after a cold engine is started. The pressure will decrease as the engine warms up. The pressure will increase when the engine rpm is increased. The pressure will stabilize when the engine rpm and temperature are stable. The typical range at low idle rpm is 186 to 344 kPa (27 to 50 psi). The typical range at rated rpm is 345 to 600 kPa (50 to 87 psi).



Oil Filter Differential Pressure – This gauge indicates the difference in pressure between the inlet side and the outlet side of the engine oil filters. As the oil filter elements become plugged, the pressure will increase. Replace the engine oil filter elements when the oil filter differential pressure reaches 103 kPa (15 psi).



Jacket Water Coolant Temperature – This gauge indicates the temperature of the engine coolant at the outlet for the jacket water. The temperature may vary according to the load. The temperature should never be allowed to exceed the boiling temperature of the pressurized cooling system. The operating range is 88 to 100 °C (190 to 210 °F). Higher temperatures may occur under certain conditions. Engines that use fuel with a low Btu content may have temperatures up to 110 °C (230 °F). Cogeneration engines may have a maximum temperature up to 127 °C (260 °F).

The engine should operate within the normal temperature range. The sensor for jacket water coolant temperature must be fully submerged in order to detect the temperature correctly. If the engine is operating above the normal temperature range, perform the following procedure:

1. Reduce the load and/or the engine rpm.
2. Inspect the cooling system for leaks.
3. Determine if the engine must be shut down immediately or if the engine can be cooled by reducing the load and/or rpm.



Inlet Manifold Air Temperature – This gauge indicates the inlet manifold air temperature to the cylinders. The sensor for inlet manifold air temperature is located after the aftercooler.

NOTICE

High inlet manifold air temperature increases the risk of detonation. Detonation can cause damage to the engine. Ensure that the aftercooling system is operating properly.

For operating temperatures and shutdown temperatures, see this Operation and Maintenance Manual, "Alarms and Shutoffs" topic (Operation Section).



Inlet Manifold Air Pressure (TA Engines) and Inlet Manifold Vacuum (NA Engines) – For TA engines, this gauge indicates the air pressure (turbocharger boost pressure) in the air plenum (air inlet manifold) after the aftercooler. For NA engines, this gauge is the pressure of the inlet manifold vacuum. For all engines, this pressure depends on the engine rating, the load, and the operating conditions.

The display on the engine panel is the gauge pressure. The gauge pressure is the difference between the barometric pressure and the absolute pressure.

The Digital Diagnostic Tool can be used to display the pressure that is sensed by the manifold air pressure sensor. If the engine is operating, the display is the absolute pressure. If the engine is not operating, the display is the barometric pressure.

Note: For more information on Inlet Manifold Air Pressure and Inlet Manifold Vacuum, see one of the following two publications:

- Engine Performance, LEBQ6117, "G3500 Industrial"
- Engine Performance, LEBQ6169, "G3500 Generator Set"

Pyrometer – The pyrometer indicates the exhaust stack temperature at the exhaust elbows. For engines with two exhaust stacks, the two exhaust stack temperatures may vary slightly. This may be due to variation of the sensitivity of the two thermocouples.

- For Low Emission engines, the nominal exhaust stack temperature is less than 554 °C (1030 °F).
- For Standard engines, the nominal exhaust stack temperature is less than 510 °C (950 °F).
- The exhaust stack temperature of NA engines depends on the engine rpm and the oxygen that is in the exhaust. For NA engines, the nominal range is 538 to 649 °C (1000 to 1200 °F).

The pyrometer also indicates the temperature of the exhaust gas of each individual cylinder. These temperatures are measured at the exhaust port of each cylinder head. The exhaust temperature will vary slightly between the cylinders. Table 5 lists nominal temperatures and maximum temperatures.

Table 5

Exhaust Port Temperatures		
Engine	Nominal Temperature	Maximum Temperature
Low Emission	621 °C (1150 °F)	670 °C (1238 °F)
Standby (Low Emission)	621 °C (1150 °F)	700 °C (1292 °F)
Standard	643 °C (1190 °F)	700 °C (1292 °F)
Standby (Standard)	643 °C (1190 °F)	730 °C (1346 °F)



Tachometer – This gauge indicates the engine rpm.

NOTICE

An overspeed can result in serious damage to the engine. To help prevent engine damage, never allow the engine to exceed the rated rpm.

Note: The rated rpm is stamped on the engine Information Plate.



Service Hour Meter – The meter indicates the total number of clock hours of engine operation.

Fuel Filter Differential Pressure – This gauge is provided by the customer. This gauge indicates the difference in fuel pressure between the inlet side and the outlet side of the fuel filter. As the fuel filter element becomes plugged, the difference in pressure between the two sides of the fuel filter increases.

For high pressure gas fuel systems, service the fuel filter when the fuel filter differential pressure reaches 34 kPa (5 psi).

For low pressure gas fuel systems, service the fuel filter when the fuel filter differential pressure reaches 1.7 kPa (.25 psi).

Optional Gauges



Air Cleaner Differential Pressure – This gauge indicates the difference in air pressure between the inlet side and the engine side of the air filter element. The pressure is measured from the turbocharger air inlet. As the air filter element becomes plugged, the difference in pressure between the two sides of the air cleaner element will increase. For optimum engine performance, replace the air filter elements or clean the air filter elements when the air cleaner pressure differential reaches 2.5 kPa (10 inches of H₂O). Maximum air cleaner differential pressure is 3.7 kPa (15 inches of H₂O).



Ammeter – This gauge indicates the amount of charge or discharge in the battery charging circuit. Operation of the indicator should be to the right side of "0"(zero).



Engine Oil Temperature – This gauge indicates the engine oil temperature after the oil has passed through the oil cooler. The oil cooler is thermostatically controlled. The oil temperature is controlled by an 82 °C (180 °F) temperature regulator that is in contact with the oil. The maximum oil temperature at rated rpm and rated load is 104 °C (220 °F).



Coolant Pressure – This gauge can be used for jacket water pressure or auxiliary water pressure. On cogeneration engines, this gauge is a differential pressure gauge.

Features and Controls

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Performance Parameters

SMCS Code: 1000

Note: For information on the following topics, see the Service Manual, "Systems Operation/Testing and Adjusting" or see Special Instruction, SEHS9769, "Installation and Initial Start-Up Procedure for G3500 Engines".

- Adjusting the carburetor
- Adjusting the control linkage for the carburetor
- Adjusting the exhaust bypass

Consult your Caterpillar dealer for assistance.

Air/Fuel Ratio

The correct air/fuel ratio is very important for the following considerations:

- Margin of detonation
- Control of emissions
- Achieving optimum service life for the engine

If the air/fuel ratio is not appropriate for the fuel and the operating conditions, a failure of the engine may occur. The service life of the turbocharger, the valves, and other components may be reduced.

Fuel Supply Pressure

Fluctuations of the fuel pressure can change the air/fuel ratio. For high pressure gas fuel systems, the maximum fluctuation that is allowed in the fuel pressure is 3.4 kPa (0.50 psi). For low pressure gas fuel systems, the maximum fluctuation that is allowed in the fuel pressure is 1.7 kPa (0.25 psi). Ensure a stable fuel pressure to the engine by installing a second gas pressure regulator prior to the gas pressure regulator on the engine.

Gas Pressure Regulator

The gas pressure regulator maintains a pressure differential between the air and the fuel that is supplied to the carburetor. Set the pressure of the fuel supply to a maximum of 1.5 kPa (6 inch of H₂O) more than the pressure of the air supply. The gas pressure regulator will maintain the pressure differential in response to changes in the air pressure. If high idle is important, lower the differential pressure to 1 kPa (4 inch of H₂O). The higher differential pressures will give better engine response to load changes.

A water manometer is used to measure the pressure differential. This measurement is taken when the engine is operating at high idle rpm. When a load is applied, the fuel pressure will usually decrease by approximately 0.25 to 0.5 kPa (0.25 to 0.5 kPa (1 to 2 inch of H₂O)). If the performance of the gas pressure regulator is erratic, the gas pressure regulator may require service.

Temperature of the Fuel Supply

Changes in the temperature of the fuel supply affects the air/fuel ratio. Warmer fuel is less dense than cold fuel. This results in a leaner mixture that causes a noticeable reduction of power. The recommended temperature differential of the air and the fuel is 2.8 °C (5 °F).

The maximum fuel temperature depends on the temperature regulator of the aftercooler:

- For engines with a 32 °C (90 °F) aftercooler, the maximum temperature of the air/fuel mixture is 38 °C (100 °F).
- For engines with a 54 °C (130 °F) aftercooler, the maximum temperature of the air/fuel mixture is 60 °C (140 °F).

For more information, see Application and Installation Guide, LEKQ7260, "Low BTU Engines". Consult your Caterpillar dealer for assistance.

Temperature of the Air Supply

Changes in the temperature of the air supply affects the air/fuel ratio. In addition to seasonal changes, the air temperature changes overnight. Control of the temperature in the engine room will help to maintain the air/fuel ratio.

To optimize the inlet air temperature, use ducting and a heat exchanger. This will help to avoid exposure to hot air from a generator. For more information, see Application and Installation Guide, LEKQ7250, "Air Intake". Consult your Caterpillar dealer for assistance.

Carburetor

Engines That Use Bio-Gas

The Impco carburetor that is used on some applications tends to supply a rich air/fuel mixture during partial load operation. The rich air/fuel mixture and rapid loading can cause detonation. This depends on the following factors:

- Temperature of the inlet air and fuel
- Btu of the fuel
- Air/fuel setting
- Carburetor jet
- Ignition timing
- Deposits in the combustion chamber

To reduce the risk of detonation during loading, adjust the ramp time so that the load is applied over five to ten minutes.

If detonation still occurs, or if startability is inhibited, the air/fuel ratio for partial load operation can be made leaner. Install 7E-1569 Washers behind each gas valve of the carburetor. Use a maximum of three washers per valve. After the washers are installed, adjust the setting for the oxygen at full load.

Angle of the Throttle Plate

The angle of the throttle plate is adjusted for full load operation. The angle is adjusted by changing the setting of the exhaust bypass valve. The proper angle depends on the type of governor or actuator that is used.

- For the Woodward 3161 Governor and the EG3P Actuator, adjust the angle of the throttle plate between 60 and 65 degrees.

The following factors affect the angle of the throttle:

- LHV of the fuel
- Setting of the air/fuel ratio (inlet manifold air pressure)
- Setting of the exhaust bypass (wastegate)
- Altitude

Ensure that the angle of the throttle plate is properly set. This will maintain the margin for detonation. This will also enable the engine to accept load changes without lugging.

Setting of the Exhaust Bypass (Wastegate)

The engines are equipped with exhaust bypass valves that are adjustable. This enables the throttle position to be correctly set for the application. Adjustments must be made for the following variables:

- Altitude
- Setting of the air/fuel ratio
- Methane number of the fuel

The exhaust bypass is adjusted in order to achieve the proper angle of the throttle plate when the engine is operating under a rated load.

Oil Consumption

High loads will cause the engine to consume more oil.

The rate of oil consumption is called the Brake Specific Oil Consumption (BSOC). The unit of measure is grams per brake kilowatt hour (pounds per brake horsepower hour). The BSOC depends on the following factors: engine model, aspiration, and operating load.

Table 6 lists the normal mid-life BSOC for G3500 Engines under the following conditions:

- Load factor of 100 percent
- Maintenance is performed according to this Operation and Maintenance Manual, "Maintenance Interval Schedule" (Maintenance Section).

Table 6

BSOC for G3500 Engines	
Naturally Aspirated Engine	0.913 g/bkw h (0.0015 lb/bhp h)
Turbocharged Aftercooled Engine	0.426 g/bkw h (0.0007 lb/bhp h)

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Sensors and Electrical Components

SMCS Code: 1900; 7400

Note: This section contains some general information about the engine electronic system and sensors. For more information, see the following publications:

- Systems Operation/Testing and Adjusting, SENR6412, "G3500 Engines"
- Specifications, SENR6417, "G3500 Engine Attachments"
- Systems Operation/Testing and Adjusting, SENR6418, "G3500 Engine Attachments"
- Electronic Troubleshooting, SENR6413, "G3500 Engines"
- Electronic Troubleshooting, SENR6517, "G3500 Air/Fuel Ratio Control"

Electronic Ignition System

The Caterpillar Electronic Ignition System was designed to replace the type of ignition system that has a magneto. The following benefits are the most significant advantages of the electronic ignition system:

- Addition of more extensive system diagnostics
- Elimination of parts that are prone to mechanical wear
- Precise control of ignition timing

The electronic ignition system provides control for the following activities:

- Diagnostics of the engine control system
- Ignition timing
- Protection from detonation

If operating parameters are outside of acceptable limits, the electronic ignition system provides warnings. The system may inhibit the engine operation or may shut down the engine. Also, the system can display some of the operating parameters of the engine.

The electronic ignition system includes the following components:

- Detonation sensor

- Engine control module
- Engine speed/timing sensor
- Ignition harness
- Manifold air pressure sensor
- Sensor harnesses
- Spark plugs
- Transformers

Control of the Electronic Ignition System

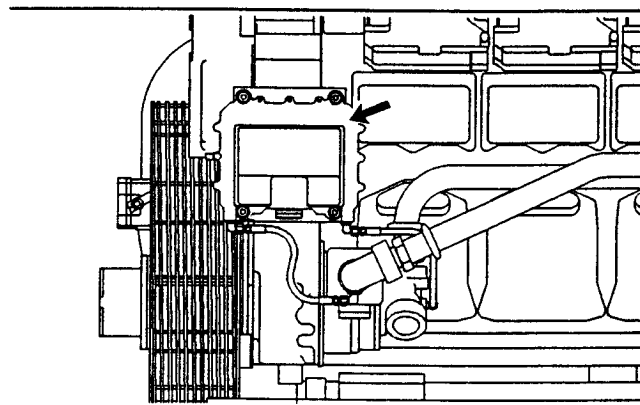


Illustration 24

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Engine control module

The engine control module is a sealed unit with no serviceable parts. Sensors are used in order to monitor engine operation. Wiring harnesses connect the sensors to the engine control module. The module uses information from the sensors in order to determine the ignition timing. The information is also used to provide diagnostics.

Note: On newer engines, there is a small door on the front face of the control module. Replace the computer chip inside the control module if updates or special modifications are required.

The primary ignition wiring is routed through the engine block. Ignition timing is based on the following variables:

- Map of ignition timing that is desired
- Engine parameters

The operator can use a Digital Diagnostic Tool to change the following parameters:

- Desired timing
- Map of speed and timing

The engine control module has outputs to each ignition transformer. The module also uses sensors and internal circuitry to monitor the system components. If a problem develops in a component or a wiring harness, the control system will sense the problem. The control system will notify the operator by creating a diagnostic code.

Ignition Transformers

Each cylinder has an ignition transformer that is located under the valve cover. To initiate combustion in each cylinder, the engine control module sends a pulse to the primary coil of the ignition transformer. The transformer increases the voltage which creates a spark across the spark plug electrode.

For the electronic ignition system, the transformers are grounded through the valve cover. Use caution when a valve cover is removed.

Always disconnect the ignition harness from the transformer when a valve cover is removed.

An ignition harness connects each transformer to the engine control module. The harness is routed inside the engine along the camshaft.

Junction Box

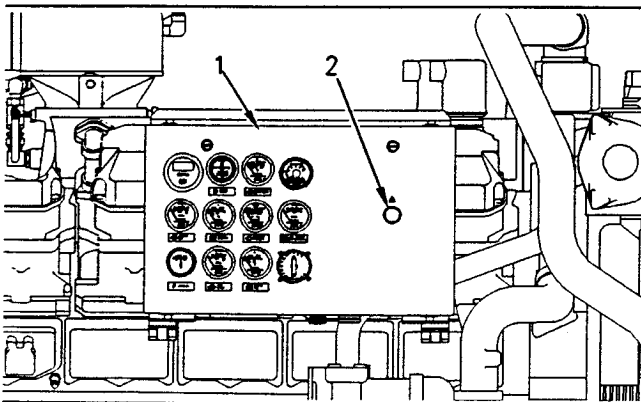


Illustration 25

g00787967

- (1) Junction box
(2) Emergency stop button

Junction box (1) contains these components:

- Gauges
- Meters
- Indicators
- Switches

The junction box also contains the electrical terminal strips that connect the sensors, pickups, and relays to the gauges. In addition, the junction box provides shutoff protection for the engine.

Emergency stop button (2) is mounted on the junction box. When this button is pressed, both the fuel and the ignition are shut off.

NOTICE

Do not use this method to stop the engine unless an emergency has occurred. Continuous emergency shutdowns can cause damage to some engine components. This will leave unburned fuels in the combustion chambers and in the exhaust system. If an emergency shutdown occurs, purge the system by cranking the engine for 5 to 10 seconds with the ignition shutoff.

The emergency stop button must be reset before the engine will start. Turn the button clockwise. The spring-loaded button will move to the reset position.

G3500 Engines use an energize-to-run system. The system can also be configured as an energize-to-shutoff system.

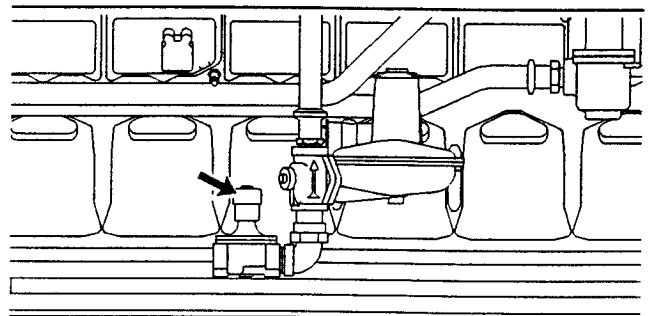


Illustration 26

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Gas shutoff valve (GSOV)

For an energize-to-run system, the gas shutoff valve (GSOV) must remain energized in order to supply fuel to the engine.

For an energize-to-shutoff system, the GSOV must be energized in order to shut off the fuel to the engine.

The junction box is used to monitor the following parameters:

- Engine oil pressure
- Engine coolant temperature

If the engine oil pressure is too low, or if the coolant temperature is too high, a relay will shut off the fuel.

Sensors

Sensors provide information to the junction box and the engine control module. The information enables the module to control the engine as efficiently as possible over a wide range of operating conditions. The information is used for monitoring engine operation via gauges and indicators on the junction box and/or the control panel.

The sensors also enable the activation of alarms and shutoffs in response to abnormal operation.

Air Inlet Temperature

A probe for monitoring the air inlet temperature is located in the air inlet manifold. No adjustment can be made to the temperature range. Excessive inlet air temperature can activate an alarm or a shutdown.

Coolant Level

Monitoring of the coolant level is an optional attachment.

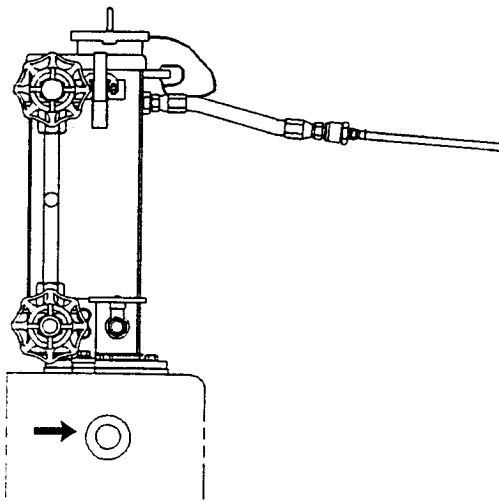


Illustration 27

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The coolant level sensor is mounted in the expansion tank. If the coolant level is too low, the sensor can activate an alarm or a shutoff. Coolant must be added to the cooling system in order to correct the condition.

Detonation

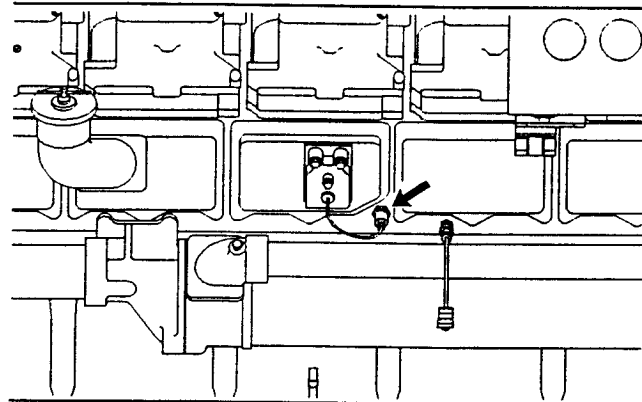


Illustration 28

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Detonation sensor

The detonation sensors monitor the engine for detonation. One sensor is mounted in the center of each cylinder bank. The sensor produces a voltage signal that is proportional to the engine detonation. This information is processed by the engine control module in order to determine detonation levels. To eliminate detonation, the engine control module retards the engine timing, if necessary. If excessive detonation continues, the engine control module will shut down the engine.

Engine Oil Pressure

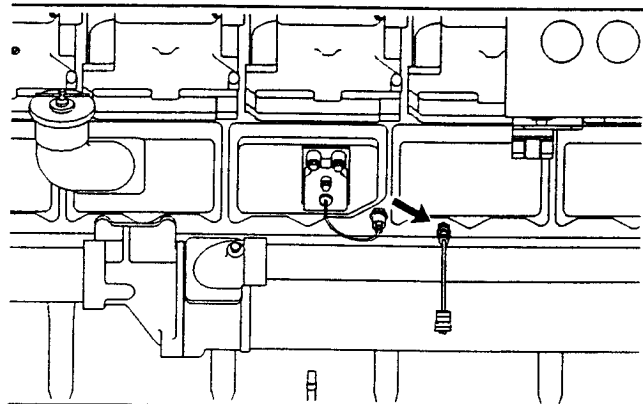


Illustration 29

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Oil pressure sensor

The engine oil pressure sensor is located in the side of the engine block. The sensor measures the oil pressure in the bearing oil gallery. Low oil pressure will cause a shutdown.

Engine Speed/Timing Sensor

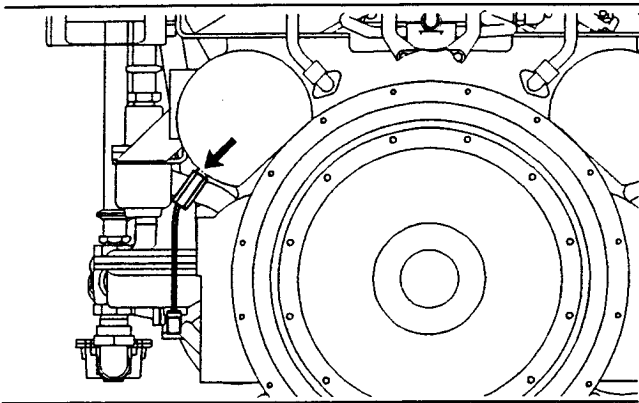


Illustration 30
Engine speed/timing sensor

The engine speed/timing sensor provides accurate information about the speed of the crankshaft and the position of the crankshaft. A ring that is mounted on the camshaft provides the information that is detected by the sensor. The engine control module uses the information in order to determine ignition timing.

Manifold Air Pressure

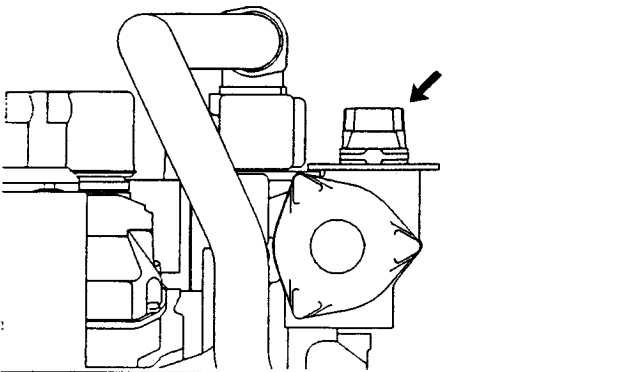


Illustration 31
Manifold air pressure sensor

The manifold air pressure sensor is connected to the air inlet manifold. The sensor monitors the absolute manifold air pressure. This is the atmospheric pressure plus the gauge pressure. The information is used by the engine control module to determine the engine load. The output of the sensor can be read with the Digital Diagnostic Tool.

Overspeed

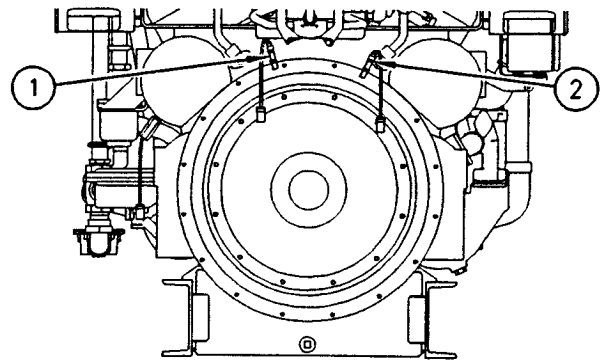


Illustration 32
(1) Magnetic pickup for the governor
(2) Magnetic pickup for the service meter

Two magnetic pickups are mounted in the flywheel housing. The magnetic pickups monitor the rpm of the flywheel ring gear. The following conditions will cause a shutdown:

- The engine rpm exceeds the setpoint for overspeed.
- The control system does not receive a signal from the magnetic pickup.

Water Temperature

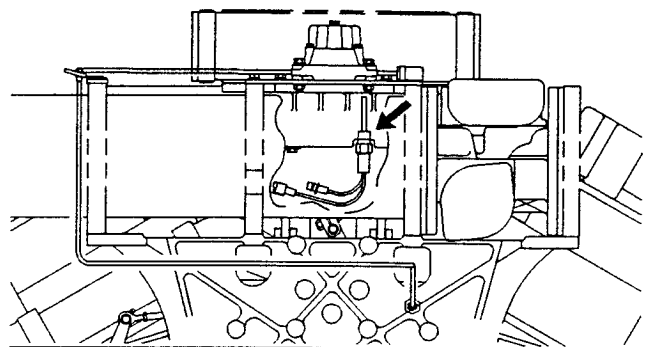


Illustration 33
Water temperature sensor

The water temperature sensor is located in the water temperature regulator housing. To monitor the coolant temperature, the element must be in contact with the coolant. If overheating occurs due to low coolant level or no coolant, the sensor will not function properly. The sensor can be wired into an alarm system or an indicator in order to indicate high water temperature. After an overheated engine is allowed to cool, the contactor is automatically reset.

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Alarms and Shutoffs

SMCS Code: 7400

Engines may be equipped with optional engine protective devices that are not included in this section. This section contains some general information about the function of typical engine protective devices.

Alarms and shutoffs are electronically controlled. The operation of all alarms and shutoffs utilize components which are actuated by a sensing unit. The alarms and shutoffs are set at critical operating temperatures, pressures, or speeds in order to protect the engine from damage.

The alarms function in order to warn the operator when an abnormal operating condition occurs. The shutoffs function in order to shut down the engine when a more critical abnormal operating condition occurs. The shutoffs help to prevent damage to the engine.

WARNING

Unburned gas in the inlet manifold and/or in the exhaust manifold can ignite when the engine is started. Personal injury and/or property damage can result. Use this procedure to clear the engine and the exhaust system of unburned gas:

Before starting an engine that was stopped by terminating the ignition system, turn the gas supply OFF. Crank the engine for approximately 15 seconds in order to clear any unburned gas from the engine and the exhaust system.

If an engine protective device shuts off the engine, always determine the cause of the shutoff. Make the necessary repairs before attempting to start the engine.

Become familiar with the following information:

- Types of the alarm and shutoff controls
- Locations of the alarm and shutoff controls
- Conditions which cause each control to function
- Resetting procedure that is required before starting the engine

Testing Alarms and Shutoffs

Alarms must function properly in order to provide timely warning to the operator. Shutoffs help to prevent damage to the engine. It is impossible to determine if the engine protective devices are in good working order during normal operation. Malfunctions must be simulated in order to test the engine protective devices.

NOTICE

During testing, abnormal operating conditions must be simulated.

The tests must be performed correctly in order to prevent possible damage to the engine.

Periodic testing of engine protective devices for proper operation is recommended maintenance. **To prevent damage to the engine, only authorized service personnel or your Caterpillar dealer should perform the tests.**

Setpoints for Alarms and Shutoffs

Inlet Manifold Air Temperature

Table 7 lists information on the operating temperatures and the shutdown temperatures for inlet manifold air temperature. The temperatures are associated with different water temperature regulators for separate circuit aftercoolers. The temperatures are also associated with different types of gas engines.

Table 7

Approximate Operating Temperatures And Shutdown Temperatures For G3500 Engine Inlet Manifold Air Temperature		
Opening Temperature for the Water Temperature Regulator (SCAC)	Approximate Operating Temperature	Shutdown Temperature
32 °C (90 °F) Low Emission engine	43 °C (110 °F)	47 °C (117 °F)
54 °C (130 °F) Low Emission engine	64 °C (147 °F)	68 °C (154 °F)
70 °C (158 °F) Low Emission engine	78 °C (172 °F)	81 °C (178 °F)
32 °C (90 °F) Standard engine	41 °C (106 °F)	45 °C (113 °F)
54 °C (130 °F) Standard engine	62 °C (144 °F)	66 °C (151 °F)

Cogeneration and Bio-Gas Fuel Applications

G3500 Engines that are in cogeneration and bio-gas applications operate with jacket water coolant temperatures that are higher than normal. The protective system is optional for cogeneration engines. The protective system is standard for engines that use bio-gas fuel.

Table 8 lists the setpoints for cogeneration engines. Table 9 lists the setpoints for engines that use bio-gas fuel.

Table 8

Setpoints For Cogeneration Engines	
Condition	Setpoint
Alarm signal of differential pressure of jacket water pressure	34.5 kPa (5 psi)
Alarm signal of jacket water coolant temperature	127 °C (260 °F)
Alarm signal of engine oil temperature	102 °C (215 °F)
Shutdown temperature of engine oil	104 °C (220 °F)
Alarm signal of inlet air temperature or shutdown ⁽¹⁾	68 °C (154 °F)

⁽¹⁾ High inlet air temperature is a shutdown for NA engines. High inlet air temperature is an alarm for all other engines.

Table 9

Setpoints For Engines that use Bio-Gas Fuel	
Condition	Setpoint
Alarm signal of differential pressure of jacket water pressure	48.3 kPa (7 psi)
Alarm signal of jacket water coolant temperature	124 °C (255 °F)
Arming relay of jacket water pressure	98 °C (208 °F)
Shutdown temperature of engine oil	107 °C (225 °F)
Shutdown temperature of inlet air	68 °C (154 °F)

Engines Without A Caterpillar Remote Control Panel (Status)

The customer must provide the relay logic for engines that are not equipped with a Caterpillar Remote Control Panel (Status). The customer must provide the relay logic for the following parameters:

- Oil pressure (high idle limit)
- Oil pressure (low idle limit)
- Jacket water coolant temperature (high temperature)
- Overspeed

The specific limits are listed in Table 10. Relay logic must be provided for shutting off the engine in case any of the limits are reached. Consult your Caterpillar dealer for assistance.

Table 10

G3500 Engine Shutdown Setpoints				
Rated RPM	Minimum Oil Pressure		Jacket Water ⁽¹⁾ Temp.	Overspeed RPM
	High Idle RPM	Low Idle RPM		
1000	275 kPa (40 psi)	100 kPa (15 psi)	105 °C (221 °F)	1200
1400	275 kPa (40 psi)	100 kPa (15 psi)	105 °C (221 °F)	1680
1500	275 kPa (40 psi)	100 kPa (15 psi)	105 °C (221 °F)	1800
1800	275 kPa (40 psi)	100 kPa (15 psi)	105 °C (221 °F)	2160

(1) To prevent overheating, the coolant pressure must be a minimum of 27.6 kPa (4 psi).

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Control Panel

SMCS Code: 7451

Remote Control Panel (Status)

This section contains some general information about the Remote Control Panel (Status). For more detailed information, see these publications:

- Systems Operation/Testing and Adjusting, SENR6420, "Control Panel (Status-Timing)"
- Electronic Troubleshooting, SENR6413, "G3500 Engines".

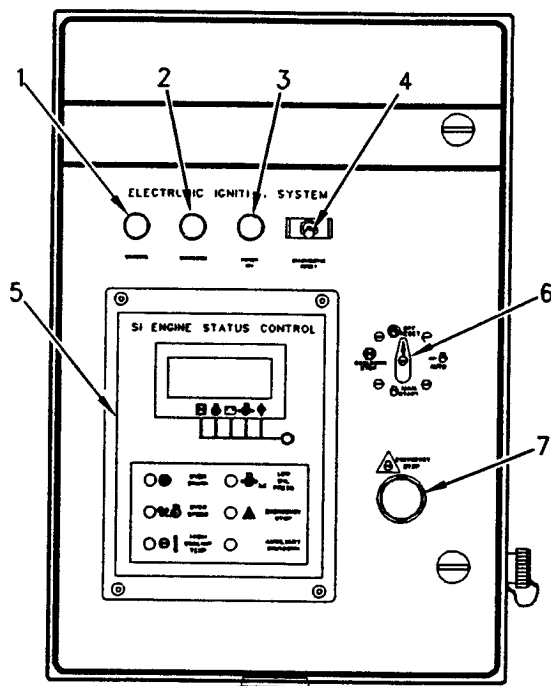


Illustration 34

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Remote Control Panel (Status)

- (1) "WARNING" indicator
- (2) "SHUTDOWN" indicator
- (3) "POWER ON" indicator
- (4) "DIAGNOSTIC RESET" switch
- (5) Status control module
- (6) Engine control switch
- (7) "EMERGENCY STOP" button

The yellow "WARNING" indicator (1) flashes or stays lighted in order to indicate the occurrence of an abnormal operating condition. A warning is not severe enough to cause a shutdown. However, this signifies a serious problem. If a warning occurs, a diagnostic code for the condition is logged in the engine control module. Correct the cause of the warnings as soon as possible in order to avoid problems with operation.

The red "SHUTDOWN" indicator (2) illuminates continuously when an adverse operating condition causes a shutdown. A diagnostic code for the condition is logged in the engine control module. If the engine is shut down due to parameters that are out of acceptable limits, the red indicators on the status control module (5) will also illuminate.

"POWER ON" indicator (3) illuminates continuously when power is supplied to the control panel.

"DIAGNOSTIC RESET" switch (4) is a toggle switch that is used to clear diagnostic codes from the engine control module. The switch cannot clear individual codes. Use of the switch will clear all codes that are active in the engine control module. **Do not clear the codes until the problems that caused the codes are addressed.**

Status control module (5) has several engine monitoring and control functions.

Engine control switch (6) is used to control starting the engine and stopping the engine.

"EMERGENCY STOP" button (7) is used to stop the engine in an emergency situation. When the button is pressed, the status control module shuts off the fuel via the gas shutoff valve. The module also terminates the ignition. The "EMERGENCY STOP" button must be reset before the engine will start.

Status Control Module

The status control module receives information from the following sources:

- The operator
- Magnetic pickups
- Transducers (oil pressure and water temperature)
- Optional remote sources

The basic performance of the status control module includes the following functions:

When the status control module receives a signal to start the engine, the module enables fuel to flow to the engine. The module activates the starting motor. After the rpm for crank termination is achieved, the module deactivates the starting motor.

When the status control module receives a signal to stop the engine, the module shuts off the fuel. The module sends a signal to the engine control module. The engine control module terminates the ignition.

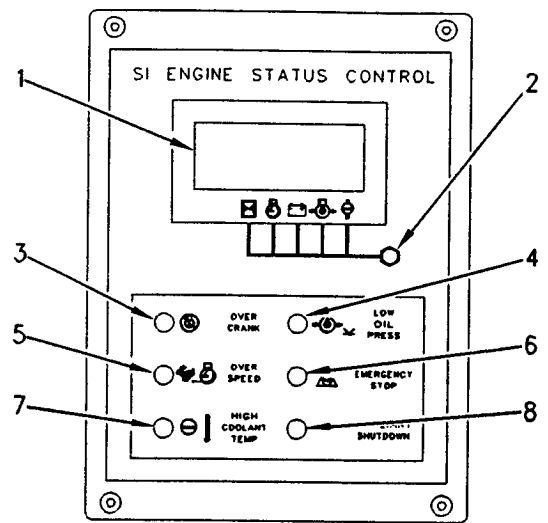







Illustration 35

g00785287

- (1) Liquid crystal display (LCD)
- (2) Switch
- (3) "OVERCRANK" indicator
- (4) "LOW OIL PRESSURE" indicator
- (5) "OVERSPEED" indicator
- (6) "EMERGENCY STOP" indicator
- (7) "HIGH COOLANT TEMPERATURE" indicator
- (8) "AUXILIARY SHUTDOWN" indicator

Liquid Crystal Display (LCD) – Symbols for the following parameters are located under LCD (1). The LCD provides a digital display of the status of these parameters. When the status of a parameter is displayed, an arrow at the bottom of the LCD points the corresponding symbol. The display can be in metric units or English units.

-  Hour meter – When the arrow points to this symbol, the hours of engine operation are displayed.
-  Engine speed – When the arrow points to this symbol, the engine rpm is displayed.
-  System battery voltage – When the arrow points to this symbol, the voltage of the electrical system's battery is displayed.
-  Engine oil pressure – When the arrow points to this symbol, the engine oil pressure is displayed.
-  Coolant temperature – When the arrow points to this symbol, the Coolant temperature is displayed.


The parameters are displayed sequentially. To lock the display onto one of the parameters, press switch (2). To resume the sequential display, press the switch again.


The LCD is also used to display diagnostic codes. A diagnostic code indicates that the system has detected a problem with a component that is associated with the status control module. When a diagnostic code is displayed, the arrow that indicates the display of the parameters will be missing. A flashing "DIAG" will be displayed. If more than one diagnostic code is present, the diagnostic codes will be displayed in sequence.


To clear the diagnostic codes from the LCD, turn the engine control switch to the "OFF/RESET" position. For information on diagnostic codes, see these publications:

- Systems Operation/Testing and Adjusting, SENR6420, "Control Panel (Status-Timing)"
- Electronic Troubleshooting, SENR6413, "G3500 Engines".
- Electronic Troubleshooting, SENR6517, "G3500 Air/Fuel Ratio Control".


The status control module has six indicators (Illustration 35) that indicate engine shutdowns. The shutdowns that are associated with the indicators are described below.

 "OVERCRANK" – If the engine fails to start within a programmed amount of time or if the number of crank cycles are exceeded, the status control module will deactivate the starting sequence. Indicator (3) will flash. The engine control switch must be turned to the "OFF/RESET" position before another attempt to start the engine can be made.


 "LOW OIL PRESSURE" – There are two setpoints for low oil pressure. The setpoints depend on the engine rpm. One setpoint is for engine rpm that is below the oil step speed setting. The other setpoint is for engine rpm that is above the oil step speed setting. If the engine oil pressure decreases below the setpoint, the fuel to the engine will be shut off. Indicator (4) will flash.

 "OVERSPEED" – If the engine rpm exceeds the setpoint for overspeed, the fuel and the ignition will be shut off. Indicator (5) will flash.

Note: A verify button for overspeed is located on the back of the status control module. This enables a test of the overspeed protection system to be performed. See Systems Operation/Testing and Adjusting, SENR6420, "Control Panel (Status-Timing)" for information on the service procedure.

 "EMERGENCY STOP" – Indicator (6) will flash if the "EMERGENCY STOP" button is used to stop the engine.

Note: Do not use the coolant temperature sensor to monitor the operation of jacket water heaters (if equipped).

 "HIGH COOLANT TEMPERATURE" – If the coolant temperature exceeds the setpoint, the fuel will be shut off. Indicator (7) will flash.

"AUXILIARY SHUTDOWN" indicator (8) indicates that an external request was used to stop the engine. If the auxiliary shutdown is not used, the "AUXILIARY SHUTDOWN" indicator can be used as a spare indicator.

Engine Control Switch

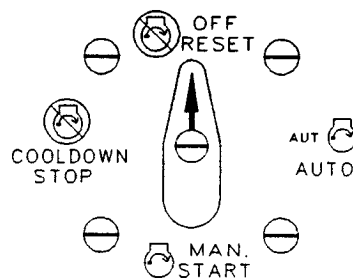


Illustration 36

g00307929

Engine control switch in the "OFF/RESET" position

The engine control switch is a rotary switch that has four positions:

- "OFF/RESET"
- "AUTO"
- "MAN. START"
- "COOLDOWN/STOP"

Note: Only the indicators on the status control module are reset when the engine control switch is turned to the "OFF/RESET" position. Diagnostic codes must be cleared with the "DIAGNOSTIC RESET" switch (Illustration 34).

"OFF/RESET" – When the engine control switch is turned to this position (12 o'clock), the indicators on the status control module are reset and the engine shuts down immediately. The power to the engine control module and the status control module is shut off. This method is not recommended for normal stopping.

"AUTO" – When the engine control switch is in this position (3 o'clock), the system is configured for remote operation. When the remote start/stop initiate contact closes, the engine will start. When the remote start/stop initiate contact opens, the engine will shut down. If the cooling cycle is programmed, the engine will operate for the cooldown period before the engine stops.

"MAN. START" – When the engine control switch is turned to this position (6 o'clock), the engine will start. The engine will continue to operate when the switch is in this position. However, if a setpoint for a shutdown is exceeded, the engine will shut down.

"COOLDOWN/STOP" – This is the preferred method for normal stopping. When the engine control switch is turned to this position (9 o'clock), the engine will continue to operate until a programmable cooling cycle has elapsed. The cooling cycle can be programmed for a 0 to 30 minute period. The default setting is five minutes.

Engine Starting

i01627461

Before Starting Engine

SMCS Code: 1000; 1400; 1450

Note: Certain procedures are required before an engine is started for the first time. See Special Instruction, SEHS9769, "Installation and Initial Start-UP Procedure for G3500 Engines".

Perform the required daily maintenance and other periodic maintenance before starting the engine. This can prevent major repairs at a later date. See this Operation and Maintenance Manual, "Maintenance Interval Schedule" (Maintenance Section).

Walk-Around Inspection

NOTICE

For any type of leak, clean up the fluid. If leaking is observed, find the source and correct the leak. If leaking is suspected, check the fluid levels more often than recommended until the leak is found or fixed, or until the suspicion of a leak is proved to be unwarranted.

To obtain maximum service life for your engine, make a thorough inspection before starting the engine. Make a walk-around inspection of the installation. Look for items such as oil or coolant leaks, loose bolts and trash buildup. Remove any trash. Make repairs, if necessary.

- The guards must be in the proper place. Repair damaged guards or replace missing guards.
- Ensure that the areas around the rotating parts are clear.

Air Inlet System

- Ensure that the air inlet piping and the air filters are in place.
- Ensure that all clamps and connections are secure.
- Inspect the air cleaner service indicator (if equipped). Service the air cleaner filter element when the yellow diaphragm enters the red zone, or the red piston locks in the visible position.

Cooling System

- Inspect the cooling system for leaks or loose connections. Inspect the condition of all the hoses and pipes for the cooling system. Ensure that the connections are properly clamped.
- Inspect the water pumps for evidence of leaks.
- Check the coolant level. Add coolant, if necessary. For information on the proper coolant to use, see this Operation and Maintenance Manual, "Cooling System Specifications" (Maintenance Section).

Driven Equipment

- If necessary, check the oil levels of the driven equipment. Perform any maintenance that is required for the driven equipment. Refer to the literature that is provided by the OEM of the driven equipment.
- If the engine is equipped with a clutch, ensure that the clutch is disengaged.
- For generator set engines, ensure that the main circuit breaker is open.

Electrical System

Inspect the wiring for the following conditions:

- Loose connections
- Wiring that is worn or frayed

Inspect the gauge panel and the control panel for good condition. Reset any shutoff or alarm components.

Fuel System

WARNING

NEVER use a flame to check for gas leaks. Use a gas detector.

An open flame can ignite mixtures of air and fuel. This will cause explosion and/or fire which could result in severe personal injury or death.

- Check the fuel lines for leaks with a gas detector.
- Inspect the fuel lines for loose fittings and leaks. Ensure that the fuel lines are properly clamped.
- Ensure that the fuel is supplied to the engine at the correct pressure for the engine.

Lubrication System

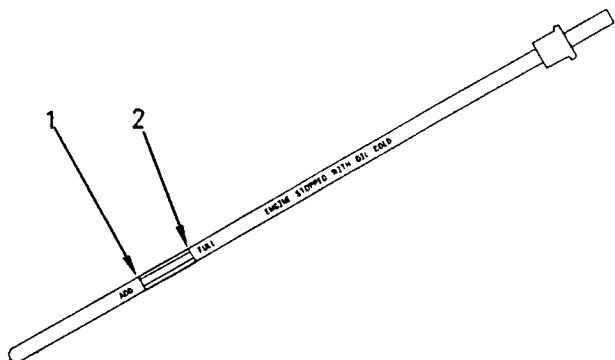


Illustration 37
Oil level gauge (dipstick)

g00760044

- (1) "ADD" mark
- (2) "FULL" mark

NOTICE

Excessive engine oil will increase oil consumption and result in excessive deposits in the combustion chamber. Do not overfill the engine with oil.

- Check the engine crankcase oil level. Maintain the oil level between the "ADD" and "FULL" marks on the "ENGINE STOPPED WITH OIL COLD" side of the oil level gauge. For information on the proper oil to use, see this Operation and Maintenance Manual, "Lubricant Specifications" (Maintenance Section).
- Check for leaks at the following components: crankshaft seals, crankcase, oil filters, oil gallery plugs, sensors, and valve covers.
- Inspect the tubes, tee pieces, and clamps on the crankcase breathers.

Starting System

Note: If the engine is equipped with a system for external support, prepare the system before starting the engine. Ensure that all of the systems for engine support are enabled. Perform all prestart checks for the control system.

Air Starting Motor

- Drain moisture and sediment from the air tank and from any other air piping.
- Check the oil level in the lubricator. Keep the lubricator at least half full. Add oil, if necessary. For temperatures above 0 °C (32 °F), use a nondetergent 10W oil. For temperatures below 0 °C (32 °F), use air tool oil.

- Check the air pressure for starting. The air starting motor requires a minimum of 690 kPa (100 psi). The maximum allowable air pressure is 1030 kPa (150 psi). Open the air supply valve.

Electric Starting Motor

- Disconnect any battery chargers that are not protected against the high current drain that is created when the electric starting motor engages.

Inspect the wiring, the electrical cables, and the battery for the following conditions:

- Loose connections
- Wires that are worn or frayed
- Corrosion

i01489240

Cold Weather Starting

SMCS Code: 1000; 1250; 1450; 1453; 1456; 1900

Note: Oil pan immersion heaters are not recommended for heating the lube oil. To ensure the compatibility of the components, only use equipment that is recommended by Caterpillar.

A jacket water heater is available as an option for starting in temperatures as low as 0 °C (32 °F). The jacket water heater can maintain the water temperature at approximately 32 °C (90 °F). The heated water will help to keep the oil in the engine block warm enough to flow when the engine is started. A jacket water heater is recommended for starting when the temperature is less than 16 °C (60 °F).

For air starting motors, a larger volume of starting air and/or a higher air pressure may be necessary in order to start the engine at colder temperatures.

For electric starting, extra battery capacity may be necessary.

Consult your Caterpillar dealer for more information on the starting aids that are available for cold weather starting.

i00758716

Starting the Engine

SMCS Code: 1000; 1450

WARNING

Engine exhaust contains products of combustion which may be harmful to your health. Always start and operate the engine in a well ventilated area and, if in an enclosed area, vent the exhaust to the outside.

NOTICE

For initial start-up of a new or rebuilt engine, and for start-up of an engine that has been serviced, make provision to shut the engine off should an overspeed occur. This may be accomplished by shutting off the fuel supply and/or the ignition to the engine.

Note: Using the "EMERGENCY STOP" button will shut off both the fuel and the ignition.

WARNING

Unburned gas in the inlet manifold can ignite when the engine is started. Personal injury and/or property damage can result. Clear the engine and the exhaust system of unburned gas

Before starting an engine that was stopped by terminating the ignition system, turn the gas supply OFF. Crank the engine for approximately 15 seconds in order to clear any unburned gas from the engine and the exhaust system.

Do not start the engine or move any of the controls if there is a "DO NOT OPERATE" warning tag or similar warning tag attached to the start switch or to the controls.

Ensure that no one will be endangered before the engine is started and when the engine is started.

Perform the procedures that are described in this Operation and Maintenance Manual, "Before Starting Engine" (Operation Section).

Operation of the Generator Set Control Panel

For information on operation for a specific generator set control panel, refer to the Operation and Maintenance Manual for the generator and the control panel.

Automatic Starting

WARNING

When the engine is in the AUTOMATIC mode, the engine can start at any moment. To avoid personal injury, always remain clear of the the engine when the engine is in the AUTOMATIC mode.

If the engine control switch is in the "AUTO" position, the engine will automatically start when the remote start/stop initiate contact closes. The engine will accelerate to rated rpm when the oil pressure is sufficient.

Manual Starting

1. Ensure that fuel is supplied to the engine. Ensure that no gas is leaking.
2. Ensure that the driven equipment is unloaded.
 - a. For generator set engines, ensure that the main circuit breaker is open.
 - b. For industrial engines, unload the compressor or pump. Disengage the clutch (if equipped). Place the transmission and/or other attachments for the power take-off in NEUTRAL.

Note: Before starting an industrial engine, move the governor control lever to the position for 1/2 of rated rpm.

NOTICE

Do not engage the starting motor when flywheel is turning. Do not start the engine under load.

If the engine fails to start within 30 seconds, release the starter switch or button and wait two minutes to allow the starting motor to cool before using it again.

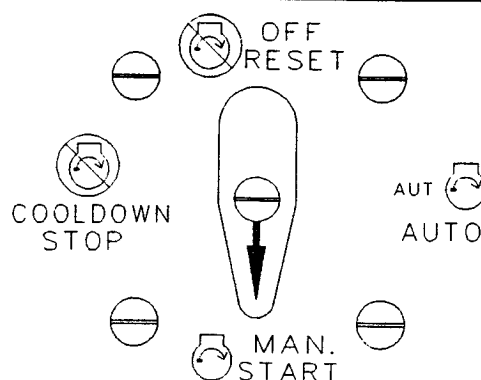


Illustration 38

Engine control switch in the "Man. Start" position

g00319402

3. Turn the engine control switch to the "Man. Start" position in order to start the engine.

Note: After starting an industrial engine, move the governor control lever to the position for low idle rpm.

4. Allow the engine to idle for three to five minutes. The engine speed should stabilize at low idle rpm. Check all of the pressure gauges. Inspect the engine for leaks and listen for unusual noises. When all systems are normal, the rpm may be increased.

Table 11

Rated RPM And Low Idle RPM					
Rated rpm	1000	1200	1400	1500	1800
Low idle rpm	700	900	1000	1000	1200

Starting Failure

Note: If the cycle crank feature is enabled, the Status Control Module (SCM) will attempt to start the engine for the programmed period. If the engine fails to start within the programmed period, the SCM will execute an overcrank fault. The "OVERCRANK" indicator on the Remote Control Panel (Status) will illuminate. The SCM must be reset before the engine can be started. Turn the engine control switch to the "OFF/RESET" position.

If the engine fails to start after cranking for 30 seconds, stop cranking. Perform the following procedure:

1. Turn the engine control switch to the "OFF/RESET" position.
2. Turn the gas supply OFF.
3. Allow the starting motor to cool for two minutes. Crank the engine for approximately 15 seconds in order to disperse any unburned gas from the engine and the exhaust system.
4. Allow the starting motor to cool for two minutes. Turn the gas supply ON. Repeat the starting procedure.

i01037941

Starting with Jump Start Cables

SMCS Code: 1000; 1401; 1402; 1900

WARNING

Improper jump start cable connections can cause an explosion resulting in personal injury.

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

If the installation is not equipped with a backup battery system, it may be necessary to start the engine from an external electrical source.

First, determine the reason that it is necessary to start with power from an external source. Refer to Special Instruction, SEHS7768, "Use of the 6V-2150 Starting/Charging Analyzer".

Many batteries which are considered unusable are still rechargeable. After jump starting, the alternator may not be able to fully recharge batteries that are severely discharged. The batteries must be charged to the proper voltage with a battery charger. For information on testing and charging, refer to the Special Instruction, SEHS7633, "Battery Test Procedure".

NOTICE

Using a battery source with the same voltage as the electric starting motor. Use **ONLY** equal voltage for jump starting. The use of higher voltage will damage the electrical system.

Do not reverse the battery cables. The alternator can be damaged. Attach ground cable last and remove first.

When using an external electrical source to start the engine, turn the engine control switch to the "OFF" position. Turn all electrical accessories OFF before attaching the jump start cables.

Ensure that the main power switch is in the OFF position before attaching the jump start cables to the engine being started.

1. Turn the start switch on the stalled engine to the OFF position. Turn off all accessories.

2. Connect one positive end of the jump start cable to the positive cable terminal of the discharged battery. Connect the other positive end of the jump start cable to the positive cable terminal of the electrical source.
3. Connect one negative end of the jump start cable to the negative cable terminal of the electrical source. Connect the other negative end of the jump start cable to the engine block or to the chassis ground. This procedure helps to prevent potential sparks from igniting combustible gases that are produced by some batteries.
4. Charge the batteries. The engine will not continue to run after starting if the batteries have not been charged.
5. Start the engine.
6. Immediately after the stalled engine is started, disconnect the jump start cables in reverse order.

Refer to the Electrical Schematic for your engine. Consult your Caterpillar dealer for more information.

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After Starting Engine

SMCS Code: 1000

For new installations and engines that are recently rebuilt, carefully monitor the engine in order to detect any unusual engine performance.

The engine rpm can be increased from low idle rpm to rated rpm after one minute.

Engines that use pipeline natural gas are capable of ramping to full load in 30 seconds or less. For engines that use bio-gas, increased time for ramping the load will help to provide protection from detonation. Avoid detonation during loading. Generally, no load operation to full load operation can be accomplished in five to ten minutes without any problems.

It may be necessary to apply some load in order to attain normal operating temperatures. The operator can ramp the load manually. For automatic loading, programmable logic control can be used.

Engaging the Driven Equipment

Generator Set Engines

1. Increase the engine speed to rated rpm.
2. Ensure that the outlet temperature of the jacket water reaches 77 °C (170 °F). Ensure that the gauges are in the normal ranges for the engine rpm.
3. Close the main circuit breaker in order to apply the load.

Industrial Engines

1. Increase the engine rpm. Ensure that the gauges are in the normal ranges for the engine rpm.
2. Engage the driven equipment with no load on the driven equipment.

The engine can be loaded up to 50 percent of full load before the outlet temperature of the jacket water reaches 77 °C (170 °F). The temperature is usually achieved in two to four minutes. After this temperature is reached, begin to ramp the engine to full load.

3. Ramp to full load after the outlet temperature of the jacket water reaches 77 °C (170 °F). Five minutes may be required.

Engine Operation

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Engine Operation

SMCS Code: 1000

Proper operation and maintenance are key factors in attaining the maximum service life and economy for the engine. Follow the instructions in this Operation and Maintenance Manual in order to minimize operating costs and maximize the service life of the engine.

Observe the gauges frequently while the engine is operating. Record the data from the gauges in a log regularly. Compare the data to the specifications for normal engine operation. Comparing the data over time will help to detect changes in engine performance.

Investigate any significant change in the gauge readings. Monitor the engine operation and take action when discrepancies are found.

Operating the Engine and the Driven Equipment

Check the gauges and the driven equipment frequently while the engine is operating under a load. The engine can be operated for extended periods of time at full load.

Partial Load Operation

Extended operation at low idle or at a reduced load will cause increased oil consumption and carbon buildup in the cylinders. Carbon buildup results in the following effects:

- Power loss
- Poor performance
- Accelerated wear of components

Caterpillar Engines can be operated at very light loads (torques) for limited times with no harmful effects. Table 12 lists the limits for hours of operation at various torques.

After the time limit for reduced load operation has expired, operate the engine for a minimum of two hours at a torque that is more than 70 percent.

For example, an engine is operating at 20 percent of the rated torque. The engine may be operated at this load factor for a maximum of one-half hour. After the one-half hour, operate this engine for at least two hours at a load factor of more than 70 percent.

To keep engine maintenance at a minimum, follow the guidelines that are listed in Table 12.

Table 12

Time Limits For Low Load Operation		
Engine Torque	NA Engines	TA Engines
0 to 30%	1/2 hour	1/2 hour
31 to 50%	2 hours	2 hours
51 to 60%	24 hours	Continuous ⁽¹⁾
61 to 100%	Continuous	Continuous ⁽¹⁾

⁽¹⁾ For continuous operation of TA engines, the manifold air pressure should be greater than the atmospheric pressure.

Engine Stopping

i01664488

Emergency Stopping

SMCS Code: 1000; 7418

NOTICE

Emergency shutoff controls are for EMERGENCY use ONLY. DO NOT use emergency shutoff devices or controls for normal stopping procedure.

Ensure that any system that provides external support to the engine is secured after the engine is stopped.

NOTICE

Do not start the engine until the problem necessitating the emergency stop has been located and corrected.

Emergency Stop Button

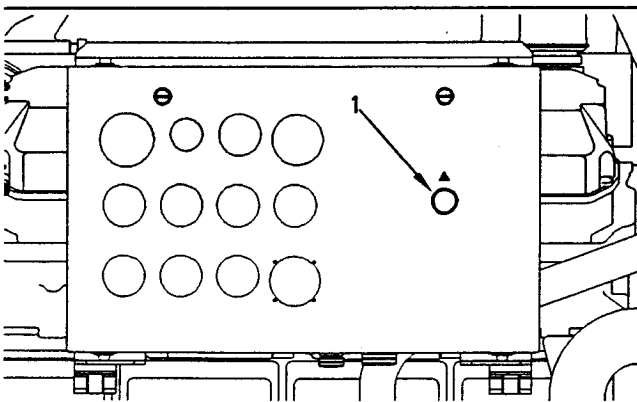


Illustration 39

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(1) Emergency stop button on a junction box

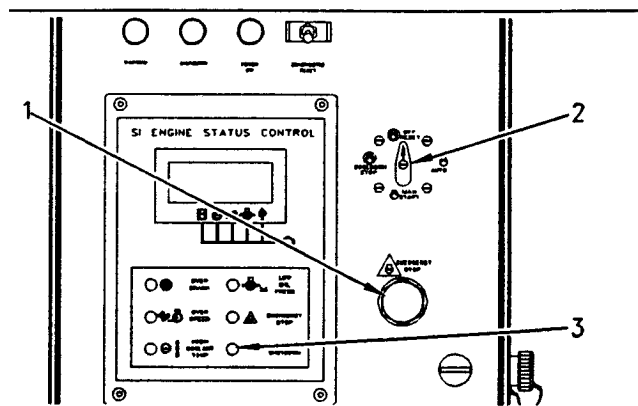


Illustration 40

g00786735

Remote control panel (status)

- (1) Emergency stop button
- (2) Engine control switch
- (3) "AUXILIARY SHUTDOWN" indicator

Emergency stop button (1) is in the OUT position for normal engine operation. Push the button for emergency stopping. This shuts off both the fuel and the ignition. The engine will not start when the button is locked. To reset the button, turn the button clockwise. The spring-loaded button will return to the OUT position.

NOTICE

Do not use this method to stop the engine unless an emergency has occurred. Continuous emergency shutdowns can cause damage to some engine components. This will leave unburned fuels in the combustion chambers and in the exhaust system. If an emergency shutdown occurs, purge the system by cranking the engine for 5 to 10 seconds with the ignition shutoff.

The control panel must also be reset before the engine will start. To reset the control panel, turn engine control switch (2) to the "OFF/RESET" position.

The customer may also provide other means for emergency stopping. This will cause the fuel to be shut off, but the ignition may not be shut off. This shutdown will cause "AUXILIARY SHUTDOWN" indicator (3) to illuminate. The control panel must be reset before the engine will start. To reset the control panel, turn engine control switch (2) to the "OFF/RESET" position.

i00720970

Manual Stop Procedure

SMCS Code: 1000; 7418

NOTICE

Stopping the engine immediately after the engine has been operating under a load can result in overheating and accelerated wear of the engine components.

Allow the engine to gradually cool before stopping the engine.

Note: Remove the load at a rate that will avoid detonation.

1. Disengage the driven equipment.
 - a. For generator set engines, open the main circuit breaker.
 - b. For industrial engines, unload the compressor or pump. Disengage the clutch (if equipped). Place the transmission and/or other attachments for the power take-off in NEUTRAL.

Note: Extended idling can cause excessive oil consumption and related problems. See this Operation and Maintenance Manual, "Engine Operation" topic (Operation Section).

2. Reduce the engine rpm to low idle.

Note: If the cooldown feature is not utilized, operate the engine at low idle rpm for a cooldown period before stopping the engine. If the engine has been operated at a low load, operate the engine at low idle for approximately 30 seconds before stopping the engine. If the engine has been operated at a high load, operate the engine at low idle for three to five minutes before stopping the engine.

3. Use one of the following methods in order to stop the engine:
 - a. Turn the engine control switch to the "COOLDOWN/STOP" position. If the cooldown feature is utilized, the engine will operate for a programmed period of time before the engine stops. Otherwise, the engine will immediately shut off.

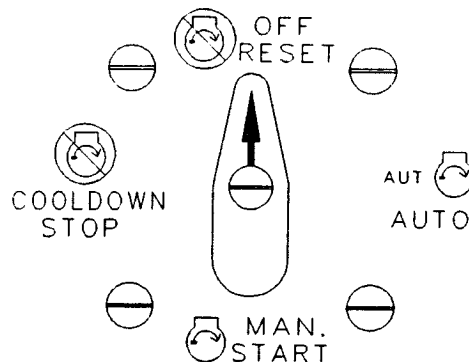


Illustration 41

g00320124

Engine control switch in the "OFF/RESET" position

- b. Turn the engine control switch to the "OFF/RESET" position. The engine will immediately shut off.
- c. If the engine control switch is in the "AUTO" position, open the remote start/stop initiate contact. If the cooldown feature is utilized, the engine will operate for a programmed period of time before the engine stops. Otherwise, the engine will immediately shut off.

The engine will coast to a stop. Ensure that any system that provides external support to the engine is secured after the engine is stopped.

i00662051

After Stopping Engine

SMCS Code: 1000

- Check the engine crankcase oil level. Maintain the oil level between the "ADD" and "FULL" marks on the "ENGINE STOPPED" side of the oil level gauge.
- If necessary, perform minor adjustments. Repair any leaks and tighten loose bolts.
- Note the service hour meter reading. Perform the maintenance that is scheduled in this Operation and Maintenance Manual, "Maintenance Interval Schedule" (Maintenance Section).

NOTICE

Only use antifreeze/coolant mixtures recommended in the Coolant Specifications of this manual. Failure to do so can cause engine damage.

- Allow the engine to cool. Check the coolant level.
- If freezing temperatures are expected, check the coolant for protection against freezing. The cooling system must be protected against freezing to the lowest expected outside temperature. Add the proper coolant/water mixture, if necessary.
- Perform all required periodic maintenance on all driven equipment. Refer to the instructions that are provided by the OEM of the driven equipment.

Maintenance Section

Torque Specifications

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General Torque Information

i01252954

SMCS Code: 1000; 7553

WARNING

Mismatched or incorrect fasteners can result in damage or malfunction, or personal injury.

Take care to avoid mixing metric dimensioned fasteners and inch dimensioned fasteners.

Exceptions to these torques are given in the Service Manual, if necessary.

Prior to installation of any hardware, ensure that components are in near new condition. Bolts and threads must not be worn or damaged. Threads must not have burrs or nicks. Hardware must be free of rust and corrosion. Clean the hardware with a noncorrosive cleaner. Do not lubricate the fastener threads except for the rust preventive. The rust preventive should be applied by the supplier of that component for purposes of shipping and storage. Other applications for lubricating components may also be specified in the Service Manual.

Standard Torque for Metric Fasteners

SMCS Code: 1000; 7553

Table 13

Metric Nuts and Bolts	
Thread Size Metric	Standard Torque
M6	12 ± 3 N·m (9 ± 2 lb ft)
M8	28 ± 7 N·m (21 ± 5 lb ft)
M10	55 ± 10 N·m (41 ± 7 lb ft)
M12	100 ± 20 N·m (75 ± 15 lb ft)
M14	160 ± 30 N·m (120 ± 22 lb ft)
M16	240 ± 40 N·m (175 ± 30 lb ft)
M20	460 ± 60 N·m (340 ± 44 lb ft)
M24	800 ± 100 N·m (590 ± 75 lb ft)
M30	1600 ± 200 N·m (1180 ± 150 lb ft)
M36	2700 ± 300 N·m (2000 ± 220 lb ft)

Table 14

Metric Taperlock Studs	
Thread Size Metric	Standard Torque
M6	8 ± 3 N·m (6 ± 2 lb ft)
M8	17 ± 5 N·m (13 ± 4 lb ft)
M10	35 ± 5 N·m (26 ± 4 lb ft)
M12	65 ± 10 N·m (48 ± 7 lb ft)
M16	110 ± 20 N·m (80 ± 15 lb ft)
M20	170 ± 30 N·m (125 ± 22 lb ft)
M24	400 ± 60 N·m (300 ± 44 lb ft)
M30	750 ± 80 N·m (550 ± 60 lb ft)
M36	1200 ± 150 N·m (880 ± 110 lb ft)

i00621349

i01206505

Standard Torque for Inch Fasteners

SMCS Code: 1000; 7553

Table 15

Inch Nuts and Bolts	
Thread Size Inch	Standard Torque
1/4	12 ± 3 N·m (9 ± 2 lb ft)
5/16	25 ± 6 N·m (18 ± 4 lb ft)
3/8	47 ± 9 N·m (35 ± 7 lb ft)
7/16	70 ± 15 N·m (50 ± 11 lb ft)
1/2	105 ± 20 N·m (75 ± 15 lb ft)
9/16	160 ± 30 N·m (120 ± 22 lb ft)
5/8	215 ± 40 N·m (160 ± 30 lb ft)
3/4	370 ± 50 N·m (275 ± 37 lb ft)
7/8	620 ± 80 N·m (460 ± 60 lb ft)
1	900 ± 100 N·m (660 ± 75 lb ft)
1 1/8	1300 ± 150 N·m (960 ± 110 lb ft)
1 1/4	1800 ± 200 N·m (1320 ± 150 lb ft)
1 3/8	2400 ± 300 N·m (1780 ± 220 lb ft)
1 1/2	3100 ± 350 N·m (2280 ± 260 lb ft)

Table 16

Inch Taperlock Studs	
Thread Size Inch	Standard Torque
1/4	8 ± 3 N·m (6 ± 2 lb ft)
5/16	17 ± 5 N·m (13 ± 4 lb ft)
3/8	35 ± 5 N·m (26 ± 4 lb ft)
7/16	45 ± 10 N·m (33 ± 7 lb ft)
1/2	65 ± 10 N·m (48 ± 7 lb ft)
5/8	110 ± 20 N·m (80 ± 15 lb ft)
3/4	170 ± 30 N·m (125 ± 22 lb ft)
7/8	260 ± 40 N·m (190 ± 30 lb ft)
1	400 ± 60 N·m (300 ± 44 lb ft)
1 1/8	525 ± 60 N·m (390 ± 44 lb ft)
1 1/4	750 ± 80 N·m (550 ± 60 lb ft)
1 3/8	950 ± 125 N·m (700 ± 90 lb ft)
1 1/2	1200 ± 150 N·m (880 ± 110 lb ft)

Standard Torque for Worm Drive Band Hose Clamps

SMCS Code: 1000; 7553; 7554



Illustration 42

g00280501

Table 17

Width of Clamp	Initial Installation Torque On New Hose
7.9 mm (0.31 inch)	0.9 ± 0.2 N·m (8 ± 2 lb in)
13.5 mm (0.53 inch)	4.5 ± 0.5 N·m (40 ± 4 lb in)
15.9 mm (0.63 inch)	7.5 ± 0.5 N·m (65 ± 4 lb in)
Width of Clamp	Reassembly or Retightening Torque
7.9 mm (0.31 inch)	0.7 ± 0.2 N·m (6 ± 2 lb in)
13.5 mm (0.53 inch)	3.0 ± 0.5 N·m (27 ± 4 lb in)
15.9 mm (0.63 inch)	4.5 ± 0.5 N·m (40 ± 4 lb in)

i01394891

Standard Torque for Constant Torque Hose Clamps

SMCS Code: 1000; 7553; 7554

Use a constant torque hose clamp in place of any standard hose clamp. Ensure that the constant torque hose clamp is the same size as the standard hose clamp. Due to extreme temperature changes, the hose will heat set. Heat setting can cause hose clamps to loosen. Loose hose clamps can result in leaks. There have been reports of component failures that have been caused by hose clamps that have loosened. The constant torque hose clamp will help prevent these failures.

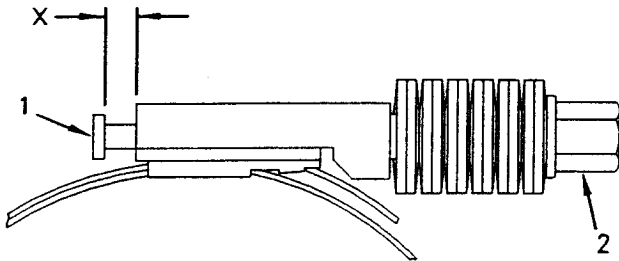


Illustration 43

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Use a torque wrench for proper installation of the constant torque hose clamps. The constant torque hose clamp is installed correctly under the following conditions:

- Screw tip (1) extends 6.35 mm (0.25 inch) (X) beyond the housing.
- The Belleville washers are collapsed nearly flat after screw (2) is tightened to a torque of 11 ± 1 N·m (98 ± 9 lb in).

Lubricant Specifications

i00708567

Lubricant Information

SMCS Code: 1000; 1300; 7581

Engine oil performs several functions:

- Keeping the engine clean
- Preventing rust and corrosion
- Acting as a coolant
- Reducing friction and wear

Engines that use gaseous fuel require oils that are formulated with additives that are specific to these engines.

No performance specifications are available to define the performance levels that are required by engines that use gaseous fuels. Field tests must be used in order to define oils that are acceptable. To aid in oil selection, guidelines are provided in Supplement, SEBU6400, "Caterpillar Gaseous Fueled Spark Ignited Engines Lubrication Specifications".

Grease is classified by the National Lubricating Grease Institute (NLGI). The classification is based on the "ASTM D217-68 Worked Penetration" characteristics. The characteristics have a number for consistency that is defined. For information on grease, see this Operation and Maintenance Manual, "Lubricating Grease" topic (Maintenance Section).

i01071552

Engine Oil

SMCS Code: 1300; 1348; 7581

Caterpillar Oils have been developed and tested in order to provide the full performance and service life that has been designed and built into Caterpillar Engines. These oils are offered by Caterpillar dealers for continued use when the engine oil is changed. Consult your Caterpillar dealer for more information on these oils.

Due to significant variations in the quality and in the performance of commercially available oils, Caterpillar makes the following recommendation:

- **Caterpillar Natural Gas Engine Oil (NGEO)**

Caterpillar NGEO has been tested throughout the world in demanding environments. Caterpillar NGEO has been tested in engines that use all types of gaseous fuel. The formulation of the oil has been proven to be superior to many brands of oil that are locally available.

For maximum service life of the engine and the engine oil, use Caterpillar NGEO with low sulfur gaseous fuels that contain less than 0.43 mg H₂S/MJ (.45 µg H₂S/Btu).

Caterpillar NGEO may also be used with high sulfur natural gas and with bio-gas. Bio-gas is formed in landfills and sewage digesters. The use of these fuels may require a shorter oil change interval.

Caterpillar NGEO is formulated and blended with special additives in order to provide protection against oxidation and nitration. Caterpillar NGEO also has thermal stability.

Caterpillar NGEO also provides the following benefits:

- Reduction of the formation of carbon and sludge
- Resistance to foaming
- Protection against corrosion
- Protection of valves and valve seats
- Improved cleanliness of pistons
- Protection against scoring of the pistons and scuffing of the pistons
- Protection against cylinder liner wear

Table 18 lists the oil properties of Caterpillar NGEO. The properties are based on ASTM test specifications.

Table 18

Caterpillar NGENO Properties			
Characteristic	ASTM Test	SAE Viscosity Grade	
		30W	40W
API Gravity	"D 0286"	28.4	28
Flash Point	"D 0092"	238	248
Pour Point	"D 0097"	-15	-15
Viscosity (cSt) at 40 °C (104 °F)	"D 0455"	89.8	130.5
Viscosity (cSt) at 100 °C (212 °F)	"D 0455"	10.4	13.4
Viscosity Index	"D 0567"	97	97
Weight (Percent) of Sulfated Ash	"D 0874"	0.45	0.45
Total Base Number	"D 2896"	4.8	4.8

Commercial Oils

Commercial oil specifications do not exist for Caterpillar Engines that operate on gaseous fuels. The performance of lubrication oil for gas engines is determined by a field test. Successful field operation has been achieved with oils that meet the following guidelines:

- Caterpillar recommends the use of oils that are formulated specifically for heavy-duty gas engines. Oils that are specially formulated for gasoline engines or for diesel engines should not be used.
- Caterpillar recommends the use of oils that have a sulfated ash content between 0.40 and 0.60 percent.
- The oil must demonstrate adequate protection for a minimum of 7000 hours in a field test under controlled conditions.

NOTICE

Failure to follow these oil recommendations can cause shortened engine service life due to deposits and/or excessive wear.

NOTICE

Caterpillar recommends the use of oils that are formulated specifically for heavy duty spark ignited gaseous fueled engines. Oils that are formulated for gasoline engines only or for diesel engines only should not be used.

7000 Hour Field Test

Caterpillar recommends oils for gas engines that meet the requirements of the 7000 hour field test. The 7000 hours of field service must be documented. Standard and/or Low Emission engine configurations may be used for the test. The field test must be performed in an engine configuration that is similar to the engine that will use the oil that is proposed. The field test must be performed at a power level that is at least equal to the power that is required by the engine that will use the oil that is proposed.

Field tests may identify commercial brands of oil with successful results. Caterpillar will not endorse a commercial brand of oil because of the results. The oil company can use the results of the field test as a proof of the oil's performance. The oil company is responsible for the performance and the quality of the oil, and for any changes in the formulation of the oil. Before purchasing a lubrication oil for a gas engine, discuss the claims of performance for the oil with the oil supplier.

For additional details on the 7000 hour field test, see Supplement, SEBU6400, "Caterpillar Gaseous Fueled Spark Ignited Engines Lubrication Specifications".

Sour Gas and Bio-Gas Applications

Note: For more information, see this Operation and Maintenance Manual, "Fuel Recommendations" topic (Maintenance Section).

Many gaseous fuels contain sulfur compounds. These compounds are primarily composed of hydrogen sulfide (H₂S). Gaseous fuels with less than 0.43 mg H₂S/MJ (.45 µg H₂S/Btu) are considered to be "sweet" gas.

Gaseous fuels with more than 0.43 mg H₂S/MJ (.45 µg H₂S/Btu) are considered to be "sour" gas. Sour gas can reduce the service life of an engine and the engine oil. When the sulfur compounds are combined with water, acids are produced in the engine oil. These acids attack the metals in the engine crankcase. This causes corrosive wear. To reduce the effects of these sulfur compounds, Caterpillar recommends the use of devices that treat the fuel.

If the sour gas cannot be treated in order to reduce the level of sulfur, additional measures must be taken in order to protect the engine. To reduce the harmful effects of sour gas, Caterpillar recommends the following guidelines:

- Use a "low energy fuel engine" configuration.

- Maintain the jacket water temperature at 110 °C (230 °F).
- Reduce the oil change interval according to the results of oil analysis.

Caterpillar does not recommend the use of engine oils with a high concentration of sulfated ash in order to reduce the harmful effects of sour gas. High levels of sulfated ash may produce excessive deposits on the valves and on the turbine wheel of the turbocharger. These deposits will reduce the service life of the engine. These deposits will also increase the cost of maintenance.

For additional information on gaseous fuels and on treatment of the fuel, see the following publications:

- Application and Installation, LEKQ7256, "Fuels/Fuel Systems"
- Application and Installation, LEKQ7260, "Low BTU Engines"
- Maintenance Management Schedules, SEBU6127, "Schedules for Industrial and EPG Spark Ignited Gas Engines"

For information regarding condemning limits of the lubrication oil, refer to this Operation and Maintenance Manual, "S·O·S Oil Analysis" topic (Maintenance Section).

Lubricant Viscosity Recommendations

The proper SAE viscosity grade of oil is determined by the minimum ambient temperature during cold engine start-up, and the maximum ambient temperature during engine operation. To determine the oil viscosity that is required for starting a cold soaked engine, refer to the minimum temperature in Table 19. To select the oil viscosity for operation at the highest anticipated ambient temperature, refer to the maximum temperature in Table 19. Use the highest oil viscosity that is available in order to meet the required temperature during start-up.

Table 19

Engine Oil Viscosity		
Caterpillar NGEO Grade of Viscosity	Ambient Temperature	
	Minimum	Maximum
SAE 30 ⁽¹⁾	0 °C (32 °F)	40 °C (104 °F)
SAE 40 ⁽¹⁾	5 °C (41 °F)	50 °C (122 °F)

⁽¹⁾ Caterpillar NGEO is available in these grades only. Multigrade oils are NOT recommended for use in Caterpillar Gas Engines. If other grades of viscosity are selected, ensure that the oil meets the requirements for Caterpillar Gas Engines. Consult the supplier of the oil.

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Synthetic Base Stock Oils

SMCS Code: 1348; 7581

Synthetic base oils are acceptable for use in Caterpillar engines if these oils meet the performance requirements that are specified for the engine compartment.

Synthetic base oils generally perform better than conventional oils in the following two areas:

- Synthetic base oils have improved flow at low temperatures especially in arctic conditions.
- Synthetic base oils have improved oxidation stability especially at high operating temperatures.

Some synthetic base oils have performance characteristics that enhance the service life of the oil. However, Caterpillar does not recommend the automatic extension of oil change intervals for any type of oil. Oil change intervals for Caterpillar engines can only be adjusted after an oil analysis program that contains the following tests: oil condition and wear metal analysis (Caterpillar's S·O·S oil analysis), trend analysis, fuel consumption, and oil consumption.

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Aftermarket Oil Additives

SMCS Code: 1348; 7581

Caterpillar does not recommend the use of aftermarket additives in oil. It is not necessary to use aftermarket additives in order to achieve the engine's maximum service life or rated performance. Fully formulated, finished oils consist of base oils and of commercial additive packages. These additive packages are blended into the base oils at precise percentages in order to help provide finished oils with performance characteristics that meet industry standards.

- There are no industry standard tests that evaluate the performance or the compatibility of aftermarket additives in finished oil.
- Aftermarket additives may not be compatible with the finished oil's additive package, which could lower the performance of the finished oil.
- The aftermarket additive could fail to mix with the finished oil. This could produce sludge in the crankcase.
- Caterpillar discourages the use of aftermarket additives in finished oils.

To achieve the best performance from a Caterpillar engine, conform to the following guidelines:

- Select the proper Caterpillar oil or commercial oil.
- See the appropriate "Lubricant Viscosities" table in order to find the correct oil viscosity grade for your engine.
- At the specified interval, service the engine compartment. Use new oil and install a new oil filter.
- Perform maintenance at the intervals that are specified in the Operation and Maintenance Manual, "Maintenance Interval Schedule".

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Lubricating Grease

SMCS Code: 7581

Caterpillar provides greases in order to cover a variety of applications and extreme temperature conditions. Consult your Caterpillar dealer for part numbers and for available sizes of containers.

Note: Some greases may not be used with other greases. When a commercial grease is used, ensure that the grease is compatible with the grease that is currently used in the system. If the commercial grease is not compatible, the system must be purged. If any questions arise concerning the compatibility of a grease, consult the supplier.

Multipurpose Greases

Multipurpose Lithium Complex Grease (MPGL)

Multipurpose Lithium Complex Grease (MPGL) is a general purpose lithium complex grease for medium-duty applications. This product has good characteristics at high temperatures such as a dropping point of 260 °C (500 °F). MPGL contains unleaded extreme pressure additives, antiwear inhibitors, and corrosion inhibitors that provide extra protection in the following applications:

- Construction
- Agricultural
- Automotive

MPGL meets the requirements for extended service intervals of automotive chassis points. MPGL also meets the requirements for extended service intervals of wheel bearings with disc brakes in automobiles, in vans and in light trucks. This product meets the NLGI certification of "GC-LB". MPGL is also available in a NLGI No. 2 grade. Normal operating temperatures for this product are -28 to 149 °C (-18 to 300 °F). This product is also available as a white lithium complex grease.

Multipurpose Lithium Complex Grease with Molybdenum (MPGM)

Multipurpose Lithium Complex Grease with Molybdenum (MPGM) is a general purpose lithium complex grease that is used for light-duty applications and for medium-duty applications. The MPGM is available in the following grades: NLGI No. 2 grade and NLGI No. 0 grade. The MPGM is strengthened with a molybdenum disulfide and a polymer for extra lubrication and protection. MPGM contains unleaded additives. MPGM also contains antiwear inhibitors, rust inhibitors, and corrosion inhibitors that are for protection and lubrication in many environments. The MPGM is formulated with a base fluid that has high viscosity.

The MPGM has the following features:

- Increased protection against water washout

- Increased retention
- Resistance to heavy loads

This product is recommended for heavily loaded pin joints and for journal bearings. This product meets the certification of "GC-LB". Normal operating temperatures for this product are -28 to 149 °C (-18 to 300 °F) for the NLGI No. 0 grade. Normal operating temperatures for this product are -18 to 149 °C (0 to 300 °F) for the NLGI No. 2 grade.

Note: If MPGM is not available, use a multipurpose type grease which contains three to five percent molybdenum.

Special Purpose Grease (SPG)

Bearing Lubricant (SPG)

Bearing Lubricant (SPG) is available in a NLGI No. 2 grade with a polyurea thickener. This grease is recommended for high temperature antifriction bearings in the following applications: electric starting motors, alternators, fan drives, and generators. The Bearing Lubricant (SPG) has an effective operating range of -29 to 177 °C (-20 to 350 °F).

Water and Temperature Resistant Grease (WTR)

The Water and Temperature Resistant Grease is designed for use whenever the following conditions are a concern: water washout, severe corrosion, and high operating temperatures. The Water and Temperature Resistant Grease provides extreme pressure protection, antiwear protection, rust protection and corrosion protection. The Water and Temperature Resistant Grease is an environmentally friendly grease which does not contain the following materials: antimony, sulfur, barium, zinc, lead, and phosphorous materials. The Water and Temperature Resistant Grease has excellent shear stability. Water and Temperature Resistant Grease can also resist breakdown in the presence of water. The Water and Temperature Resistant Grease works well in the following applications:

- Construction
- Agricultural
- Automotive
- Industrial
- Marine

This product meets the NLGI certification of "GC-LB". Normal operating temperatures for this product are -40 to 204°C (-40 to 400°F).

Caterpillar Premium Grease (CPG)

Desert Gold (CPG)

Desert Gold is a heavy-duty, premium synthetic grease that is developed for the most extreme operating environments. This grease is formulated with the following characteristics: high viscosity synthetic base fluid, polymers, molybdenum disulfide, high viscosity index, and high dropping point.

Desert Gold will protect equipment against heavy shock loads. Desert Gold protects against corrosion in extreme heat, in moist conditions, or in dusty conditions. This product has excellent characteristics of adhesion and of stability. Desert Gold provides longer protection than other greases. Desert Gold is an environmentally friendly grease which does not contain the following materials: antimony, sulfur, barium, zinc, lead, and phosphorous materials. Normal operating temperatures are -6 to 230 °C (21 to 450 °F). Desert Gold can operate at higher temperatures for short time periods. Desert Gold has additional extreme pressure protection for highly loaded pin joints.

Arctic Platinum (CPG)

Arctic Platinum is a super-premium extreme pressure lubricating grease that is developed for lubrication in temperatures that are below zero to moderate operating temperatures. Arctic Platinum is available in grades 000, 00, 0, 1, and 2. These grades ensure pumpability in central lube systems in a variety of ambient temperatures from -60 to 18 °C (-76 to 65 °F). Arctic Platinum has a high dropping point. Arctic Platinum contains a five percent concentrate of molybdenum disulfide for protection against extra heavy loads. Arctic Platinum provides excellent corrosion protection and rust protection. Arctic Platinum is an environmentally friendly grease which does not contain the following materials: antimony, sulfur, barium, zinc, and phosphorous.

Arctic Platinum is designed for long life lubrication of the following components: horizontal pivot bearings, lower link bearings, steering cylinders, kingbolt bearings, upper hitch link bearings, and ejector carrier roller bearings. This grease is extra tacky for retention on excavator carbody bearings. Arctic Platinum has additional extreme pressure protection for highly loaded pin joints.

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S·O·S Oil Analysis

SMCS Code: 1348; 7542-008

Caterpillar recommends the S·O·S oil analysis program in order to monitor the condition of the oil and the maintenance requirements of the engine. The S·O·S program is part of the preventive maintenance program.

The S·O·S oil analysis includes these tests:

- The Wear Rate Analysis monitors wear by detecting, identifying and assessing the amount and the type of wear metal that is in the oil. The increase in the rate of engine wear metal in the oil is as important as the quantity of engine wear metal in the oil. For this reason, regular sampling at specified intervals is necessary in order to establish wear rates. Intermittent sampling does not allow wear rate trend lines to be established. Engine wear metals in the oil sample are compared to established Caterpillar norms in order to determine acceptability. Potential failures can be identified when the wear rate and/or the contaminants exceed the established trend.
- Tests are conducted in order to detect contamination of the oil by water and/or glycol.
- The Oil Condition Analysis determines the loss of the oil's lubricating properties. An infrared analysis is used to compare the properties of new oil to the properties of the used oil sample. This analysis allows technicians to determine the amount of deterioration of the oil during use.

The test results of the oil samples will then be used as a basis for determining the oil change interval for the engine. The results of the S·O·S oil analysis may enable the engine to operate longer between oil changes without the risk of damage.

Obtain each oil sample when the oil is warm and well mixed in order to ensure that the sample is representative of the oil in the engine crankcase.

Oil analysis is essential in order to determine satisfactory performance of the oil.

Refer to Special Publication, PEDP7036, "S·O·S Fluid Analysis" for more information.

Consult your Caterpillar dealer for complete information and assistance about the program.

Condemning Limits of the Oil

Oil analysis is the only method of determining if an oil is protecting the engine. The oil analysis is compared to limits that have been established through experience.

The condemning limits for lubrication oil were developed from experience with engine operation and from the analysis of used oil. The limits provide guidelines for determining the useful service life of the engine oil. Table 20 lists the limits for the service life of the oil.

Table 20

S·O·S Oil Analysis Condemning Limits	
Parameter	Limit
Oxidation	100% defined by the S·O·S Oil Analysis
Nitration	100% defined by the S·O·S Oil Analysis
Water	0.5% maximum
Glycol	0%
Silicon (Bio-gas)	25 ppm
Wear Metals	Based on Caterpillar norms and on the trend of the Wear Rate Analysis ⁽¹⁾
Additional Oil Analysis	
Viscosity at 100 °C (212 °F) by "ASTM D445"	Increase of 3 cSt from new oil
Total acid number (TAN) by "ASTM D664"	3.0 maximum TAN or 2.0 greater TAN than the new oil
Total base number by "ASTM D2896"	50% of new oil TBN

⁽¹⁾ A trend can be established from the results of three oil analyses.

Fuel Specifications

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Fuel Recommendations

SMCS Code: 1280

General Fuel Information

Gaseous fuels consist primarily of hydrocarbons (combinations of hydrogen and carbon) and some inert gases. Pipeline natural gas and propane gas have been used for many years. Other types of fuels such as wellhead, bio-gas, and manufactured gas need to be reviewed for acceptability.

Each commercial fuel gas is a mixture of gases. Some of the gases are combustible and some of the gases are inert. The compositions of these gas mixtures have extreme variations.

Caterpillar Gas Engines will operate successfully on a broad range of gaseous fuels. Adjustments must be made to the fuel system when the fuel is changed. Consult your Caterpillar dealer about the proper adjustments.

Permissible fuels must be analyzed in order to determine the following characteristics:

- Composition
- Specific gravity
- Heat value
- Methane number

The fuel analysis enables the requirements for the following parameters to be established:

- Ignition timing
- Rated load
- Compression ratio

A fuel's potential for detonation is indicated by a methane number. The methane number of any gas (fuel) can be determined with the following method:

1. Obtain a fuel analysis of the gas.
2. Enter the data from the fuel analysis into the Caterpillar Software Program, LEKQ6378, "Methane Number Program".

This software program calculates the fuel's methane number.

The methane number and the appropriate Engine Performance, "Fuel Usage Guide" are used for determining the following parameters:

- Compression ratio
- Ignition timing
- Rated load

For a detailed explanation of methane numbers, see Application and Installation Guide, LEKQ7256, "Fuels/Fuel Systems".

Follow the guide for fuel usage that is in the engine's Engine Performance publication. These publications are available from your Caterpillar dealer.

Dry Natural Gas

Dry natural gas is a mixture of methane, ethane, propane, and butane. Dry natural gas may also have traces of heavier hydrocarbons.

The Low Heat Value (LHV) of a gas is the high heat value (HHV) minus the heat that is required to vaporize the water that is formed by combustion. For more information on heat values, see Application and Installation Guide, LEKQ7256, "Fuels/Fuel Systems".

The heat value of dry natural gases may vary. This depends on the composition of the gas. Dry natural gas usually has an LHV that is between 33.53 to 34.65 kJ/L (900 to 930 Btu/ft³). Caterpillar Gas Engines are adjusted at the factory with a dry natural gas that is within this range.

For dry natural gas, the acceptable limit of hydrogen sulfide is 0.43 mg H₂S/MJ (.450 µg H₂S/Btu).

Propane

NOTICE

Propane and blends of propane will cause detonation in high compression engines. Do not use propane or blends of propane in high compression engines.

Propane is transported to a site as a liquid. The liquid is converted into a gas at the site. Some regulations do not permit the use of liquid propane inside of a facility. Review the local building codes before final plans are made for a propane system.

For the guidelines in this Operation and Maintenance Manual, propane must meet these HD-5 specifications:

- 95 percent propane

- Remaining 5 percent is not heavier than butane.

HD-5 propane can be used in all naturally aspirated engines. Turbocharged engines can run on propane fuels. In either case, the engine must be properly equipped for the use of propane. The use of pistons with a low compression ratio and a derating is required.

Consult your Caterpillar dealer before operating your gas engine with this fuel.

HD-5 propane has an LHV between 2427 to 2532 kJ/0.305 m³ (2300 to 2400 Btu/ft³).

Mixtures of Propane and Air

Mixtures of propane and air have an LHV that is approximately the same LHV of natural gas. Mixtures of propane and air are generally used as a standby fuel for occasions when the flow of natural gas is interrupted. Mixtures of propane and air require the ignition timing, the rated load, and the compression ratio that is required by propane. Some derating may be required in order to use this fuel. Consult your Caterpillar dealer before operating the engine with this fuel.

Sour Gas

Note: For sour gas, Caterpillar recommends engine arrangements for landfill gas.

Sour gas refers to fuels that contain more than 0.43 mg H₂S/MJ (.450 µg H₂S/Btu). The following gases are within this category:

- Some wellhead gases
- Landfill gas
- Digester gas

"Sweet" gas pertains to fuels that have less than 0.43 mg H₂S/MJ (.450 µg H₂S/Btu).

The use of gases that have hydrogen sulfide can damage the engine. Products of combustion (water vapor and sulfur oxides) form sulfurous acid and sulfuric acid. Sulfur reacts easily with "bright" metals such as copper. Therefore, oil coolers are usually the first components that are affected by the acids. Other engine parts that are attacked by the acids include the following components:

- Valves
- Valve guides
- Piston pin bushings

- Piston rings
- Cylinder liners
- Exhaust manifolds
- Aftercoolers

Analyze the gas before use. If the gas has more than 0.43 mg H₂S/MJ (.450 µg H₂S/Btu), treat the gas in order to reduce the content of hydrogen sulfide.

Various devices can reduce the content of hydrogen sulfide. Examples are chemically active filters, reactive beds, and solutions. The performance of the devices deteriorates as the reactive chemicals are depleted. The devices must be serviced or replaced in order to maintain effectiveness.

Take the following precautions even if the gas is treated in order to reduce the level of hydrogen sulfide. This will help to protect the engine against intervals when the devices for treating the fuel deteriorate. Even brief intervals of operation with high sulfur fuels can damage the engine, unless precautions are taken.

- Maintain the temperature of the coolant outlet to a minimum of 110 °C (230 °F). Do not allow the rise in temperature across the engine to exceed 8.3 °C (15 °F). A rise in temperature of 5.6 °C (10 °F) is preferable.

Lower jacket water temperatures permit water vapor and hydrogen sulfide to condense on the cylinder liners. Higher temperatures will reduce this condensation.

- Establish an oil analysis program in order to ensure that the oil change intervals are not extended beyond the condemning limits of the oil. The oil analysis will also be able to detect other problems that may occur.

Wellhead Gas (Field Gas)

Wellhead gas is natural gas that has not been processed. The composition of gas from the wellheads in different gas fields varies. The composition of the gas from different wellheads within the same gas field can vary. As a result, the gas from one source may be acceptable for use but the gas from a different source may not be acceptable. For this reason, a fuel analysis is required to determine if the fuel is acceptable for a particular Caterpillar Engine.

Note: The composition of the gas from a field can change over time. Allow some adaptability for this change during the life of the project.

Wellhead gas has minimal processing before entering the fuel manifold. This fuel is commonly used in engines that power gas compressors. The engines burn the same gas that is compressed in order to be transferred through pipelines.

Some gas fields contain significant amounts of hydrogen sulfide. In these cases, follow the precautions that are recommended for using sour gas. Obtain a fuel analysis and determine the methane number.

Follow the guide for fuel usage that is in the engine's Engine Performance publication. These publications are available from your Caterpillar dealer.

Many wellhead gases have some heavier hydrocarbons such as pentane, isobutane and other "gasolines". These heavier hydrocarbons cause detonation and other problems.

Consult your Caterpillar dealer before operating the engine with fuel that has more than one percent of hydrocarbons that are heavier than butane.

Bio-Gas

Bio-gas is generally classified as gas that is obtained from these sources:

- Landfills
- Facilities that produce digester gas

Although these gases are both the result of organic decomposition, the compositions are different.

Landfill Gas

The decomposition of organic material produces landfill gas. The composition of landfill gas depends on the materials that are in the landfill. The gas is collected through a grid of pipes that are laid out within the landfill.

The collection of landfill gas was prompted by ecological concerns. Landfill gas contains methane and other pollutants. These harmful pollutants are consumed in order to produce useful energy.

Caterpillar offers a variety of engines that can be operated successfully with landfill gas.

Fuel analysis is required in order to provide guidelines for treatment of the fuel. When an application that uses landfill gas initiates operation, the operation and maintenance that is recommended by Caterpillar must be followed.

Landfill gas may contain the following contaminants that can cause harmful effects on engines:

- Chlorine
- Fluorine
- Siloxanes
- Sulfur
- Water vapor

The sulfur compounds in landfill gas cause the same engine problems as sulfur in sour gas. When landfill gas is used, follow the precautions that are recommended for using sour gas.

Landfills can contain chlorine and fluorine compounds in the form of volatile organic compounds and chlorofluorocarbons. When these substances are burned in engines, corrosive hydrochloric acid and hydrofluoric acid can be produced.

Landfill gas can corrode both the equipment that handles the gas and the engine. Vapor is produced by combustion. If that vapor condenses in the crankcase, a solution that is potentially corrosive to the engine can form.

Landfill gas and digester gas can contain siloxanes. Siloxanes are formed when silica ions attach to the methane hydrocarbon chain. These gaseous compounds enter the combustion chamber with the fuel. This enables deposits that are similar to silica to form in the cylinders.

Because the engine oil contains some calcium, deposits in the combustion chamber are generally a combination of these materials: silicon, calcium, and some traces of other elements. These substances can coagulate during combustion. Larger particles can be formed.

The larger particles can be abrasive to exhaust valve faces and valve seats. This causes the valves to become pitted and indented. The particles can also build up on the valve seat. The buildup can cause guttering of the valves.

Deposits also form on the pistons and on the bottom deck of the cylinder heads. Detonation can loosen the deposits. The deposits that are loosened can be trapped between the valve and the valve seat. The valve will be held open. Guttering of the valve will result.

The formation of deposits depends on the following factors:

- Composition of the fuel
- Operating conditions

- Type of lubrication oil

Most landfill applications will generate some deposits in the combustion chamber and the turbocharger. Siloxanes are a major contributor to these deposits. The fuel requires treatment in order to remove the siloxanes. For information on equipment for processing landfill gas, see Application and Installation Guide, LEKQ7260, "Low Energy Fuels".

Note: The amount of silicon in the fuel can be measured with a test that was developed by Caterpillar and Bio-Engineering Services. The test kit enables a sample of the fuel to be analyzed. The fuel can also be analyzed for other harmful contaminants such as chlorines, fluorines, sulfur, and halides. Details can be obtained from the following address:

Bio-Engineering Services
36 Virginia Street
Southport, Merseyside PR8 6RU England
Telephone: 44 (0) 1704-539094
Fax: 44 (0) 1704-501660

During normal combustion, some exhaust gas and unburned fuel is forced past the piston rings and into the crankcase. The contaminants in this blowby are vented away from the crankcase by positive crankcase ventilation. The contaminants are diluted and purged.

The formation of water in the crankcase can result in an acid solution which allows corrosion to occur. A highjacket water coolant temperature helps to prevent the condensation of water in the crankcase. Engines that are used for landfill gas have a high temperature jacket water cooling system as standard equipment. The standard water temperature regulators begin to open at 110 °C (230 °F).

Because of the higher jacket water coolant temperature, the oil must be cooled by other means. In engines that use landfill gas, the oil is cooled by the water in the system for separate circuit aftercooling.

To protect the service life of the engine, it is necessary to follow the guidelines for operation and maintenance that are recommended by Caterpillar. For engines that use landfill gas, practice the following recommendations in addition to the precautions for using sour gas:

- Exhaust gases are likely to contain acids. If the engine installation has a device that uses the heat from the exhaust, maintain a minimum exhaust gas temperature of 204 °C (400 °F). This will prevent condensation in the device.

- Landfill gas requires regular, careful maintenance of the spark plugs. Misfire causes the engine to run rough. The cylinder temperatures are reduced. Cooler cylinders allow deposits to build up faster in the combustion chamber, the exhaust manifold, and the turbocharger. Exhaust port temperatures can indicate the performance of the spark plugs. An exhaust port temperature that decreases more than 66 °C (150 °F) below the average operating temperature may indicate the misfire of a spark plug. Clean the spark plug. Inspect the spark plug and set the electrode gap. Replace the spark plug if the performance is in question.

- Caterpillar Natural Gas Engine Oil (NGEO) is recommended for engines that use landfill gas. NGEO has 0.45 percent sulfated ash. The use of an oil that has a high concentration of sulfated ash will result in excessive deposits in the combustion chamber. Because of the inconsistent composition of landfill gas, oil may react differently to a particular landfill gas. Use the S·O·S oil analysis program to determine proper oil change intervals.

For new installations, sample the oil frequently in order to establish a consistent program for oil changes. Initially, sample the oil on a daily basis. The properties of landfill gas can change rapidly. Therefore, it is necessary to continue to monitor the oil on a weekly basis or two times per month in order to ensure adequate protection.

Note: For more information on landfill gas and digester gas, see Application and Installation Guide, LEKQ7260, "Low Energy Fuels".

Digester Gas

A variety of materials can produce digester gas:

- Sewage
- Animal waste
- Liquid effluent from mills that produce vegetable oil or alcohol

Digester gas has properties that are similar to the properties of landfill gas. Digester gas usually has some sulfur and siloxanes. However, the chlorofluorocarbons that are commonly found in landfill gas are not usually found in digester gas. The same precautions for treatment of the fuel and protecting the engine are required. Until experience proves otherwise, the same maintenance recommendations are used.

Gaseous Fuel Filters

The customer is responsible for supplying clean, dry fuel to the engine.

Fuel filters are no less important than air filters to protect gas engines from dirt and debris. A proper fuel filter removes impurities that can damage the internal components of the engine.

The gas must be supplied to the engine at a pressure that is acceptable. For optimum operation, use a fuel filter that is properly sized for the gas pressure.

For many gas engines, fuel filters are a provision of the design for the application. These devices are included in the normal maintenance of the plant. Therefore, Caterpillar does not include a standard fuel filter as a part of each gas engine. However, fuel filters are available from your Caterpillar dealer.

Consult your Caterpillar dealer about the requirements for filtering your engine's fuel.

Cooling System Specifications

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General Coolant Information

SMCS Code: 1350; 1395

NOTICE

Never add coolant to an overheated engine. Engine damage could result. Allow the engine to cool first.

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 outside temperature or drained completely to prevent damage.

NOTICE

Frequently check the specific gravity of the coolant for proper freeze protection or for anti-boil protection.

Clean the cooling system for the following reasons:

- Contamination of the cooling system
- Overheating of the engine
- Foaming of the coolant

Note: Air pockets can form in the cooling system if the cooling system is filled at a rate that is greater than 20 L (5 US gal) per minute.

After you drain the cooling system and after you refill the cooling system, operate the engine. Operate the engine without the filler cap until the coolant reaches normal operating temperature and the coolant level stabilizes. Ensure that the coolant is maintained to the proper level.

NOTICE

Never operate an engine without water temperature regulators in the cooling system. Water temperature regulators help to maintain the engine coolant at the proper operating temperature. Cooling system problems can develop without water temperature regulators.

Refer to Special Instruction, SEBD0518, "Know Your Cooling System" and Special Instruction, SEBD0970, "Coolant and Your Engine" for more detailed information.

Many engine failures are related to the cooling system. The following problems are related to cooling system failures: overheating, leakage of the water pump, plugged radiators or heat exchangers, and pitting of the cylinder liners.

These failures can be avoided with proper cooling system maintenance. Cooling system maintenance is as important as maintenance of the fuel system and the lubrication system. Quality of the coolant is as important as the quality of the fuel and the lubricating oil.

Coolant is normally composed of three elements: water, additives, and glycol.

Water

NOTICE

Never use water alone without Supplemental Coolant Additives (SCA) or without inhibited coolant. Water alone is corrosive at engine operating temperatures. Water alone does not provide adequate protection against boiling or freezing.

Water is used in the cooling system in order to transfer heat.

Distilled water or deionized water is recommended for use in engine cooling systems.

DO NOT use the following types of water in cooling systems: hard water, softened water that has been conditioned with salt, and sea water.

If distilled water or deionized water is not available, use water with the properties that are listed in Table 21.

Table 21

Caterpillar Minimum Acceptable Water Requirements		
Property	Maximum Limit	ASTM Test
Chloride (Cl)	40 mg/L (2.4 grains/US gal)	"D512", "D4327"
Sulfate (SO ₄)	100 mg/L (5.9 grains/US gal)	"D516"
Total Hardness	170 mg/L (10 grains/US gal)	"D1126"
Total Solids	340 mg/L (20 grain/US gal)	"D1888"
Acidity	pH of 5.5 to 9.0	"D1293"

For a water analysis, consult one of the following sources:

- Caterpillar dealer
- Local water utility company
- Agricultural agent
- Independent laboratory

Additives

Additives help to protect the metal surfaces of the cooling system. A lack of coolant additives or insufficient amounts of additives enable the following conditions to occur:

- Corrosion
- Formation of mineral deposits
- Rust
- Scale
- Pitting and erosion from cavitation of the cylinder liner
- Foaming of the coolant

Many additives are depleted during engine operation. These additives must be replaced periodically. This can be done by adding Supplemental Coolant Additives (SCA) to Diesel Engine Antifreeze/Coolant (DEAC).

Additives must be added at the proper concentration. Overconcentration of additives can cause the inhibitors to drop out-of-solution. The deposits can enable the following problems to occur:

- Formation of gel compounds

- Reduction of heat transfer
- Leakage of the water pump seal
- Plugging of radiators, coolers, and small passages

Glycol

Glycol in the coolant helps to provide protection against the following conditions:

- Boiling
- Freezing
- Cavitation of the water pump and the cylinder liner

For optimum performance, Caterpillar recommends a 1:1 mixture of a water/glycol solution.

Note: Use a mixture that will provide protection against the lowest ambient temperature.

Note: 100 percent pure glycol will freeze at a temperature of -23°C (-9°F).

Most conventional heavy-duty coolant/antifreezes use ethylene glycol. Propylene glycol may also be used. In a 1:1 mixture with water, ethylene and propylene glycol provide similar protection against freezing and boiling. See Tables 22 and 23.

Table 22

Ethylene Glycol		
Concentration	Freeze Protection	Boil Protection
50 Percent	-36°C (-33°F)	106°C (223°F)
60 Percent	-51°C (-60°F)	111°C (232°F)

NOTICE

Do not use propylene glycol in concentrations that exceed 50 percent glycol because of propylene glycol's reduced heat transfer capability. Use ethylene glycol in conditions that require additional protection against boiling or freezing.

Table 23

Propylene Glycol		
Concentration	Freeze Protection	Anti-Boil Protection
50 Percent	-29 °C (-20 °F)	106 °C (223 °F)

To check the concentration of glycol, use the 1U-7298 Coolant/Battery Tester (Degree Celsius) or use the 1U-7297 Coolant/Battery Tester (Degree Fahrenheit). The testers give readings that are immediate and accurate. The testers can be used with ethylene or propylene glycol.

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Coolant Recommendations

SMCS Code: 1350; 1352; 1395

NOTICE

Do not use a commercial coolant/antifreeze that only meets the ASTM D3306 or D4656 specification. This type of coolant/antifreeze is made for light duty automotive applications.

The following coolants are the primary types of coolants that are used in Caterpillar Gas Engines:

Preferred – Caterpillar Diesel Engine Antifreeze/Coolant (DEAC) or a commercial heavy-duty coolant/antifreeze that meets "ASTM D4985" or "ASTM D5345" specifications

Acceptable – A mixture of Caterpillar Supplemental Coolant Additive and water that has the acceptable characteristics

Caterpillar recommends a 1:1 mixture of water and glycol. This mixture will provide optimum heavy-duty performance as a coolant/antifreeze.

Note: Caterpillar DEAC DOES NOT require a treatment with an SCA at the initial fill. Commercial heavy-duty coolant/antifreeze that meets "ASTM D4985" or "ASTM D5345" specifications MAY require a treatment with an SCA at the initial fill. Read the label or the instructions that are provided by the OEM of the product.

In those engine applications that do not require protection from boiling or freezing, a mixture of SCA and water is acceptable. **Caterpillar recommends a minimum of six percent to a maximum of eight percent SCA concentration in those cooling systems.** Distilled water or deionized water is preferred. Water which has the acceptable characteristics may be used. For the acceptable characteristics, see this publication, "General Coolant Information" topic (Maintenance Section).

Note: Table 24 is a list of the coolants that are recommended and the service life (calendar) of the coolants. The service life of coolant is also limited by use (service hours). Refer to the specific engine's Operation and Maintenance Manual, "Maintenance Interval Schedule" (Maintenance Section). **To achieve this service life, the coolants must be properly maintained. The maintenance program includes S-O-S coolant analysis.**

Table 24

Coolant Service Life	
Coolant Type	Service Life ⁽¹⁾
Caterpillar DEAC	Three Years
Commercial Heavy-Duty Coolant/Antifreeze that meets "ASTM D5345"	Two Years
Commercial Heavy-Duty Coolant/Antifreeze that meets "ASTM D4985"	One Year
Caterpillar SCA and Water	Two Years
Commercial SCA and Water	One Year

⁽¹⁾ The service life of coolant is also limited by use (service hours). Refer to the specific engine's Operation and Maintenance Manual, "Maintenance Interval Schedule" (Maintenance Section).

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Diesel Engine Antifreeze/Coolant (DEAC)

SMCS Code: 1350; 1352; 1395

Caterpillar recommends using Caterpillar Diesel Engine Antifreeze/Coolant (DEAC) for cooling systems that require a heavy-duty coolant/antifreeze. Caterpillar DEAC is an alkaline single-phase ethylene glycol type antifreeze that contains corrosion inhibitors and antifoam agents.

Caterpillar DEAC is formulated with the correct amount of Caterpillar Supplemental Coolant Additive (SCA). Do not use SCA at the initial fill when DEAC is used.

Containers of several sizes are available. Consult your Caterpillar dealer for the part numbers.

If concentrated DEAC is used, Caterpillar recommends mixing the concentrate with distilled water or with deionized water. If distilled water is not available or deionized water is not available, use water which has the required properties. For the water properties, see this publication, "General Coolant Information" topic (Maintenance Section).

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Commercial Heavy-Duty Coolant/Antifreeze and SCA

SMCS Code: 1350; 1352; 1395

If Caterpillar DEAC is not used, select a coolant/antifreeze with low silicate content for heavy-duty applications that meets "ASTM D5345" or "ASTM D4985" specifications.

Note: When you are not using Caterpillar DEAC the cooling system must be drained one time during every year. The cooling system must be flushed at this time as well.

When a heavy-duty coolant/antifreeze is used, treat the cooling system with three to six percent Caterpillar SCA by volume. For more information, see this publication, "Conventional Coolant/Antifreeze Cooling System Maintenance" topic (Maintenance Section).

If Caterpillar SCA is not used, select a commercial SCA. The commercial SCA must provide a minimum of 1200 mg/L or 1200 ppm (70 grains/US gal) of nitrites in the final coolant mixture.

Coolant/antifreeze that meets "ASTM D5345" or "ASTM D4985" specifications MAY require treatment with SCA at the initial fill. These coolants WILL require treatment with SCA on a maintenance basis.

When concentrated coolant/antifreeze is mixed, Caterpillar recommends mixing the concentrate with distilled water or with deionized water. If distilled water or deionized water is not available, water which has the required properties may be used. For the water properties, see this publication, "General Coolant Information" topic (Maintenance Section).

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Supplemental Coolant Additive (SCA)

SMCS Code: 1350; 1352; 1395

The use of SCA helps to prevent the following conditions from occurring:

- Corrosion
- Formation of mineral deposits
- Cavitation erosion of the cylinder liners
- Foaming of the coolant

Caterpillar Diesel Engine Antifreeze/Coolant (DEAC) is formulated with the correct level of Caterpillar SCA. When the cooling system is initially filled with DEAC, adding more SCA is not necessary until the concentration of SCA has been depleted. To ensure that the correct amount of SCA is in the cooling system, the concentration of SCA must be tested on a scheduled basis. Refer to the specific engine's Operation and Maintenance Manual, "Maintenance Interval Schedule".

Containers of SCA are available in several sizes. Consult your Caterpillar dealer for the part numbers.

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Conventional Coolant/Antifreeze Cooling System Maintenance

SMCS Code: 1350; 1352; 1395

NOTICE

Never operate an engine without water temperature regulators in the cooling system. Water temperature regulators help to maintain the engine coolant at the proper operating temperature. Cooling system problems can develop without water temperature regulators.

Check the coolant/antifreeze (glycol concentration) in order to ensure adequate protection against boiling or freezing. Caterpillar recommends the use of a refractometer for checking the glycol concentration. Use the 1U-7298 Coolant/Battery Tester (Celsius) or use the 1U-7297 Coolant/Battery Tester (Fahrenheit). The testers give readings that are immediate and accurate. The testers can be used with ethylene or with propylene glycol.

Adding the SCA to Conventional Coolant/Antifreeze at the Initial Fill

Note: Caterpillar DEAC DOES NOT require an addition of SCA when the cooling system is initially filled.

Commercial heavy-duty coolant/antifreeze that meets "ASTM D4985" or "ASTM D5345" specifications MAY require an addition of SCA when the cooling system is initially filled. Read the label or the instructions that are provided by the OEM of the product.

The size of the cooling system determines the amount of SCA that is required. Use the equation that is in Table 25 to determine the amount of Caterpillar SCA that may be required when the cooling system is initially filled with heavy-duty coolant/antifreeze that meets "ASTM D4985" or "ASTM D5345" specifications.

Table 25

Equation For Adding The SCA At The Initial Fill Coolant/Antifreeze That Meets "ASTM D4985" or "ASTM D5345" Specifications ⁽¹⁾
$V \times 0.045 = X$
V is the total volume of the cooling system.
X is the amount of SCA that is required.

⁽¹⁾ Read the label or the instructions that are provided by the OEM of the product.

Table 26 is an example for using the equation that is in Table 25.

Table 26

Example of the Equation For Adding The SCA At The Initial Fill Coolant/Antifreeze That Meets "ASTM D4985" or "ASTM D5345" Specifications		
Total Volume of the Cooling System (V)	Factor for Multiplication	Amount of SCA that is Required (X)
946 L (250 US gal)	× 0.045	43 L (11 US gal)

Adding the SCA to Conventional Coolant/Antifreeze For Maintenance

Heavy-duty coolant/antifreeze of all types REQUIRE periodic additions of an SCA.

Test the coolant/antifreeze periodically for the concentration of SCA. For the interval, see the specific engine's Operation and Maintenance Manual, "Maintenance Interval Schedule" (Maintenance Section). SCA test kits are available from your Caterpillar dealer. Test the concentration of SCA or submit a coolant sample to your Caterpillar dealer. For more information on coolant analysis, see the Operation and Maintenance Manual, "S-O-S Coolant Analysis" topic (Maintenance Section).

Additions of SCA are based on the results of the test or based on the results of the coolant analysis. The size of the cooling system determines the amount of SCA that is needed.

Use the equation that is in Table 27 to determine the amount of Caterpillar SCA that is required.

Table 27

Equation For Adding The SCA To Conventional Coolant/Antifreeze For Maintenance
$V \times 0.014 = X$
V is the total volume of the cooling system.
X is the amount of SCA that is required.

Table 28 is an example for using the equation that is in Table 27.

Table 28

Example Of The Equation For Adding The SCA To Conventional Coolant/Antifreeze For Maintenance		
Total Volume of the Cooling System (V)	Factor for Multiplication	Amount of SCA that is Required (X)
946 L (250 US gal)	× 0.014	13 L (3.5 US gal)

Note: Specific engine applications may require maintenance practices to be periodically evaluated in order to properly maintain the engine's cooling system.

Table 29 lists part numbers and quantities of SCA that is available from your Caterpillar dealer.

Table 29

Caterpillar Liquid SCA	
Part Number	Quantity
8C-3680	19 L (5 US gal)
5P-2907	208 L (55 US gal)

Cleaning the Cooling System of Heavy-Duty Coolant/Antifreeze

Caterpillar Cooling System Cleaner dissolves mineral scale, corrosion products, light oil contamination and sludge.

- Clean the cooling system after used coolant is drained or before the cooling system is filled with new coolant.
- Clean the cooling system whenever the coolant is contaminated or whenever the coolant is foaming.

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Water/Supplemental Coolant Additive (SCA)

SMCS Code: 1350; 1352; 1395

NOTICE

To help prevent water pump cavitation, Caterpillar recommends a minimum of 30 percent of glycol in the coolant/antifreeze mixture.

Use a mixture that will provide protection against the lowest ambient temperature.

100 percent pure glycol will freeze at a temperature of -13°C (9°F).

NOTICE

Never use water alone without Supplemental Coolant Additives (SCA) or without inhibited coolant. Water alone is corrosive at engine operating temperatures. Water alone does not provide adequate protection against boiling or freezing.

Do not use water alone as an engine coolant. Supplemental Coolant Additive (SCA) helps to prevent the following conditions from occurring:

- Corrosion
- Formation of mineral deposits
- Cavitation of the cylinder liner
- Foaming of the coolant

If Caterpillar SCA is not used, select a commercial SCA. The commercial SCA must provide a minimum of 2400 mg/L or 2400 ppm (140 grains/US gal) of nitrites in the final coolant mixture.

The quality of the water is a very important factor in this type of cooling system. Distilled water or deionized water is recommended for use in cooling systems. If distilled water or deionized water is not available, water that has the required properties may be used. For the water properties, see this Operation and Maintenance Manual, "General Coolant Information" topic (Maintenance Section).

A cooling system that uses a mixture of only SCA and water requires more SCA than a cooling system that uses a mixture of glycol and water. The SCA and water requires six to eight percent of SCA.

Adding the SCA to Water at the Initial Fill

The capacity of the cooling system determines the amount of SCA that is required. Use the equation that is in Table 30 to determine the amount of Caterpillar SCA that is required at the initial fill. This equation is for a mixture of only SCA and water.

Table 30

Equation For Adding The SCA To Water At The Initial Fill
$V \times 0.07 = X$
V is the total volume of the cooling system.
X is the amount of SCA that is required.

Table 31 is an example for using the equation that is in Table 30.

Table 31

Example Of The Equation For Adding The SCA To Water At The Initial Fill		
Total Volume of the Cooling System (V)	Factor for Multiplication	Amount of SCA that is Required (X)
946 L (250 US gal)	× 0.07	66 L (18 US gal)

Adding the SCA to Water for Maintenance

Test the mixture of SCA and water periodically for the concentration of SCA. For the interval, see the specific engine's Operation and Maintenance Manual, "Maintenance Interval Schedule" (Maintenance Section).

Test the concentration of SCA with the 8T-5296 Coolant Conditioner Test Kit or with S-O-S coolant analysis. For more information on coolant analysis, see this Operation and Maintenance Manual, "S-O-S Coolant Analysis" topic (Maintenance Section).

Instructions are provided with the 8T-5296 Coolant Conditioner Test Kit. Make the following modifications to Steps 3 and 5 of the instructions. These modifications are needed for mixtures of SCA and water:

STEP 3 – Add tap water to the vial up to the “20 ml” mark.

STEP 5 – When the defined procedure is used, a concentration of six to eight percent will yield between 20 drops and 27 drops. If the number of drops is below 20 drops, the concentration of SCA is low. If the number of drops is above 27 drops, the concentration of SCA is high. Make the appropriate adjustments to the concentration of SCA.

Additions of SCA are based on the results of the test or based on the results of the coolant analysis. The capacity of the cooling system determines the amount of SCA that is required.

Use the equation that is in Table 32 to determine the amount of Caterpillar SCA that is required.

Table 32

Equation For Adding the SCA To Water For Maintenance
$V \times 0.023 = X$
V is the total volume of the cooling system.
X is the amount of SCA that is required.

Table 33 is an example for using the equation that is in Table 32.

Table 33

Example Of The Equation For Adding the SCA To Water For Maintenance		
Total Volume of the Cooling System (V)	Factor for Multiplication	Amount of SCA that is Required (X)
946 L (250 US gal)	× 0.023	22 L (6 US gal)

Note: Specific engine applications may require maintenance practices to be periodically evaluated in order to properly maintain the engine’s cooling system.

Table 34 lists part numbers and quantities of SCA that is available from your Caterpillar dealer.

Table 34

Caterpillar Liquid SCA	
Part Number	Quantity
8C-3680	19 L (5 US gal)
5P-2907	208 L (55 US gal)

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S·O·S Coolant Analysis

SMCS Code: 1350; 1352; 1395

Testing the engine coolant is important to ensure that the engine is protected from internal cavitation and from corrosion. The analysis also tests the ability of the coolant to protect the engine from boiling and from freezing.

Coolant analysis can be performed at your Caterpillar dealership. Caterpillar’s S·O·S coolant analysis is an excellent way to monitor the condition of your coolant and your cooling system.

The most critical aspect of coolant analysis is the interpretation of the results. The analyst must be properly trained in order to provide a correct diagnosis. The analyst must understand several variables.

Different coolants have different formulations and different condemning limits. Different commercial labs may use different methods to test for the same variable. These other considerations are also important for interpreting the results of a coolant analysis:

- The number of hours on the sample
- The equipment that uses the coolant
- The application of the equipment

Analysts at Caterpillar’s S·O·S fluid labs are trained to determine the acceptability of coolants. These analysts have knowledge of the equipment and applications. These qualifications enable the analysts to detect problems before damage occurs.

NOTICE

Do not use the same vacuum sampling pump for extracting oil samples that is used for extracting coolant samples.

A small residue of either type sample may remain in the pump and may cause a false positive analysis for the sample being taken.

Always use a designated pump for oil sampling and a designated pump for coolant sampling.

Failure to do so may cause a false analysis which could lead to customer and dealer concerns.

Caterpillar's S-O-S coolant analysis is a program with two levels. The program is based on periodic samples. The samples are analyzed. The results are reported, and appropriate recommendations are made according to the results.

S-O-S Coolant Analysis (Level I)

A coolant analysis (Level I) is a test of the properties of the coolant that includes the following items:

- Glycol concentration for protection from boiling and freezing
- Ability to protect from erosion and corrosion
- pH
- Conductivity
- Water hardness
- Visual analysis
- Analysis of the odor

The results are reported, and appropriate recommendations are made.

S-O-S Coolant Analysis (Level II)

A coolant analysis (Level II) is a comprehensive chemical evaluation of the coolant. This analysis is also a check of the overall condition of the inside of the cooling system. The following services are provided:

- Full Level I analysis
- Identification of the source of metal corrosion and of contaminants
- Identification of buildup of the impurities that cause corrosion

- Identification of buildup of the impurities that cause scaling
- Determination of possible electrolysis within the engines' cooling system

The results are reported, and appropriate recommendations are made.

For more information on S-O-S coolant analysis, consult your Caterpillar dealer.

Refill Capacities

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Refill Capacities

SMCS Code: 1000; 1348; 1395; 7560

Lubrication System

The capacity of the Engine Crankcase includes the capacity of the oil filters that are installed at the factory. Auxiliary oil filter systems (if equipped) will require additional oil.

For the recommended oil, see this Operation and Maintenance Manual, "Engine Oil" topic (Maintenance Section).

Table 35

G3508 Engine Lubrication System Refill Capacities (Approximate)		
Compartment or System	Liters	US Gallons
Engine Crankcase	231 L	61 US gal

Table 36

G3512 Engine Lubrication System Refill Capacities (Approximate)		
Compartment or System	Liters	US Gallons
Engine Crankcase	338 L	89 US gal

Table 37

G3516 Engine Lubrication System Refill Capacities (Approximate)		
Compartment or System	Liters	US Gallons
Engine Crankcase	423 L	112 US gal

Auxiliary Oil Filter System Capacities

Table 38

Auxiliary Oil Filter System Capacities (Approximate)		
Auxiliary Oil Filter System	With Elements	Without Elements ⁽¹⁾
117-9550 Oil Filter Assembly ⁽²⁾	132 L (35 US gal)	176 L (46.5 US gal)
1118-8419 Oil Filter Assembly ⁽³⁾	132 L (35 US gal)	176 L (46.5 US gal)
119-2104 Oil Filter Assembly ⁽⁴⁾	178 L (47 US gal)	244 L (64 US gal)

- (1) Auxiliary oil filter systems increase the oil capacity in order to increase the service life of the oil. Caterpillar recommends operation without the auxiliary oil filter elements.
- (2) This assembly holds 14 elements and is for use with G3508 Engines.
- (3) This assembly holds 14 elements and is for use with G3512 Engines.
- (4) This assembly holds 21 elements and is for use with G3516 Engines.

Cooling System

To properly maintain the cooling system, the Total Cooling System capacity must be determined. The Total Cooling System capacity will vary between individual installations. The External System capacity includes the following components: engine, expansion tank, heat exchanger, radiator, and piping. Refer to the specifications that are provided by Caterpillar or by the OEM of the equipment. Record the Total Cooling System capacity in the appropriate Table.

For the recommended coolant, see this Operation and Maintenance Manual, "Coolant Recommendations" (Maintenance Section).

Table 39

G3508 Engine Cooling System Refill Capacities (Approximate)		
Compartment or System	Liters	US Gallons
Jacket Water System Only	114 L	30 US gal
SCAC System Only	13 L	3.5 US gal
External System		
Total Cooling System		

Table 40

G3512 Engine Cooling System Refill Capacities (Approximate)		
Compartment or System	Liters	US Gallons
Jacket Water System Only	148 L	39 US gal
SCAC System Only	15 L	4 US gal
External System		
Total Cooling System		

Table 41

G3516 Engine Cooling System Refill Capacities (Approximate)		
Compartment or System	Liters	US Gallons
Jacket Water System Only	205 L	53 US gal
SCAC System Only	16.5 L	4.5 US gal
External System		
Total Cooling System		

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Maintenance Interval Schedule (Naturally Aspirated Engines)

SMCS Code: 1000; 7500

S/N: 4WD1-Up

S/N: 5JD1-Up

S/N: 8LD1-Up

S/N: 9TG1-Up

S/N: 2TJ1-Up

S/N: 7NJ1-Up

S/N: 4EK1-Up

S/N: 6JW1-Up

S/N: 8PW1-Up

S/N: 9AW1-Up

Before performing any operation or maintenance procedures, ensure that the Safety Information, warnings, and instructions are read and understood.

Before each consecutive interval is performed, all of the maintenance requirements from the previous interval must be performed.

Note: For information on generator maintenance, see the Operation and Maintenance Manual for the generator.

When Required

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Air Starting Motor Lubricator Oil Level - Check	81
Air Tank Moisture and Sediment - Drain	82
Control Panel - Inspect	85
Cooling System Coolant Level - Check	89
Driven Equipment - Inspect/Replace/Lubricate ...	93
Engine Air Cleaner Service Indicator - Inspect	96
Engine Air Precleaner - Clean	97
Engine Oil Level - Check	103
Fuel System Fuel Filter Differential Pressure - Check	108
Power Take-Off Clutch - Check/Adjust/ Lubricate	120
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Every 250 Service Hours

Battery Electrolyte Level - Check	84
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Initial 1000 Service Hours

Cooling System Supplemental Coolant Additive (SCA) - Test/Add	89
Engine Mounts - Check	98
Engine Speed/Timing Sensor - Clean/Inspect	105
Speed Sensor - Clean/Inspect	122
Valve Stem Projection - Measure/Record	124

Every 1000 Service Hours

Alternator and Fan Belts - Inspect/Adjust/ Replace	82
Carburetor Air/Fuel Ratio - Check/Adjust	85
Cooling System Supplemental Coolant Additive (SCA) - Test/Add	89
Crankshaft Vibration Damper - Inspect	91
Engine - Clean	93
Engine Crankcase Breather - Clean	97
Engine Oil - Change	99
Engine Oil Filter (Auxiliary) - Change	100
Engine Valve Rotators - Inspect	107
Exhaust Piping - Inspect	108
Gas Pressure Regulator - Check	108
Gas Pressure Regulator Condensation - Drain ..	109
Hoses and Clamps - Inspect/Replace	109
Ignition System Spark Plugs - Check/Adjust/ Replace	110
Ignition System Timing - Check/Adjust	114
Inlet Air System - Inspect	114
Radiator - Clean	121

Every 1500 Service Hours

Engine Oil Filter - Change	101
----------------------------------	-----

Every 2000 Service Hours

Actuator Control Linkage - Lubricate	80
Engine Speed/Timing Sensor - Clean/Inspect	105
Engine Valve Lash and Bridge - Adjust	106
Speed Sensor - Clean/Inspect	122

Every 4000 Service Hours

Air Starting Motor Lubricator Bowl - Clean	80
Crankcase Blowby - Measure/Record	90
Cylinder Pressure - Measure/Record	92
Driven Equipment - Check	93
Engine Mounts - Check	98
Engine Protective Devices - Check	105
Exhaust Bypass - Inspect	107
Starting Motor - Inspect	122
Water Pump - Inspect	127

Every 8000 Service Hours

Cooling System Coolant Analysis (Level II) -
Obtain 88
Water Temperature Regulator - Replace 128

Between 8000 and 10 000 Service Hours

Overhaul (Top End) 116

Every 24 000 Service Hours or 3 Years

Cooling System Coolant (DEAC) - Change 86

Between 64 000 and 80 000 Service Hours

Overhaul (Major) 115

i01631792

Maintenance Interval Schedule (Turbocharged Aftercooled Engines That Use Wellhead Gas Or Natural Gas)

SMCS Code: 1000; 7500

Before performing any operation or maintenance procedures, ensure that the Safety Information, warnings, and instructions are read and understood.

Before each consecutive interval is performed, all of the maintenance requirements from the previous interval must be performed.

Note: For information on generator maintenance, see the Operation and Maintenance Manual for the generator.

When Required

Engine Air Cleaner Element - Replace	94
Overhaul Considerations	119
Valve Stem Projection - Measure/Record	124

Daily

Air Starting Motor Lubricator Oil Level - Check	81
Air Tank Moisture and Sediment - Drain	82
Control Panel - Inspect	85
Cooling System Coolant Level - Check	89
Driven Equipment - Inspect/Replace/Lubricate ...	93
Engine Air Cleaner Service Indicator - Inspect	96
Engine Air Precleaner - Clean	97
Engine Oil Level - Check	103
Fuel System Fuel Filter Differential Pressure - Check	108
Power Take-Off Clutch - Check/Adjust/ Lubricate	120
Walk-Around Inspection	125

Every 250 Service Hours

Battery Electrolyte Level - Check	84
Engine Oil Sample - Obtain	104

Initial 1000 Service Hours

Cooling System Supplemental Coolant Additive (SCA) - Test/Add (S/N: 5ZZ1-Up; 8JZ1-Up)	89
Engine Mounts - Check	98
Engine Speed/Timing Sensor - Clean/Inspect	105
Speed Sensor - Clean/Inspect	122
Valve Stem Projection - Measure/Record	124

Every 1000 Service Hours

Aftercooler Condensation - Drain	80
--	----

Alternator and Fan Belts - Inspect/Adjust/ Replace	82
Carburetor Air/Fuel Ratio - Check/Adjust	85
Cooling System Supplemental Coolant Additive (SCA) - Test/Add	89
Crankshaft Vibration Damper - Inspect	91
Engine - Clean	93
Engine Crankcase Breather - Clean	97
Engine Oil - Change	99
Engine Oil Filter (Auxiliary) - Change	100
Engine Valve Lash and Bridge - Adjust	106
Engine Valve Rotators - Inspect	107
Exhaust Piping - Inspect	108
Gas Pressure Regulator - Check	108
Gas Pressure Regulator Condensation - Drain ..	109
Hoses and Clamps - Inspect/Replace	109
Ignition System Spark Plugs - Check/Adjust/ Replace	110
Ignition System Timing - Check/Adjust	114
Inlet Air System - Inspect	114
Radiator - Clean	121

Every 1500 Service Hours

Engine Oil Filter - Change	101
----------------------------------	-----

Every 2000 Service Hours

Actuator Control Linkage - Lubricate	80
Engine Speed/Timing Sensor - Clean/Inspect	105
Speed Sensor - Clean/Inspect	122

Every 4000 Service Hours

Air Starting Motor Lubricator Bowl - Clean	80
Crankcase Blowby - Measure/Record	90
Cylinder Pressure - Measure/Record	92
Driven Equipment - Check	93
Engine Mounts - Check	98
Engine Protective Devices - Check	105
Exhaust Bypass - Inspect	107
Starting Motor - Inspect	122
Water Pump - Inspect	127

Every 8000 Service Hours

Cooling System Coolant Analysis (Level II) - Obtain	88
Turbocharger - Inspect	123
Water Temperature Regulator - Replace	128

Between 9000 and 16 000 Service Hours

Overhaul (Top End)	116
--------------------------	-----

Every 24 000 Service Hours or 3 Years

Cooling System Coolant (DEAC) - Change	86
--	----

Between 45 000 and 80 000 Service Hours

Overhaul (Major)	115
------------------------	-----

i01631804

Maintenance Interval Schedule (Engines That Use Bio-Gas)

SMCS Code: 1000; 7500

Before performing any operation or maintenance procedures, ensure that the Safety Information, warnings, and instructions are read and understood.

Before each consecutive interval is performed, all of the maintenance requirements from the previous interval must be performed.

Note: For information on generator maintenance, see the Operation and Maintenance Manual for the generator.

When Required

Engine Air Cleaner, Element - Replace	94
Engine Oil - Change	99
Fuel Filtration System - Service	108
Overhaul Considerations	119
Valve Stem Projection - Measure/Record	124

Daily

Air Starting Motor Lubricator Oil Level - Check	81
Air Tank Moisture and Sediment - Drain	82
Control Panel - Inspect	85
Cooling System Coolant Level - Check	89
Driven Equipment - Inspect/Replace/Lubricate ...	93
Engine Air Cleaner Service Indicator - Inspect	96
Engine Air Precleaner - Clean	97
Engine Oil Level - Check	103
Fuel System Fuel Filter Differential Pressure - Check	108
Power Take-Off Clutch - Check/Adjust/ Lubricate	120
Walk-Around Inspection	125

Every 125 Service Hours

Engine Oil Sample - Obtain	104
----------------------------------	-----

Every 250 Service Hours

Battery Electrolyte Level - Check	84
---	----

Initial 1000 Service Hours

Cooling System Supplemental Coolant Additive (SCA) - Test/Add (S/N: 5ZZ1-Up; 8JZ1-Up)	89
Engine Mounts - Check	98
Engine Speed/Timing Sensor - Clean/Inspect	105
Speed Sensor - Clean/Inspect	122
Valve Stem Projection - Measure/Record	124

Every 1000 Service Hours

Aftercooler Condensation - Drain	80
Alternator and Fan Belts - Inspect/Adjust/ Replace	82
Carburetor Air/Fuel Ratio - Check/Adjust	85
Cooling System Supplemental Coolant Additive (SCA) - Test/Add	89
Crankshaft Vibration Damper - Inspect	91
Engine - Clean	93
Engine Crankcase Breather - Clean	97
Engine Oil Filter (Auxiliary) - Change	100
Engine Valve Lash and Bridge - Adjust	106
Engine Valve Rotators - Inspect	107
Exhaust Piping - Inspect	108
Gas Pressure Regulator - Check	108
Gas Pressure Regulator Condensation - Drain ..	109
Hoses and Clamps - Inspect/Replace	109
Ignition System Spark Plugs - Check/Adjust/ Replace	110
Ignition System Timing - Check/Adjust	114
Inlet Air System - Inspect	114
Radiator - Clean	121

Every 1500 Service Hours

Engine Oil Filter - Change	101
----------------------------------	-----

Every 2000 Service Hours

Actuator Control Linkage - Lubricate	80
Engine Speed/Timing Sensor - Clean/Inspect	105
Speed Sensor - Clean/Inspect	122

Every 4000 Service Hours

Air Starting Motor Lubricator Bowl - Clean	80
Crankcase Blowby - Measure/Record	90
Cylinder Pressure - Measure/Record	92
Cylinders - Inspect	92
Driven Equipment - Check	93
Engine Mounts - Check	98
Engine Protective Devices - Check	105
Exhaust Bypass - Inspect	107
Starting Motor - Inspect	122
Turbocharger - Inspect	123
Water Pump - Inspect	127

Between 7500 and 8000 Service Hours

Overhaul (Top End)	116
--------------------------	-----

Every 8000 Service Hours

Cooling System Coolant Analysis (Level II) - Obtain	88
Water Temperature Regulator - Replace	128

Every 24 000 Service Hours or 3 Years

Cooling System Coolant (DEAC) - Change	86
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Between 37 500 and 40 000 Service Hours

Overhaul (Major) 115

i01642778

Maintenance Interval Schedule (Standby)

SMCS Code: 1000; 7500

Before performing any operation or maintenance procedures, ensure that the Safety Information, warnings, and instructions are read and understood.

Note: For information on generator maintenance, refer to the Operation and Maintenance Manual for the generator.

The maintenance that is recommended for Every Week can be performed by an authorized operator. The maintenance that is recommended for the subsequent maintenance intervals must be performed by an authorized service technician or by your Caterpillar dealer.

Before each consecutive interval is performed, all of the maintenance requirements from the previous interval must be performed.

Every Week

Air Starting Motor Lubricator Oil Level - Check	81
Air Tank Moisture and Sediment - Drain	82
Battery Charger - Check	84
Battery Electrolyte Level - Check	84
Control Panel - Inspect	85
Cooling System Coolant Level - Check	89
Engine Air Cleaner Service Indicator - Inspect	96
Engine Air Precleaner - Clean	97
Engine Oil Level - Check	103
Fuel System Fuel Filter Differential Pressure - Check	108
Walk-Around Inspection	125

Every Year

Actuator Control Linkage - Lubricate	80
Aftercooler Condensation - Drain	80
Air Starting Motor Lubricator Bowl - Clean	80
Alternator - Inspect	82
Alternator and Fan Belts - Inspect/Adjust/ Replace	82
Carburetor Air/Fuel Ratio - Check/Adjust	85
Cooling System Coolant Analysis (Level II) - Obtain	88
Cooling System Supplemental Coolant Additive (SCA) - Test/Add	89
Crankcase Blowby - Measure/Record (S/N: 5ZZ1-Up; 8JZ1-Up)	90
Crankshaft Vibration Damper - Inspect	91
Cylinder Pressure - Measure/Record	92
Engine Air Cleaner Element - Replace	94
Engine Crankcase Breather - Clean	97
Engine Mounts - Check	98

Engine Oil - Change	99
Engine Oil Filter (Auxiliary) - Change	100
Engine Oil Filter - Change	101
Engine Oil Sample - Obtain	104
Engine Protective Devices - Check	105
Engine Speed/Timing Sensor - Clean/Inspect	105
Engine Valve Lash and Bridge - Adjust	106
Exhaust Bypass - Inspect	107
Exhaust Piping - Inspect	108
Gas Pressure Regulator Condensation - Drain ..	109
Hoses and Clamps - Inspect/Replace	109
Ignition System Spark Plugs - Check/Adjust/ Replace	110
Ignition System Timing - Check/Adjust	114
Inlet Air System - Inspect	114
Radiator - Clean	121
Starting Motor - Inspect	122
Valve Stem Projection - Measure/Record	124
Water Pump - Inspect	127

Every 3 Years

Batteries - Replace	83
Belts - Replace	85
Cooling System Coolant (DEAC) - Change	86
Turbocharger - Inspect	123
Water Temperature Regulator - Replace	128

i01516282

Actuator Control Linkage - Lubricate

SMCS Code: 1265-086

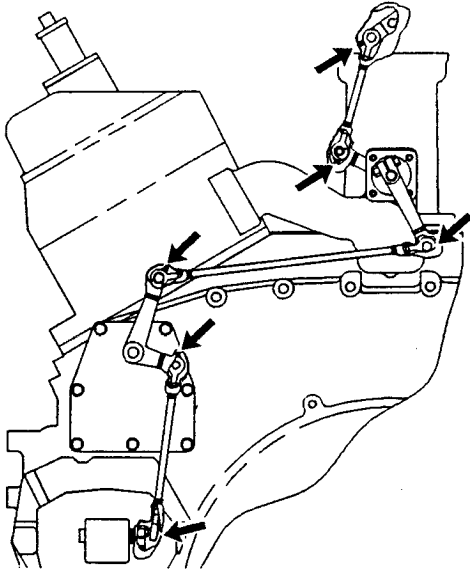


Illustration 44

g00786805

Grease fittings on the linkage

Apply grease to the grease fittings. Use a hand grease gun and lubricate the grease fittings with MPGM.

i01516337

Aftercooler Condensation - Drain

SMCS Code: 1063

The aftercooler cools the compressed air/fuel mixture from the turbocharger. Coolant passes through the tubes in the aftercooler core. The air/fuel mixture that is compressed and warmed by the turbocharger compressor is directed through the aftercooler core. The air/fuel mixture is cooled in the aftercooler.

Condensation can form in the housing of the aftercooler. A drain plug is provided for draining the condensation.

Note: An automatic drain is available for use with 32 °C (90 °F) separate circuit aftercoolers. Consult your Caterpillar dealer for details.

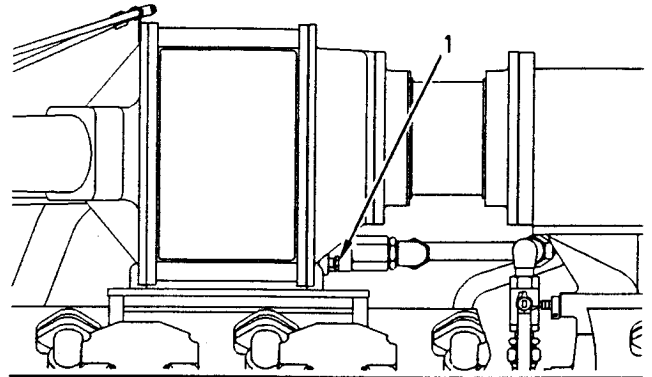


Illustration 45

g00786820

(1) Plug

Remove plug (1). Drain the moisture into a suitable container. Install the plug.

i01490186

Air Starting Motor Lubricator Bowl - Clean

SMCS Code: 1451-070

WARNING

Personal injury can result from removing hoses or fittings in a pressure system.

Failure to relieve pressure can cause personal injury.

Do not disconnect or remove hoses or fittings until all pressure in the system has been relieved.

1. Ensure that the air supply to the lubricator is OFF.

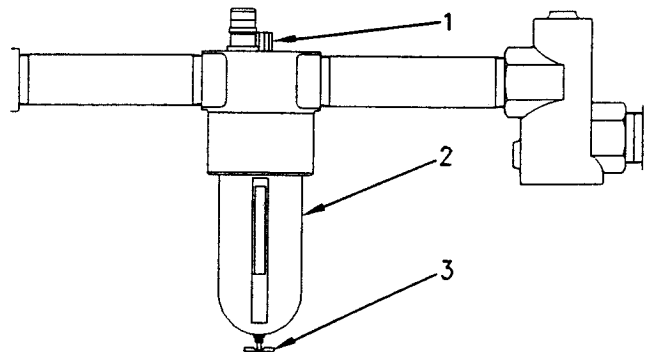


Illustration 46

g00745554

(1) Filler plug
(2) Bowl
(3) Drain valve

2. Slowly loosen filler plug (1) in order to release the pressure from the lubricator.

NOTICE

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

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

Dispose of all fluids according to local regulations and mandates.

3. Place a suitable container under bowl (2) and open drain valve (3) in order to drain the oil from the bowl.
4. Remove bowl (2). Clean the bowl with warm water.
5. Dry the bowl. Inspect the bowl for cracks. If the bowl is cracked, replace the damaged bowl with a new bowl.
6. Install the bowl.
7. Make sure that drain valve (3) is closed. Fill bowl (2) through the hole for filler plug (1).

Use nondetergent "10W" oil for temperatures that are greater than 0 °C (32 °F). Use air tool oil for temperatures that are below 0 °C (32 °F).

8. Install filler plug (1).
9. If necessary, adjust the lubricator in order to release two drops of oil per 30 seconds. For instructions, see this Operation and Maintenance Manual, "Air Starting Motor Lubricator Oil Level - Check" topic (Maintenance Section).

i01490193

Air Starting Motor Lubricator Oil Level - Check

SMCS Code: 1451-535

NOTICE

Never allow the lubricator bowl to become empty. The air starting motor will be damaged by a lack of lubrication. Ensure that sufficient oil is in the lubricator bowl.

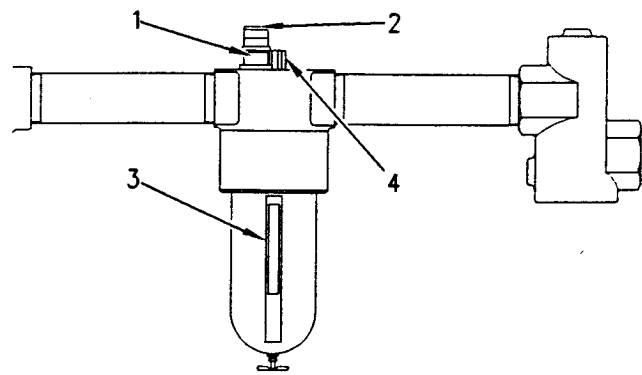


Illustration 47

g00745561

1. Observe the oil level in sight gauge (3). If the oil level is less than 1/2, add oil to the lubricator bowl.

WARNING

Personal injury can result from removing hoses or fittings in a pressure system.

Failure to relieve pressure can cause personal injury.

Do not disconnect or remove hoses or fittings until all pressure in the system has been relieved.

2. Ensure that the air supply to the lubricator is OFF. Slowly loosen filler plug (4) in order to release pressure from the lubricator bowl.
3. Remove filler plug (4). Pour oil into the lubricator bowl. Use nondetergent "10W" oil for temperatures that are greater than 0 °C (32 °F). Use air tool oil for temperatures that are below 0 °C (32 °F).
4. Install filler plug (4).

Adjust the Lubricator

Note: Adjust the lubricator with a constant rate of air flow. After the adjustment, the lubricator will release oil in proportion to variations of the air flow.

1. Ensure that the fuel supply to the engine is OFF.

NOTICE

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

2. Operate the air starting motor. Observe the drops of oil that are released in dome (1).

Note: Some lubricators have an adjustment screw rather than a knob.

3. If necessary, adjust the lubricator in order to release two drops of oil per 30 seconds. To increase the rate, turn knob (2) counterclockwise. To decrease the rate, turn the knob clockwise.

i00351324

Air Tank Moisture and Sediment - Drain

SMCS Code: 1466-543-M&S

Moisture and sediment in the air starting system can cause the following conditions:

- Freezing
- Corrosion of internal parts
- Malfunction of the air starting system

WARNING

When opening the drain valve, wear protective gloves, a protective face shield, protective clothing, and protective shoes. Pressurized air could cause debris to be blown and result in personal injury.

1. Open the drain valve that is on the bottom of the air tank. Allow the moisture and sediment to drain.
2. Close the drain valve.

i00839754

Alternator - Inspect

SMCS Code: 1405-040

Inspect the alternator for the following conditions:

- Loose connections
- Proper charging of the battery

Observe the ammeter during engine operation in order to ensure proper battery performance and/or proper performance of the electrical system.

Make repairs, if necessary. See the Service Manual for service procedures. Consult your Caterpillar dealer for assistance.

i01368836

Alternator and Fan Belts - Inspect/Adjust/Replace

SMCS Code: 1357-025; 1357-040; 1357-510; 1405

Inspection

Inspect the alternator belt and the fan drive belts for wear and for cracking. Replace the belts if the belts are not in good condition.

Check the belt tension according to the information in the Service Manual, "Specifications".

Slippage of loose belts can reduce the efficiency of the driven components. Vibration of loose belts can cause unnecessary wear on the following components:

- Belts
- Pulleys
- Bearings

If the belts are too tight, unnecessary stress is placed on the components. This reduces the service life of the components.

Replacement

For applications that require multiple drive belts, replace the drive belts in matched sets. Replacing one drive belt of a matched set will cause the new drive belt to carry more load because the older drive belts are stretched. The additional load on the new drive belt could cause the new drive belt to fail.

Alternator Belt Adjustment

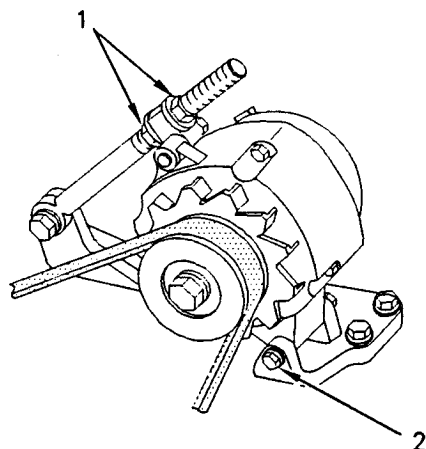


Illustration 48

g00741969

- (1) Adjusting nuts
(2) Mounting bolt

1. Remove the drive belt guard.
2. Loosen mounting bolt (2) and adjusting nuts (1).
3. Turn adjusting nuts (1) in order to increase or decrease the drive belt tension.
4. Tighten adjusting nuts (1). Tighten mounting bolt (2).
5. Reinstall the drive belt guard.

If new drive belts are installed, check the drive belt tension again after 30 minutes of engine operation at the rated rpm.

Fan Drive Belt Adjustment

1. Loosen the mounting bolt for the pulley.
2. Loosen the adjusting nut for the pulley.
3. Move the pulley in order to adjust the belt tension.
4. Tighten the adjusting nut.
5. Tighten the mounting bolt.

Batteries - Replace

SMCS Code: 1401-510

WARNING

Batteries give off combustible gases which can explode. A spark can cause the combustible gases to ignite. This can result in severe personal injury or death.

Ensure proper ventilation for batteries that are in an enclosure. Follow the proper procedures in order to help prevent electrical arcs and/or sparks near batteries. Do not smoke when batteries are serviced.

1. Turn the key start switch to the OFF position. Remove the key and all electrical loads.
2. Turn OFF the battery charger. Disconnect the charger.
3. The NEGATIVE "-" cable connects the NEGATIVE "-" battery terminal to the ground plane. Disconnect the cable from the NEGATIVE "-" battery terminal.
4. The POSITIVE "+" cable connects the POSITIVE "+" battery terminal to the starting motor. Disconnect the cable from the POSITIVE "+" battery terminal.

Note: Always recycle a battery. Never discard a battery. Return used batteries to an appropriate recycling facility.

5. Remove the used battery.
6. Install the new battery.

Note: Before connecting the cables, ensure that the key start switch is OFF.

7. Connect the cable from the starting motor to the POSITIVE "+" battery terminal.
8. Connect the cable from the ground plane to the NEGATIVE "-" battery terminal.

i01039758

Battery Charger - Check

SMCS Code: 1401-535

Checking Before Start-Up

Check the battery charger for proper operation. If the batteries are properly charged, the needle of the ammeter will register near "0" (zero).

The battery charger must not produce excessive current during start-up. Alternatively, the charger must be automatically disconnected for start-up. If the engine has an alternator, the charger must be automatically disconnected during start-up and during engine operation.

Charging the Battery

WARNING

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

Perform the following procedure to charge the battery:

1. Ensure that the charger is turned OFF.
2. Adjust the voltage of the charger in order to match the voltage of the battery.
3. Connect the POSITIVE "+" lead of the charger to the POSITIVE "+" battery terminal. Connect the NEGATIVE "-" lead of the charger to the NEGATIVE "-" battery terminal.
4. Turn ON the battery charger.

Overcharging of Batteries

Overcharging reduces the service life of batteries. Use a battery charger that will not overcharge the battery. DO NOT charge the battery if the meter of the battery charger is in the RED zone.

Overcharging is indicated by the following symptoms:

- The battery is very warm to the touch.
- A strong odor of acid is present.

- The battery emits smoke or a dense vapor (gas).

Perform one of the following procedures if the battery shows symptoms of overcharging:

- Reduce the rate of charging by a significant amount. Complete the charging at the reduced rate.
- Turn OFF the charger.

Table 42 describes the effects of overcharging on different types of batteries.

Table 42

Effects of Overcharging Batteries	
Type of Battery	Effect
Caterpillar General Service Batteries Caterpillar Premium High Output Batteries	All of the battery cells have a low level of electrolyte.
	When the plates of the battery are inspected through the filler holes, the plates may appear to be warped. This is caused by an excessive temperature.
Caterpillar Maintenance Free Batteries	The battery may not pass a load test.
	The battery may not accept a charging current.
	The battery may not pass a load test.

Checking After Stopping

Ensure that the battery charger is connected properly. Observe the meter of the charger. Record the amperage.

i01639002

Battery Electrolyte Level - Check

SMCS Code: 1401-535-FLV

When the engine is not run for long periods of time or when the engine is run for short periods, the batteries may not fully recharge. Ensure a full charge in order to help prevent the battery from freezing. If batteries are properly charged, ammeter reading should be very near zero.

! WARNING

All lead-acid batteries contain sulfuric acid which can burn the skin and clothing. Always wear a face shield and protective clothing when working on or near batteries.

1. Remove the filler caps. Maintain the electrolyte level to the "FULL" mark on the battery.

If the addition of water is necessary, use distilled water. If distilled water is not available use clean water that is low in minerals. Do not use artificially softened water.

2. Check the condition of the electrolyte with the 1U-7298 Coolant/Battery Tester (°C) or the 1U-7297 Coolant/Battery Tester (°F).

3. Keep the batteries clean.

Clean the battery case with one of the following cleaning solutions:

- A mixture of 0.1 kg (0.2 lb) of baking soda and 1 L (1 qt) of clean water
- A mixture of 0.1 L (0.11 qt) of ammonia and 1 L (1 qt) of clean water

Thoroughly rinse the battery case with clean water.

Use a fine grade of sandpaper to clean the terminals and the cable clamps. Clean the items until the surfaces are bright or shiny. DO NOT remove material excessively. Excessive removal of material can cause the clamps to not fit properly. Coat the clamps and the terminals with 5N-5561 Silicone Lubricant, petroleum jelly or MPGM grease.

i01041135

Belts - Replace

SMCS Code: 1357-510

Remove the used fan drive belt and the accessory drive belt. Install new belts.

For applications that require multiple drive belts, replace the belts in matched sets. Used belts are stretched. Replacing only one belt of a matched set will cause the new belt to carry an excessive load. The additional load on the new belt could cause the new belt to break.

Check the belt tension according to the information in the Service Manual, "Specifications" module. To adjust the belt tension, see this Operation and Maintenance Manual, "Alternator and Fan Belts - Inspect/Adjust/Replace" topic (Maintenance Section).

After new belts are installed, check the belt tension again after 30 minutes of engine operation at rated rpm.

i01005891

Carburetor Air/Fuel Ratio - Check/Adjust

SMCS Code: 1266-535; 1266

An engine failure may occur if the air/fuel ratio is not appropriate for the fuel and for the operating conditions. The service life of the turbocharger, of the valves, and of the other components may be reduced.

Ensure that the carburetor is adjusted properly so that the air/fuel ratio is correct.

For information on adjusting the carburetor, refer to the Service Manual, "Systems Operation/Testing and Adjusting", or refer to the Special Instruction, "Installation and Initial Start-Up Procedure".

i00709765

Control Panel - Inspect

SMCS Code: 4490-040; 7451-040

Inspect the condition of the panel. If a component is damaged, ensure that the component is repaired or that the component is replaced. Ensure that the electronic displays are operating properly.

Inspect the wiring for good condition. Ensure that the wiring connections are secure.

Record the Data and Review the Data

Check the gauges and indicators frequently during normal operation. Record the data in a log. Compare the new data to the data that was previously recorded. Comparing the new data to the recorded data will establish the normal gauge readings for the engine. A gauge reading that is abnormal may indicate a problem with operation or with the gauge.

i01649014

Cooling System Coolant (DEAC) - Change

SMCS Code: 1350-044

Clean the cooling system before the recommended maintenance interval if the following conditions exist:

- The engine overheats frequently.
- Foaming is observed.
- Engine oil has entered the cooling system and the coolant is contaminated.

NOTICE

Use of commercially available cooling system cleaners may cause damage to cooling system components. Use only cooling system cleaners that are approved for Caterpillar engines.

Drain the Cooling System

1. Stop the engine and allow the engine to cool. Ensure that the engine will not start when the cooling system is drained.
2. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap.

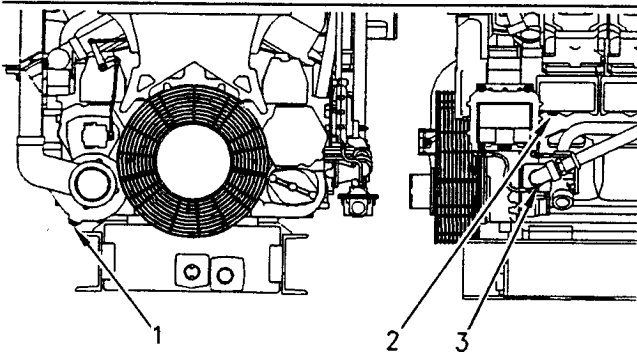


Illustration 49

g00786868

Locations of the drain plugs

- (1) Jacket water pump
- (2) Cylinder block
- (3) Auxiliary water pump

3. Open the cooling system drain valves (if equipped). If the cooling system is not equipped with drain valves, remove drain plugs (1), (2), and (3). Drain all of the cooling system components:

- Expansion tank or radiator

- Water pumps
- Aftercooler
- Thermostatic valve
- Engine block
- All coolant lines

NOTICE

Dispose of used engine coolant properly or recycle. Various methods have been proposed to reclaim used coolant for reuse in engine cooling systems. The full distillation procedure is the only method acceptable by Caterpillar to reclaim the used coolant.

For information regarding the disposal and the recycling of used coolant, consult your Caterpillar dealer or consult Caterpillar Service Technology Group:

Outside Illinois: 1-800-542-TOOL
Inside Illinois: 1-800-541-TOOL
Canada: 1-800-523-TOOL

Clean the Cooling System

1. After the cooling system has been drained, flush the cooling system with clean water in order to remove any debris.
2. Close the cooling system drain valves (if equipped). Clean the drain plugs and install the drain plugs.

NOTICE

Fill the cooling system no faster than 19 L (5 US gal) per minute to avoid air locks.

NOTICE

If the aftercooler circuit has been drained, the vent plug must be opened to allow the aftercooler to fill properly. Failure to do this will cause an air lock resulting in engine damage.

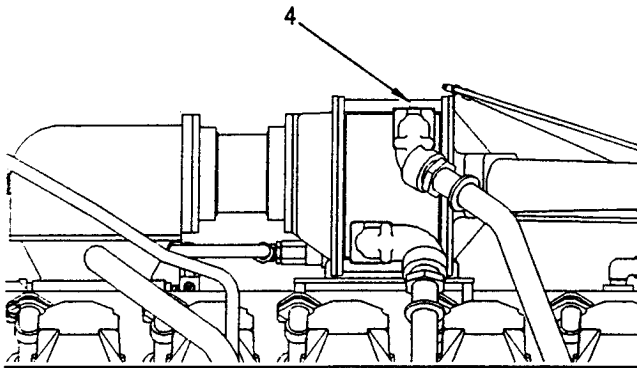


Illustration 50

g00786870

Vent plug

The vent line of the ebullient cooled engine will be installed by the customer.

If a customer has not installed the vent lines, loosen the vent cap from the tee.

3. Remove vent plug (4) for the aftercooler.
4. Fill the cooling system with a mixture of clean water and Caterpillar Fast Acting Cooling System Cleaner. Add .5 L (1 pint) of cleaner per 15 L (4 US gal) of the cooling system capacity. Install the cooling system filler cap. Install vent plug (4).
5. Start the engine. Operate the engine for a minimum of 30 minutes with a coolant temperature of at least 82 °C (180 °F).
6. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap. Open the cooling system drain valves (if equipped) or remove drain plugs (1), (2), and (3). See Illustration 49.

NOTICE

Improper or incomplete rinsing of the cooling system can result in damage to copper and other metal components.

To avoid damage to the cooling system, make sure to completely flush the cooling system with clear water. Continue to flush the system until all signs of the cleaning agent are gone.

Note: The cleaner has a smell of ammonia. Continue to flush the cooling system until the smell is gone.

7. Allow the water to drain. Flush the cooling system with clean water until the water that drains is clean. Close the cooling system drain valves (if equipped). Clean the drain plugs and install the drain plugs.

Cleaning a Cooling System that has Heavy Deposits or Plugging

Note: For the following procedure to be effective, there must be an active flow through the cooling system components.

1. After the cooling system has been drained, flush the cooling system with clean water in order to remove any debris.
2. Close the cooling system drain valves (if equipped). Clean drain plugs and install drain plugs (1), (2), and (3). See Illustration 49.

NOTICE

Fill the cooling system no faster than 19 L (5 US gal) per minute to avoid air locks.

NOTICE

If the aftercooler circuit has been drained, the vent plug must be opened to allow the aftercooler to fill properly. Failure to do this will cause an air lock resulting in engine damage.

3. Remove vent plug (4) for the aftercooler. See Illustration 50.
4. Fill the cooling system with a mixture of clean water and Caterpillar Fast Acting Cooling System Cleaner. Add .5 L (1 pint) of cleaner per 7.5 L (2 US gal) of the cooling system capacity. Install the cooling system filler cap. Install vent plug (4).
5. Start the engine. Operate the engine for a minimum of 90 minutes with a coolant temperature of at least 82 °C (180 °F).
6. Stop the engine and allow the engine to cool. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap. Open the cooling system drain valves (if equipped) or remove drain plugs (1), (2), and (3). See Illustration 49. Allow the water to drain.

NOTICE

Improper or incomplete rinsing of the cooling system can result in damage to copper and other metal components.

To avoid damage to the cooling system, make sure to completely flush the cooling system with clear water. Continue to flush the system until all signs of the cleaning agent are gone.

Note: The cleaner has a smell of ammonia. Continue to flush the cooling system until the smell is gone.

7. Flush the cooling system with clean water until the water that drains is clean. Close the cooling system drain valves (if equipped). Clean the drain plugs and install the drain plugs.

Fill the Cooling System

NOTICE

Fill the cooling system no faster than 19 L (5 US gal) per minute to avoid air locks.

Note: For information about the proper coolant to use, see this Operation and Maintenance Manual, "Coolant Recommendations" (Maintenance Section). For the capacity of the cooling system, see this Operation and Maintenance Manual, "Refill Capacities" (Maintenance Section).

1. Remove vent plug (4) for the aftercooler. See Illustration 50.
2. Fill the cooling system with coolant/antifreeze. Install vent plug (4). Do not install the cooling system filler cap.
3. Start the engine. Operate the engine in order to purge the air from the cavities of the engine block. Allow the coolant to warm and allow the coolant level to stabilize. Stop the engine.
4. Check the coolant level. Maintain the coolant to the proper level on the sight gauge (if equipped). If a sight gauge is not equipped, maintain the coolant within 13 mm (.5 inch) below the bottom of the filler pipe.
5. Clean the cooling system filler cap. Inspect the gaskets of the cooling system filler cap. If the gaskets of the cooling system filler cap are damaged, discard the old cooling system filler cap and install a new cooling system filler cap. If the gaskets of the cooling system filler cap are not damaged, use a 9S-8140 Pressurizing Pump in order to pressure test the cooling system filler cap. The correct pressure is stamped on the face of the cooling system filler cap. If the cooling system filler cap does not maintain the correct pressure, install a new cooling system filler cap.
6. Start the engine. Inspect the cooling system for leaks and for proper operating temperature.

i01065859

Cooling System Coolant Analysis (Level II) - Obtain

SMCS Code: 1350

For conventional heavy-duty coolant/antifreeze, check the concentration of supplemental coolant additive (SCA) regularly. The concentration of SCA can be checked with an S-O-S coolant analysis (Level I). A more detailed coolant analysis is recommended periodically.

For example, considerable deposits are found in the water jacket areas on the external cooling system, but the concentrations of coolant additives were carefully maintained. The coolant water probably contained minerals which were deposited on the engine over time.

A coolant analysis can be conducted in order to verify the condition of the water that is being used in the cooling system. A full water analysis may be obtained from the following sources:

- Caterpillar dealer
- Local water utility company
- Agricultural agent
- Independent laboratory

Caterpillar recommends an S-O-S coolant analysis (Level II). This is a comprehensive chemical evaluation of the coolant. This analysis is also a check of the overall condition of the inside of the cooling system. The following services are provided:

- Full Level I analysis
- Identification of the source of metal corrosion and of contaminants
- Identification of buildup of the impurities that cause corrosion
- Identification of buildup of the impurities that cause scaling
- Determination of possible electrolysis within the engines' cooling system

A report of the results of the analysis is provided. Maintenance recommendations are based on the results.

For more information about S-O-S coolant analysis, consult your Caterpillar dealer.

i01664672

Cooling System Coolant Level - Check

SMCS Code: 1350-535-FLV

WARNING

Climbing equipment may be required to access this service point. Refer to the Operation and Maintenance Manual, "Mounting and Dismounting" topic for safety information.

NOTICE

Overfilling the overflow tank (if equipped) will result in damage to the cooling system.

If the cooling system has an overflow tank, maintain the coolant level in the tank below 1/2 full in order to avoid damage to the cooling system.

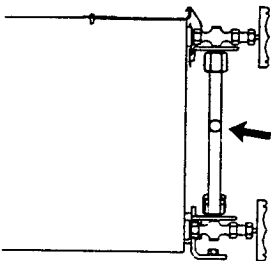


Illustration 51
Normal position of the coolant in the sight gauge during rated operation

Observe the coolant level in the sight gauge (if equipped). When the engine is running at normal operating temperature, the coolant should be in the upper half of the sight gauge. If the coolant level is low, add the proper coolant mixture.

Add Coolant

Note: For the proper coolant mixture to use, see this Operation and Maintenance Manual, "Coolant Recommendations" topic (Maintenance Section).

1. Stop the engine. Allow the engine to cool.
2. Remove the cooling system filler cap slowly in order to relieve any pressure. Pour the proper coolant mixture into the filler pipe.

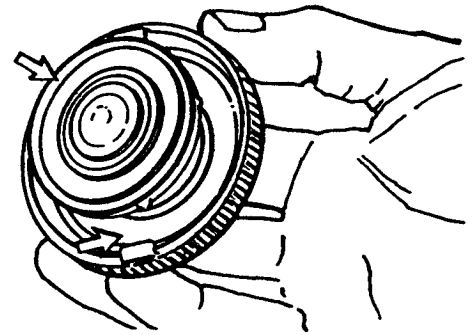


Illustration 52
Filler cap gaskets

g00103639

3. Clean the cooling system filler cap. Inspect the gaskets of the cooling system filler cap. If the gaskets are damaged, replace the old cooling system filler cap with a new cooling system filler cap. Install the cooling system filler cap.
4. Start the engine. Inspect the cooling system for leaks.

i01613281

Cooling System Supplemental Coolant Additive (SCA) - Test/Add

SMCS Code: 1352-045; 1395-081

This maintenance procedure is required for conventional coolants such as DEAC and for mixtures of water and SCA.

WARNING

Cooling system coolant additive contains alkali. To help prevent personal injury, avoid contact with the skin and eyes. Do not drink cooling system coolant additive.

Note: Test the concentration of the SCA or obtain an S-O-S coolant analysis (Level I).

Test the Concentration of the SCA

Coolant/Antifreeze and SCA

NOTICE

Do not exceed the recommended six percent supplemental coolant additive concentration.

Test the concentration of the SCA with the 8T-5296 Coolant Conditioner Test Kit or the 4C-9301 Coolant Conditioner Test Kit. Follow the instructions that are on the label of the test kit.

Water and SCA

NOTICE

Do not exceed the recommended eight percent supplemental coolant additive concentration.

Test the concentration of the SCA with the 8T-5296 Coolant Conditioner Test Kit. Follow the instructions that are in this Operation and Maintenance Manual, "Water/Supplemental Coolant Additive (SCA)" topic (Maintenance Section).

S-O-S Coolant Analysis (Level I)

Level I is a basic analysis of the coolant. The following items are tested: SCA concentration, glycol concentration, pH, and conductivity.

The results are reported, and recommendations are made according to the results. Consult your Caterpillar dealer for information on the benefits of managing your equipment with an S-O-S analysis.

Add the SCA, If Necessary

WARNING

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Remove the cooling system filler cap slowly.

Note: Always dispose of fluids according to local regulations.

2. If necessary, drain some coolant in order to allow space for the addition of the SCA.

NOTICE

Excessive supplemental coolant additive concentration can form deposits on the higher temperature surfaces of the cooling system, reducing the engine's heat transfer characteristics. Reduced heat transfer could cause cracking of the cylinder head and other high temperature components.

Excessive supplemental coolant additive concentration could also result in blockage of the heat exchanger, overheating, and/or accelerated wear of the water pump seal.

Do not exceed the recommended amount of supplemental coolant additive concentration.

3. Add the proper amount of SCA. The concentration of the SCA depends on the type of coolant that is used.
 - a. For cooling systems that use conventional coolant/antifreeze, refer to this Operation and Maintenance Manual, "Conventional Coolant/Antifreeze Cooling System Maintenance" topic (Maintenance Section).
 - b. For cooling systems that use only a mixture of water and SCA, refer to this Operation and Maintenance Manual, "Water/Supplemental Coolant Additive (SCA)" topic (Maintenance Section).
4. Clean the cooling system filler cap. Install the cooling system filler cap.

i00766712

Crankcase Blowby - Measure/Record

SMCS Code: 1317

Note: For a G3500 Engine that is rated at 1500 rpm with 1500 service hours, the crankcase blowby typically has a range of 259 to 283 L/min (550 to 600 ft³/hr).

Measure the crankcase blowby of new engines. Record the data. Continue to periodically measure the blowby. Comparing the recorded data to the new data provides information about the condition of the engine.

Note: Crankcase blowby is one of the three factors that help to determine the in-frame overhaul interval. For more information, see this Operation and Maintenance manual, "Overhaul (In-Frame)" topic (Maintenance Section).

After a new engine is used for a short time, the blowby can decrease as the piston rings are seated. The blowby will gradually increase as the following components show wear:

- piston rings
- cylinder liners

Note: A problem with the piston rings causes the oil to deteriorate rapidly. Information regarding the condition of the piston rings can be obtained from the measurement of the blowby and the results of oil analysis.

The blowby of a worn engine may exceed the blowby of a new engine by two times or more.

A sudden increase in blowby could indicate a broken piston ring. The following conditions are other potential sources of blowby:

- Worn valve guides
- A turbocharger seal that leaks

A rebuilt engine can have a high blowby due to the following factors:

- The piston rings are not seated properly.
- Worn parts such as valve guides were not replaced.

Excessive blowby may indicate the need for an overhaul. By keeping a record of the results, a gradual increase in the amount of the blowby will be noted until the amount has become excessive.

To measure the blowby, use the 8T-2700 Blowby/Air Flow Indicator. Refer to Special Instruction, SEHS8712, "Using the 8T-2700 Blowby/Airflow Indicator Group". The instruction is provided with the tool.

Keep a record of the results.

For more information, see the Service Manual, "Systems Operation/Testing and Adjusting". For assistance, consult your Caterpillar dealer.

i01664687

Crankshaft Vibration Damper - Inspect

SMCS Code: 1205-040

The crankshaft vibration damper limits the torsional vibration of the crankshaft. The visconic damper has a weight that is located inside a fluid filled case.

Damage to the crankshaft vibration damper or failure of the damper can increase torsional vibrations. This can result in damage to the crankshaft and to other engine components. A deteriorating damper can cause excessive gear train noise at variable points in the speed range.

A damper that is hot is due to excessive torsional vibration. Monitor the temperature of the damper during operation.

The 8T-2821 Temperature Indicator or the 8T-2822 Temperature Indicator are recommended for monitoring the temperature of the damper. Evenly space four of the adhesive indicators around the outer diameter of the damper.

Note: If you use an infrared thermometer to monitor the temperature of the damper, use the thermometer during operation with similar loads and speeds. Keep a record of the data. If the temperature begins to rise, reduce the interval for inspecting the damper.

If the temperature of the damper reaches 110 °C (230 °F), consult your Caterpillar dealer.

Inspect the damper for evidence of dents, cracks, and leaks of the fluid.

If a fluid leak is found, determine the type of fluid. The fluid in the damper is silicone. Silicone has the following characteristics: transparent, viscous, smooth, and sticky. If leaking silicone is found, repair the damper or replace the damper.

If the fluid leak is oil, inspect the crankshaft seal for leaks. If a leak is observed, replace the seal.

Inspect the damper and repair or replace the damper for any of the following reasons.

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

Removal and Installation

Refer to the Service Manual, "Disassembly and Assembly" or consult your Caterpillar dealer for information about damper replacement.

i01664707

Cylinder Pressure - Measure/Record

SMCS Code: 1223-082-CC; 1223; 7450-082

Measure the cylinder pressure of new engines. Record the data. Continue to periodically measure the cylinder pressure. Comparing the recorded data to the new data provides information about the condition of the engine.

Cylinder pressure can be measured during inspection of the spark plugs. Use the following guidelines for checking the cylinder pressure:

- Remove all of the spark plugs.
- Fully open the throttle plate.
- Minimize the cranking time to 3 or 4 revolutions. This will enable a maximum consistent cranking speed for the check. Also, the battery power will be conserved.

A loss of cylinder pressure or a change of pressure in one or more cylinders may indicate the following conditions. These conditions may indicate a problem with lubrication:

- Excessive deposits
- Guttering of valves
- A broken valve
- A piston ring that sticks
- A broken piston ring
- Worn piston rings
- Worn cylinder liners

If the cylinder pressure has risen by one or more compression ratios, the engine needs a top end overhaul in order to remove deposits. Failure to remove the deposits will increase the chance for detonation. Severe guttering of the valves will occur.

To measure the cylinder pressure, use the 193-5859 Cylinder Pressure Gauge Gp. Follow the procedure in the Special Instruction, NEHS0798 that is included with the gauge group. Record the pressure for each cylinder. Use the Operation and Maintenance Manual, "Valve Data Sheet" (Reference Materials Section).

Illustration 53 is a graph of typical cylinder pressures for engines with different compression ratios.

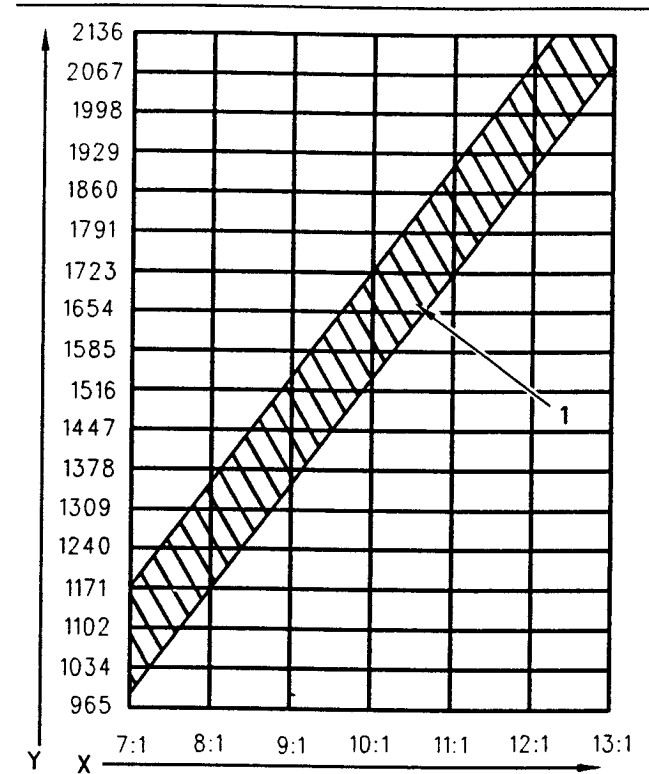


Illustration 53

g00828960

(Y) Cylinder pressure in kPa
(X) Compression ratio
(1) Normal range for cylinder pressure

i00767502

Cylinders - Inspect

SMCS Code: 1223-040; 1223

Use a borescope to inspect the cylinders. The inspection will provide information about the internal condition of the engine.

A borescope with a lens that can be rotated is recommended. This type of borescope provides a clear view of the combustion chamber and of the bottom deck of the cylinder head. Photographic documentation or video documentation is also recommended. Consult your Caterpillar dealer for information on available borescopes.

To perform this procedure, insert the borescope through the openings for the spark plugs. Use the borescope to look for the following conditions:

- Valve wear
- Deposits on the valve seat
- Deposits on the valve face

- Polishing of the cylinder walls
- Scratching of the cylinder walls
- Deposits on the cylinder walls that are above the upper limit of the piston stroke

i00449093

Driven Equipment - Check

SMCS Code: 3279-535

To minimize bearing problems and vibration of the engine crankshaft and the driven equipment, the alignment between the engine and driven equipment must be maintained properly.

Check the alignment according to the instructions that are provided by the following manufacturers:

- Caterpillar
- OEM of the coupling
- OEM of the driven equipment

i00935098

Driven Equipment - Inspect/Replace/Lubricate

SMCS Code: 3279-040

Observe the driven equipment during operation. Look for the following items:

- Unusual noise and vibration
- Loose connections
- Damaged parts

Perform any maintenance that is recommended by the OEM of the driven equipment. Refer to the literature of the OEM of the driven equipment for the following service instructions.

- Inspection
- Lubricating grease and lubricating oil requirements
- Specifications for adjustment
- Replacement of components
- Requirements for ventilation

i01664717

Engine - Clean

SMCS Code: 1000-070

WARNING

Personal injury or death can result from high voltage.

Moisture could create paths of electrical conductivity.

Make sure the unit is off line (disconnected from utility and/or other generators), locked out and tagged "Do Not Operate".

NOTICE

Water or condensation can cause damage to generator components. Protect all electrical components from exposure to water.

NOTICE

Accumulated grease and oil on an engine is a fire hazard. Keep the engine clean. Remove debris and fluid spills whenever a significant quantity accumulates on the engine.

Steam cleaning the engine will remove accumulated oil and grease. A clean engine provides the following benefits:

- Easy detection of fluid leaks
- Maximum heat transfer characteristics
- Ease of maintenance

Note: For more information on cleaning and drying electric generators, refer to Special Instruction, SEHS9124, "Cleaning and Drying of Electric Set Generators".

i01600805

Engine Air Cleaner Element - Replace

SMCS Code: 1051-510; 1054-510

NOTICE

Never run the engine without an air cleaner element installed. Never run the engine with a damaged air cleaner element. Do not use air cleaner elements with damaged pleats, gaskets or seals. Dirt entering the engine causes premature wear and damage to engine components. Air cleaner elements help to prevent air-borne debris from entering the air inlet.

NOTICE

Never service the air cleaner element with the engine running since this will allow dirt to enter the engine.

Servicing the Air Cleaner Elements

If the air cleaner element becomes plugged, the air pressure can split the filter material of the element. Unfiltered air will drastically accelerate internal engine wear. Your Caterpillar dealer has the proper air cleaner elements for your application.

- Check the precleaner (if equipped) daily for accumulation of dirt and debris. Remove any dirt and debris, as needed.
- Operating conditions (dust, dirt and debris) may require more frequent service of the air cleaner element.
- The air cleaner element may be cleaned up to six times if the element is properly cleaned and inspected.
- The air cleaner element should be replaced at least one time per year. This replacement should be performed regardless of the number of cleanings.

Replace the dirty paper elements with clean elements. Before installation, thoroughly inspect the element for tears and/or holes in the filter material. Inspect the gasket or the seal of the element for damage. Maintain a supply of suitable elements for replacement purposes.

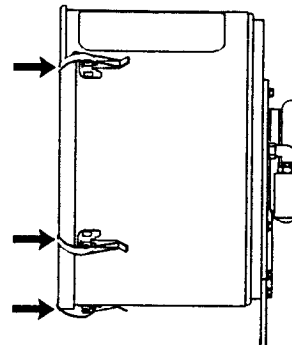


Illustration 54

g00317608

Fasteners for the air cleaner cover

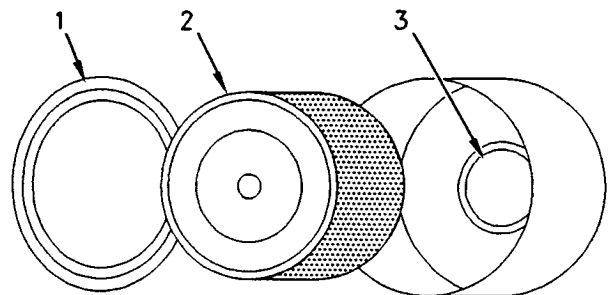


Illustration 55

g00781084

- (1) Cover
- (2) Element
- (3) Air inlet

1. Release the fasteners for cover (1).
2. Remove the cover and element (2).
3. Cover air inlet (3) with tape in order to keep dirt out.
4. Clean the inside of the cover and the body with a clean, dry cloth.
5. Remove the tape for the air inlet. Install a new element or a clean element.
6. Install the cover.
7. If necessary, reset the air cleaner service indicator.

Cleaning the Primary Air Cleaner Elements

The primary air cleaner element can be used up to six times if the element is properly cleaned and inspected. When the element is cleaned, check the filter material for rips or tears. Replace the element at least one time per year regardless of the number of cleanings.

Use clean elements while dirty elements are being cleaned.

NOTICE

Do not clean the air cleaner elements by bumping or tapping. This could damage the seals. Do not use elements with damaged pleats, gaskets or seals. Damaged elements will allow dirt to pass through. Engine damage could result.

Visually inspect the elements before cleaning. Inspect the elements for damage to the seal, the gaskets, and the outer cover. Discard any damaged elements.

Air cleaner elements can be cleaned with pressurized air and with a vacuum.

Pressurized Air

Pressurized air can be used to clean elements that have not been cleaned more than two times. Pressurized air will not remove deposits of carbon and oil. Use filtered, dry air with a maximum pressure of 207 kPa (30 psi).

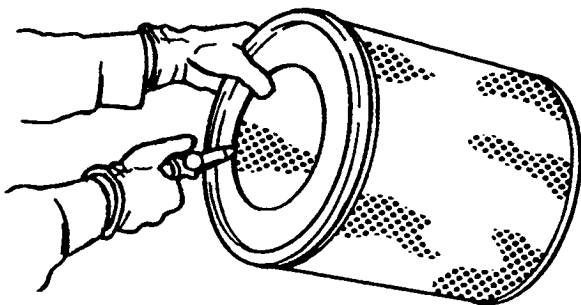


Illustration 56

g00281692

Note: When the elements are cleaned, always begin with the clean side (inside) in order to force dirt particles toward the dirty side (outside).

Aim the hose so that the air flows inside the element along the length of the filter in order to help prevent damage to the paper pleats. Do not aim the stream of air directly at the primary air cleaner element. Dirt could be forced into the pleats.

Note: Refer to "Inspecting the Primary Air Cleaner Elements".

Vacuum Cleaning

Vacuum cleaning is a good method for cleaning elements which require daily cleaning because of a dry, dusty environment. Cleaning with pressurized air is recommended prior to vacuum cleaning. Vacuum cleaning will not remove deposits of carbon and oil.

Note: Refer to "Inspecting the Primary Air Cleaner Elements".

Inspecting the Primary Air Cleaner Elements

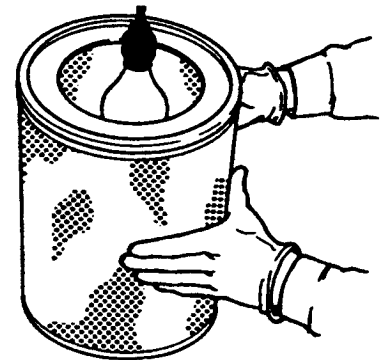


Illustration 57

g00281693

Inspect the clean, dry element. Use a 60 watt blue light in a dark room or in a similar facility. Place the blue light in the element. Rotate the element. Inspect the element for tears and/or holes. Inspect the element for light that may show through the filter material. If it is necessary in order to confirm the result, compare the element to a new element that has the same part number.

Do not use an element that has any tears and/or holes in the filter material. Do not use an element with damaged pleats, gaskets or seals. Discard damaged elements.

Storing Primary Air Cleaner Elements

If an element that passes inspection will not be used immediately, store the element for future use.

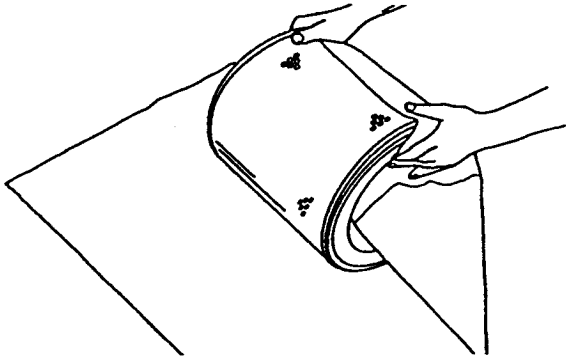


Illustration 58

g00281694

Do not use paint, a waterproof cover, or plastic as a protective covering for storage. Restricted air flow may result. To protect against dirt and damage, wrap the elements in Volatile Corrosion Inhibited (VCI) paper.

Place the element into a cardboard box for storage. For identification, mark the outside of the container and mark the element. Include the following information:

- Date of cleaning
- Number of cleanings

Store the container in a dry location.

For more detailed information on cleaning the primary air cleaner element, refer to Special Publication, SEBF8062, "Procedure to Inspect and Clean Air Filters".

i01665086

Engine Air Cleaner Service Indicator - Inspect

SMCS Code: 7452-040

A service indicator may be mounted on the air cleaner element or in a remote location.

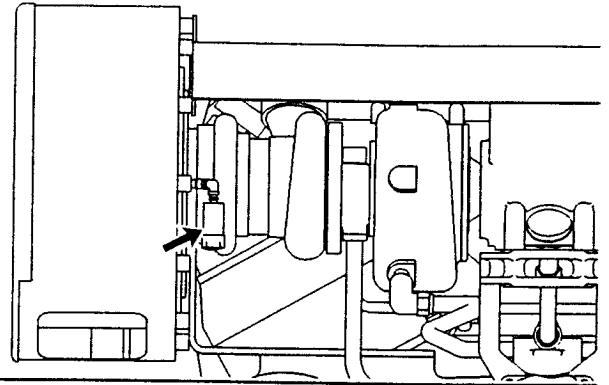


Illustration 59

g00760342

Service indicator

Some engines may be equipped with a different service indicator.

Observe the service indicator. Clean the air cleaner element or replace the element when any of the following conditions occur:

- The yellow diaphragm enters the red zone.
- The red piston locks in the visible position.
- The air restriction reaches 3.75 kPa (15 inch of H₂O).

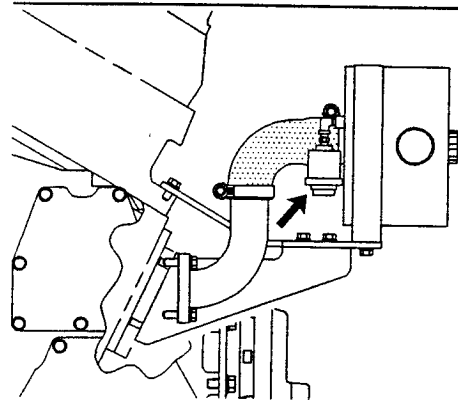


Illustration 60

g00760341

Service indicator on an air cleaner for crankcase ventilation

Some engines are equipped with an air cleaner for crankcase ventilation. The air cleaner is mounted on a camshaft cover. Clean the air cleaner element or replace the element when any of the following conditions occur:

- The yellow diaphragm enters the red zone.
- The red piston locks in the visible position.
- The air restriction reaches 0.25 kPa (1 inch of H₂O).
- The air cleaner is saturated with oil.

Inspect the service indicator daily for cracks, holes, or loose fittings. If any of these conditions are present, replace the service indicator.

Test the Service Indicator

Service indicators are important instruments.

- Apply vacuum (suction) to the service indicator.
- Reset the service indicator.

If the yellow core does not latch at the greatest vacuum, or if service indicator does not reset easily, obtain a new service indicator. If the new service indicator will not reset, the fitting for the service indicator may be plugged.

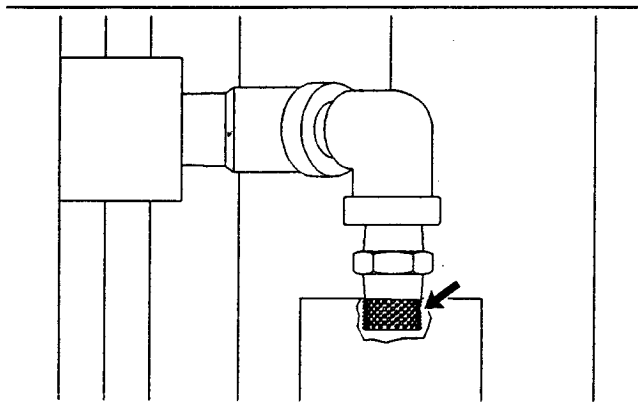


Illustration 61

g00351792

Porous filter

A porous filter is part of the fitting that is used for mounting of the service indicator. Inspect the filter for cleanliness. Clean the filter, if necessary. Use compressed air or a clean, nonflammable solvent.

Note: When service indicator is installed, excessive tightening may crack the top of the service indicator. Tighten the service indicator to a torque of 2 N·m (18 lb in).

Replace the service indicator annually regardless of the operating conditions.

Engine Air Precleaner - Clean

SMCS Code: 1055-070

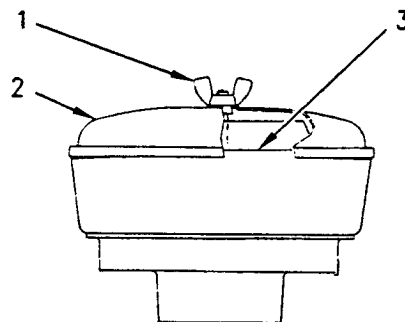


Illustration 62

g00736588

Typical precleaner

- (1) Wing nut
- (2) Cover
- (3) Body

Remove wing nut (1) and cover (2). Check for an accumulation of dirt and debris in body (3). Clean the body, if necessary.

After cleaning the precleaner, install cover (2) and wing nut (1).

Note: When the engine is operated in dusty applications, more frequent cleaning is required.

i01225429

Engine Crankcase Breather - Clean

SMCS Code: 1317-070

If the crankcase breather is not maintained on a regular basis, the crankcase breather will become plugged. A plugged crankcase breather will cause excessive crankcase pressure that may cause crankshaft seal leakage.

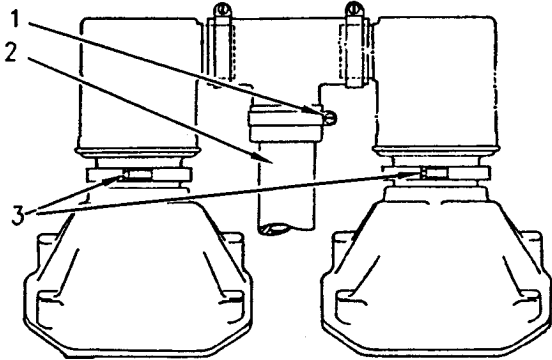


Illustration 63

g00597463

1. Loosen clamp (1). Slide the clamp down on tube (2).
2. Loosen clamps (3). Remove both breathers as a unit.

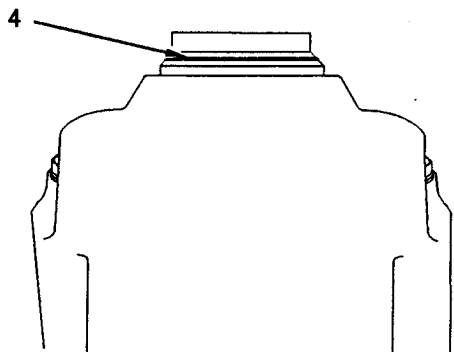


Illustration 64

g00597465

3. Remove O-ring seals (4) from the valve covers. Inspect the O-ring seals for good condition. Obtain new O-ring seals, if necessary.

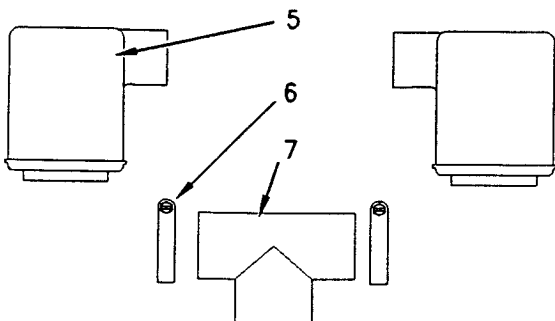


Illustration 65

g00597466

4. Remove two clamps (6). Remove both breathers (5) from hose tee (7).

Inspect the hose tee for cracks. If the tee is cracked, discard the old tee and obtain a new tee for installation.

5. Turn the breathers upside-down in order to inspect the condition of the breather elements.

Clean the breather elements with clean, nonflammable solvent. If the breather elements remain contaminated after the cleaning, discard the breathers and obtain new breathers. Do not attempt to disassemble the breathers.

Allow the breather elements to dry before installation.

Note: Coat the rubber parts with clean engine oil or petroleum jelly in order to make installation easier.

6. Place clamps (6) over the parts of hose tee (7) that will receive breathers (5). Install the breathers into the tee. Tighten the clamps to the torque that is listed in the Service Manual, "Specifications".
7. Coat O-ring seals (4) with clean engine oil. Place the O-ring seals on the valve covers.
8. Place clamps (3) around the parts of the breathers that will be attached to the valve covers. Install both breathers as a unit. Tighten the clamps.
9. Place clamp (1) on the part of the hose tee that will receive tube (2). Install the tube into the hose tee. Tighten the clamp to the torque that is listed in the Service Manual, "Specifications".

i01397742

Engine Mounts - Check

SMCS Code: 1152-535

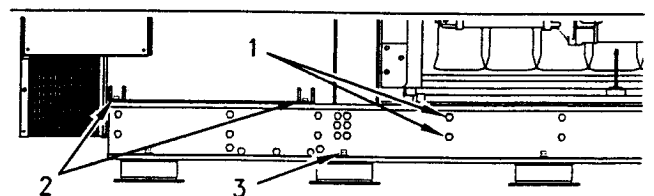


Illustration 66

g00736591

- (1) Mounting bolts for the engine
- (2) Mounting bolts for the generator
- (3) Levelling bolts for the isolators

Misalignment of the engine and the driven equipment will cause extensive damage. Excessive vibration can lead to misalignment. Excessive vibration of the engine and the driven equipment can be caused by the following conditions:

- Improper mounting
- Loose bolts
- Deterioration of the isolators

Ensure that the mounting bolts are tightened to the proper torque. For standard torques, see the Operation and Maintenance Manual, "Torque Specifications" in the Maintenance Section.

Ensure that the isolators are free of oil and contamination. Inspect the isolators for deterioration. Ensure that the bolts for the isolators are tightened to the proper torque.

Replace any isolator that shows deterioration. For more information, see the literature that is provided by the OEM of the isolators. Also see the Application and Installation Guide for the engine. Consult your Caterpillar dealer for assistance.

i01665105

Engine Oil - Change

SMCS Code: 1348-044; 1348

WARNING

Hot oil and components can cause personal injury.

Do not allow hot oil or components to contact skin.

NOTICE

Ensure that the engine is stopped before performing this procedure. Attach a DO NOT OPERATE tag to the starting controls.

Do not drain the oil when the engine is cold. As the oil cools, suspended waste particles settle on the bottom of the oil pan. The waste particles are not removed when the cold oil is drained. Drain the crankcase with the oil warm, immediately after the engine is stopped. This draining method allows the waste particles that are suspended in the oil to be drained properly.

Failure to follow this recommended procedure will allow the waste particles to be recirculated through the engine lubrication system with the new oil.

1. After the engine has been operated at normal operating temperature, STOP the engine.

Note: Drain the oil into a suitable container. Dispose of fluids according to local regulations.

2. Drain the oil by using one of the following methods. Use the method that corresponds to the equipment on the engine.

Note: If a suction device is used in order to remove the oil from the oil pan, ensure that the suction device is clean. This will prevent dirt from entering into the oil pan. Be careful not to strike the engine oil suction tubes or the piston cooling jets.

Note: Ensure that the dirty oil is thoroughly drained from the pan. Dirty oil will contaminate the new oil. The life of the new oil will be shortened.

- a. If the engine has an oil drain valve, open the valve in order to drain the oil. After the oil has drained, close the valve.
 - b. If the engine has a pump for removing dirty oil, connect a hose to the outlet of the pump. Place the hose in a suitable container. Open the valve for the drain line. Operate the pump until the crankcase is empty. Close the valve to the drain line. Disconnect the hose.
 - c. If the oil drain valve has a "quick connect" coupling, attach the coupling. Open the drain valve in order to drain the crankcase. After the oil has drained, close the drain valve. Disconnect the coupling.
 - d. If the engine does not have a drain valve or a pump, remove an oil drain plug. Allow the oil to drain. After the oil has drained, clean the drain plug and clean the fitting for the drain plug. Install the drain plug. Tighten the drain plug to 145 ± 15 N·m (105 ± 10 lb ft).
3. Replace the engine oil filter elements before filling the crankcase with new oil.
 - a. For the procedure to change the engine oil filters, refer to the Operation and Maintenance Manual, "Engine Oil Filter - Change" topic (Maintenance Section).

NOTICE

Only use oils that are recommended by Caterpillar. For the proper oil to use, refer to this Operation and Maintenance Manual, "Engine Oil" topic (Maintenance Section).

NOTICE

Engine damage can occur if the crankcase is filled above the "FULL" mark on the oil level gauge (dipstick).

An overfull crankcase can cause the crankshaft to dip into the oil. This will reduce the power that is developed and also force air bubbles into the oil. These bubbles (foam) can cause the following problems: reduction of the oil's ability to lubricate, reduction of oil pressure, inadequate cooling, oil blowing out of the crankcase breathers, and excessive oil consumption.

Excessive oil consumption will cause deposits to form on the pistons and in the combustion chamber. Deposits in the combustion chamber lead to the following problems: guttering of the valves, packing of carbon under the piston rings, and wear of the cylinder liner.

If the oil level is above the "FULL" mark on the oil level gauge, drain some of the oil immediately.

Note: For the amount of oil to use, refer to the Operation and Maintenance Manual, "Refill Capacities" (Maintenance Section).

4. Remove the oil filler cap. Fill the crankcase through the oil filler tube only. Clean the oil filler cap. Install the oil filler cap.

NOTICE

To prevent crankshaft damage or bearing damage, crank the engine with the fuel supply line closed. This will ensure that all of the oil filters are filled with oil before the engine is started. Do not crank the engine for more than 30 seconds. Allow the starting motor to cool for two minutes before cranking again.

5. Close the fuel supply line. Crank the engine until the oil pressure gauge indicates 70 kPa (10 psi). Open the fuel supply line. Allow the starting motor to cool for two minutes before cranking again.
6. Follow this Operation and Maintenance Manual, "Starting The Engine" procedure (Operation Section). Operate the engine at low idle for two minutes. This will ensure that the lubrication system and the oil filters are filled with oil. Inspect the engine for oil leaks. Ensure that the oil level is between the "ADD" and the "FULL" marks on the "LOW IDLE" side of the oil level gauge.
7. Stop the engine and allow the oil to drain back into the sump for a minimum of ten minutes.

8. Remove the oil level gauge and check the oil level. Maintain the oil level between the "ADD" and the "FULL" marks on the "ENGINE STOPPED" side of the oil level gauge.

i01665179

Engine Oil Filter (Auxiliary) - Change

SMCS Code: 1318

Note: An auxiliary oil filter system enables the oil capacity of the engine to be increased. Use of the auxiliary oil filter elements is not recommended.

Perform this procedure after the oil has been drained from the auxiliary oil filter housing.

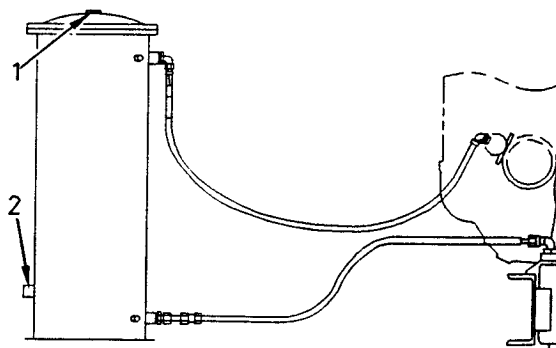


Illustration 67

g00787079

Auxiliary oil filter housing

- (1) Vent plug
- (2) Drain plug

1. If the engine is equipped with an auxiliary oil filter system, remove vent plug (1). Remove drain plug (2). Allow the oil to drain. After the oil has drained, clean the drain plug.

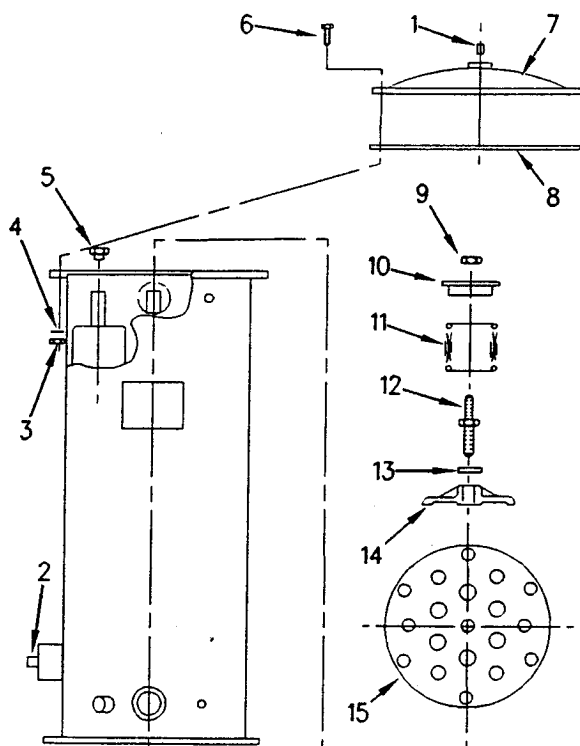


Illustration 68

g00787105

- (1) Vent plug
- (2) Drain plug
- (3) Nut
- (4) Washer
- (5) Plug
- (6) Bolt
- (7) Cover
- (8) Cover gasket
- (9) Nut
- (10) Spring retainer
- (11) Spring
- (12) Bolt
- (13) Washer
- (14) Spider
- (15) Plate

1. Remove 12 nuts (3), washers (4), and bolts (6).
2. Remove cover (7) and gasket (8). Do not damage the gasket.

WARNING

Possible injury can occur during the removal of the nut, the spring retainer, and the spring. Spring force will be released when the nut and the spring retainer are removed. Be prepared to hold the spring retainer as the nut is loosened.

3. Remove nut (9), spring retainer (10), and spring (11). Hold spring retainer (10) as nut (9) is loosened.

4. Remove bolt (12). Remove washer (13) and spider (14). Remove plate (15).

5. Remove the oil filter elements if the oil filters have been installed. Clean the inside of the oil filter housing.

Inspect the oil filter elements if the oil filters have been installed. For instructions on inspecting the oil filter elements, refer to the Operation and Maintenance Manual, "Engine Oil Filter - Change" topic (Maintenance Section).

6. Ensure that plug (5) is tight.

7. Install drain plug (2). Tighten the drain plug to 70 ± 14 N·m (50 ± 10 lb ft).

Note: Use of the auxiliary oil filter elements is not required.

8. If the use of auxiliary oil filter elements is desired, install new elements.

9. Install plate (15), spider (14), washer (13), and bolt (12).

10. Install spring (11) on spider (14). Install spring retainer (10) and nut (9) on bolt (12).

11. Tighten nut (9) in order to compress spring (11) until the spring retainer bottoms out on bolt (12). Do not overtighten the nut.

12. Fill the oil filter housing with oil. For the correct amount of oil, refer to the Operation and Maintenance Manual, "Refill Capacities" topic (Maintenance Section).

13. Inspect cover gasket (8) for tears, breaks, or other damage. If the cover gasket is damaged, replace the old cover gasket with a new cover gasket. Install cover gasket (8). Install cover (7).

14. Install twelve bolts (6), washers (4), and nuts (3). Tighten nuts sequentially around the cover until the nuts are snug. Tighten the nuts to 100 ± 15 N·m (75 ± 11 lb ft).

15. Install vent plug (1).

i01641978

Engine Oil Filter - Change

SMCS Code: 1308-510; 1308

Replace the engine oil filters when any of the following conditions are met:

- Every oil change

- The engine oil filter differential pressure reaches 100 kPa (15 psi).
- The engine oil filters have been used for 1500 operating hours.

Service tools are available to aid in the service of oil filters. Consult your Caterpillar dealer for the part names and the part numbers. Follow the instructions that are supplied with the service tools. If the service tools are not used, perform the following appropriate procedure.

Replacing the Engine Oil Filters With the Engine Stopped

WARNING

Hot oil and components can cause personal injury.

Do not allow hot oil or components to contact skin.

Perform the following procedure after the oil has been drained.

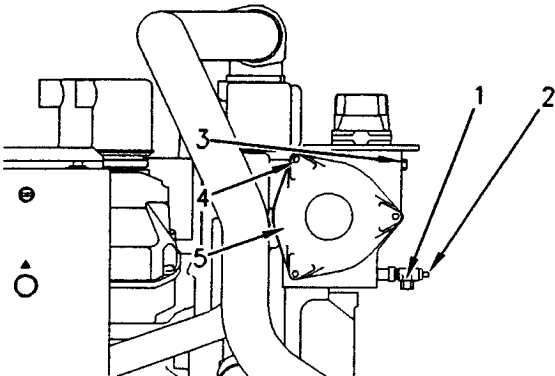


Illustration 69

g00787110

- (1) Drain
- (2) Drain valve
- (3) Plug
- (4) Bolt
- (5) Cover

1. Connect a hose to drain (1). Place the other end of the hose into a suitable container in order to collect the oil.
2. Open drain valve (2). Remove plug (3). Allow the oil to drain. Clean the plug and install the plug. Close the drain valve. Remove the hose from the drain.

Note: Some oil will remain in the housing after the oil has been drained. This oil will pour out of the housing when cover (5) is removed. Prepare to catch the oil in a suitable container. Clean up any spilled oil with absorbent pillows or towels. DO NOT use absorbent particles to clean up the oil.

WARNING

Personal injury can result from parts and/or covers under spring pressure.

Spring force will be released when covers are removed.

Be prepared to hold spring loaded covers as the bolts are loosened.

3. Be alert to the spring force. Gradually loosen but do not remove bolts (4). Before removing bolts (4), pry cover (5) loose or tap the cover with a rubber mallet in order to relieve any spring pressure.

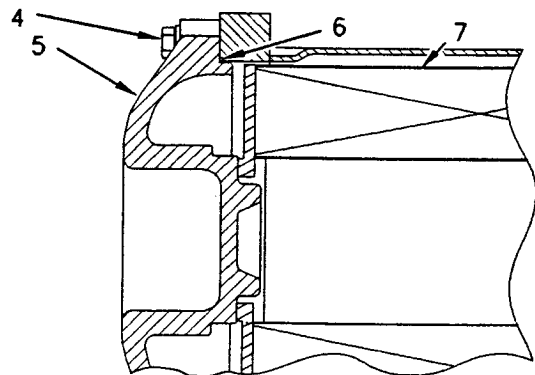


Illustration 70

g00760382

Section view

- (4) Bolt
- (5) Cover
- (6) O-ring seal
- (7) Oil filter element

4. Remove bolts (4) and the washers in order to remove cover (5) and O-ring seal (6). Remove oil filter elements (7).
5. Clean cover (5), O-ring seal (6), and the inside of the oil filter housing.

NOTICE

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

6. Ensure that the new oil filter elements are in good condition. Install the new oil filter elements.
7. Inspect O-ring seal (6). Ensure that the surfaces for the O-ring seal are clean. Install a new O-ring seal if the old O-ring seal is damaged or deteriorated.
8. Install cover (5) and O-ring seal (6). Ensure that the cover's retainer is properly seated.
9. Start the engine. Check for oil leaks.
10. Check the oil level on the "LOW IDLE" side of the oil level gauge. Maintain the oil level between the "ADD" and "FULL" marks on the "LOW IDLE" side of oil level gauge.

Replacing the Engine Oil Filters During Engine Operation

WARNING

Filter contains hot pressurized fluid when engine is running.

Follow instructions on control valve to avoid personal injury.

If rapid air movement exists to blow fluid, Stop the engine to avoid fire.

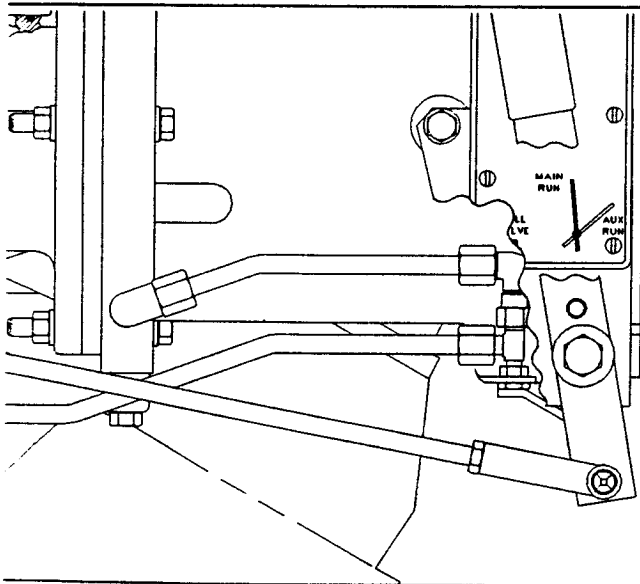


Illustration 71

g00850266

If the engine is equipped with duplex oil filters, the engine oil filter elements can be changed while the engine is operation. This is useful if the oil filter elements require more frequent replacement than the engine oil.

1. Move the control valve to the "AUX RUN" position in order to change the main oil filter elements. Move the selector valve to the "MAIN RUN" position in order to change the auxiliary oil filter elements.
2. Allow the oil pressure gauge for the oil filter that is being changed to reach a "ZERO" pressure reading.
3. Perform Step 1 through Step 10 of "Replacing the Engine Oil Filters With the Engine Stopped".
4. Open the "FILL" valve for a minimum of five minutes in order to fill the new oil filter elements.
5. Close the "FILL" valve. Rotate the control valve to the "RUN" position for the oil filter that was serviced.

Inspect the Used Oil Filter Elements

Cut the used oil filter element open with a utility knife. Cut the filter element free from the end caps. Spread apart the pleats and inspect the element for metal debris. An excessive amount of debris in the element may indicate early wear or a pending failure.

Use a magnet to differentiate between the ferrous metals and the nonferrous metals that are found in the element. Ferrous metals may indicate wear on the steel and the cast iron parts of the engine. Nonferrous metals may indicate wear on the aluminum parts, the brass parts, or the bronze parts of the engine. Parts that may be affected include the following components: main bearings, rod bearings, turbocharger bearings, and cylinder heads.

Aluminum debris may indicate problems with the bearings of the front gears. If an excessive amount of aluminum debris is found, inspect the crankshaft vibration damper and the bearings of the front idler gear.

Due to normal wear and friction, it is not uncommon to find small amounts of debris in the oil filter element. If an excessive amount of debris is found in the oil filter element, consult your Caterpillar dealer in order to arrange for further oil analysis.

i01617747

Engine Oil Level - Check

SMCS Code: 1348-535-FLV

The most accurate check of the engine oil level is obtained when the engine is stopped.

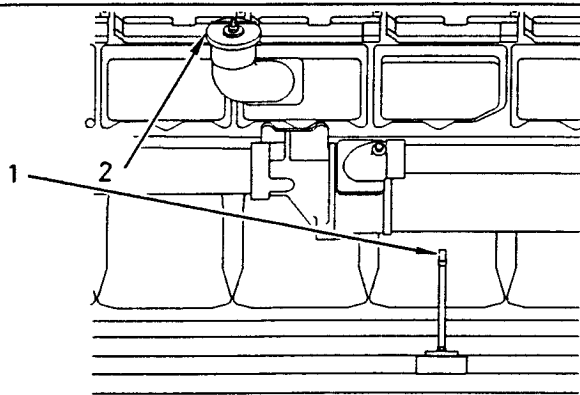


Illustration 72

g00760401

- (1) Engine oil level gauge (dipstick)
(2) Filler cap

1. Remove filler cap (2) in order to ensure that the crankcase pressure is equal to the atmospheric pressure.

Excess pressure or a slight vacuum will affect engine oil level that is measured.

2. Ensure that engine oil level gauge (1) is seated.

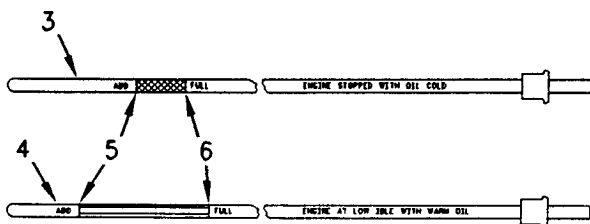


Illustration 73

g00735162

- (3) "ENGINE STOPPED WITH OIL COLD" side
(4) "ENGINE AT LOW IDLE WITH WARM OIL" side
(5) "ADD" mark
(6) "FULL" mark

- a. If the engine is stopped, remove the engine oil level gauge. Observe the engine oil level on "ENGINE STOPPED WITH OIL COLD" side (3).
- b. If the engine is operating, reduce the engine speed to low idle. Remove the engine oil level gauge and observe the engine oil level on "ENGINE AT LOW IDLE WITH WARM OIL" side (4).

The engine oil level should be between "ADD" mark (5) and "FULL" mark (6).

NOTICE

Engine damage can occur if the crankcase is filled above the "FULL" mark on the oil level gauge (dipstick).

An overfull crankcase can cause the crankshaft to dip into the oil. This will reduce the power that is developed and also force air bubbles into the oil. These bubbles (foam) can cause the following problems: reduction of the oil's ability to lubricate, reduction of oil pressure, inadequate cooling, oil blowing out of the crankcase breathers, and excessive oil consumption.

Excessive oil consumption will cause deposits to form on the pistons and in the combustion chamber. Deposits in the combustion chamber lead to the following problems: guttering of the valves, packing of carbon under the piston rings, and wear of the cylinder liner.

If the oil level is above the "FULL" mark on the oil level gauge, drain some of the oil immediately.

3. If necessary, add engine oil. For the correct engine oil to use, refer to this Operation and Maintenance Manual, "Engine Oil" topic (Maintenance Section). Do not fill the crankcase above the "FULL" mark on the engine oil level gauge. Clean the filler cap (2). Install the filler cap.
4. Record the amount of engine oil that is added. For the next engine oil sample and analysis, include the total amount of engine oil that has been added since the previous oil change. This will help to provide the most accurate analysis.

i01534451

Engine Oil Sample - Obtain

SMCS Code: 1348-554-SM

In addition to a good preventive maintenance program, Caterpillar recommends using S-O-S oil analysis at regularly scheduled intervals in order to monitor the condition of the engine and the maintenance requirements of the engine.

Obtain the Sample and the Analysis

WARNING

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

Before you take the oil sample, complete the Label, PEEP5031 for identification of the sample. In order to help obtain the most accurate analysis, provide the following information:

- Engine model
- Service hours on the engine
- The number of hours that have accumulated since the last oil change
- The amount of oil that has been added since the last oil change

To ensure that the sample is representative of the oil in the crankcase, obtain a warm, well mixed oil sample.

To avoid contamination of the oil samples, the tools and the supplies that are used for obtaining oil samples must be clean.

Caterpillar recommends using the sampling valve in order to obtain oil samples. The quality and the consistency of the samples are better when the sampling valve is used. The location of the sampling valve allows oil that is flowing under pressure to be obtained during normal engine operation.

The 169-8373 Fluid Sampling Bottle is recommended for use with the sampling valve. The fluid sampling bottle includes the parts that are needed for obtaining oil samples. Instructions are also provided.

NOTICE

Do not use the same vacuum sampling pump for extracting oil samples that is used for extracting coolant samples.

A small residue of either type sample may remain in the pump and may cause a false positive analysis for the sample being taken.

Always use a designated pump for oil sampling and a designated pump for coolant sampling.

Failure to do so may cause a false analysis which could lead to customer and dealer concerns.

If the engine is not equipped with a sampling valve, use the 1U-5718 Vacuum Pump. The pump is designed to accept sampling bottles. Disposable tubing must be attached to the pump for insertion into the sump.

For instructions, see Special Publication, PEHP6001, "How To Take A Good Oil Sample". Consult your Caterpillar dealer for complete information and assistance in establishing an S-O-S program for your engine.

i00626013

Engine Protective Devices - Check

SMCS Code: 7400-535

Alarms and shutoffs must function properly. Alarms provide timely warning to the operator. Shutoffs help to prevent damage to the engine. It is impossible to determine if the engine protective devices are in good working order during normal operation. Malfunctions must be simulated in order to test the engine protective devices.

A calibration check of the engine protective devices will ensure that the alarms and shutoffs activate at the setpoints. Ensure that the engine protective devices are functioning properly.

NOTICE

During testing, abnormal operating conditions must be simulated.

The tests must be performed correctly in order to prevent possible damage to the engine.

To prevent damage to the engine, only authorized service personnel or your Caterpillar dealer should perform the tests.

Visual Inspection

Visually check the condition of all gauges, sensors and wiring. Look for wiring and components that are loose, broken, or damaged. Damaged wiring or components should be repaired or replaced immediately.

i01617784

Engine Speed/Timing Sensor - Clean/Inspect

SMCS Code: 1905-040; 1905-070; 1907-040; 1907-070

An engine speed/timing sensor is mounted in the flywheel housing. The speed/timing sensor provides information about engine speed and the position of the crankshaft to the ECM.

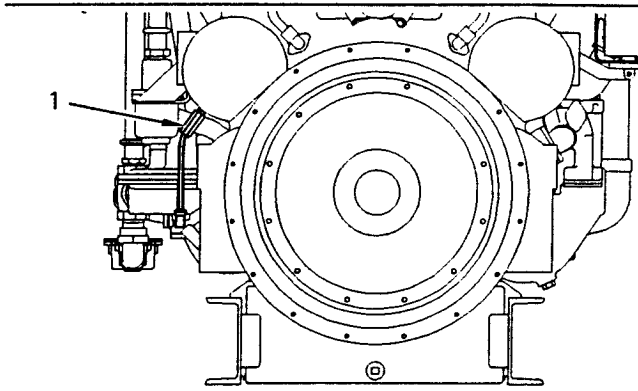


Illustration 74

g00760464

1. Remove engine speed/timing sensor (1). Inspect the condition of the end of the magnet. Look for signs of wear and contaminants.
2. Clean any debris from the face of the magnet.

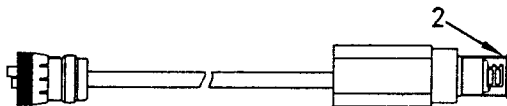


Illustration 75

g00760465

3. Check the tension of the sliphed. Gently extend sliphed (2) for a minimum of 4 mm (0.16 inch). Then push back the sliphed.

When the sliphed has the correct tension, at least 22 N (5 lb) of force is required to push in the sliphed from the extended position.

NOTICE

The sliphed must be fully extended when the speed/timing sensor is installed so that the sensor maintains the correct clearance with the speed-timing wheel. If the correct clearance is not maintained, the signal from the sensor will not be generated.

Do not install the sensor between the teeth of the speed-timing wheel. Damage to the sensor would result. Before installing the sensor, ensure that a tooth of the wheel is visible in the mounting hole for the sensor.

4. Install the engine speed/timing sensor.
 - a. Ensure that a tooth on the speed-timing wheel is visible in the mounting hole for the sensor.
 - b. Extend sliphed (2) by a minimum of 4 mm (0.16 inch).

- c. Coat the threads of the sensor with 4C-5597 Anti-Seize Compound.

Note: The sliphed is designed to contact a tooth during the first revolution of the speed-timing wheel. For the maximum allowable clearance between the sliphed and the tooth, refer to the engine's Specifications manual.

- d. Install the sensor. Tighten the locknut to the torque that is listed in the engine's Specifications manual.

i01665278

Engine Valve Lash and Bridge - Adjust

SMCS Code: 1102-025; 1102

WARNING

Ignition systems can cause electrical shocks. Avoid contacting the ignition system components and wiring.

Do not attempt to remove the valve covers when the engine is operating. The transformers are grounded to the valve covers. Personal injury or death may result and the ignition system will be damaged if the valve covers are removed during engine operation. The engine will not operate without the valve covers.

For procedures on adjusting the valve bridge and the engine valve lash, refer to the following publications:

- Special Instruction, REHS0128, "Using the 147-5482 Indicator Gauge for Valve Lash and Valve Bridge Adjustment"
- Service Manual, "Systems Operation/Testing and Adjusting"

Consult your Caterpillar dealer for assistance.

Valve Bridge

Check the valve bridge and adjust the valve bridge, if necessary. Perform the procedure for both valve bridges for each cylinder.

After the valve bridge for each cylinder is satisfactory, measure the valve lash.

Engine Valve Lash

NOTICE

Only qualified service personnel should perform this maintenance. Refer to the Service Manual or your Caterpillar dealer for the complete valve lash adjustment procedure.

Operation of Caterpillar engines with improper valve adjustments can reduce engine efficiency. This reduced efficiency could result in excessive fuel usage and/or shortened engine component life.

If the valve lash is within the tolerance, an adjustment of the valve lash is NOT necessary.

Perform valve lash adjustment if the dimension is not within the tolerance. The valve bridge adjustment must be performed before making a valve lash adjustment.

Perform the valve lash setting when the engine is cold. After the engine has been shut down and the valve covers are removed, the engine is considered cold.

Before performing maintenance, prevent the entry of foreign matter into the top of the cylinder head and the valve mechanism. Thoroughly clean the area around the valve mechanism covers.

For the valve lash setting, refer to the Operation and Maintenance Manual, "Specifications" topic (Product Information Section).

i00769278

Engine Valve Rotators - Inspect

SMCS Code: 1109-040

NOTICE

A valve rotator which does not operate properly will accelerate valve face wear and valve seat wear and shorten valve life. If a damaged rotator is not replaced, valve face guttering could result and cause pieces of the valve to fall into the cylinder. This can cause piston and cylinder head damage.

Perform this procedure after the valve lash has been set.

1. Mark the tops of the valve rotators with a permanent marker. Note the position of the marks.
2. Install the valve covers. See the Service Manual for the procedure.

3. Start the engine. Operate the engine for 5 minutes. Stop the engine.
4. Remove the valve covers. Observe the position of the marks that are on the valve rotators.

If a valve fails to rotate, consult your Caterpillar dealer.

i01505507

Exhaust Bypass - Inspect

SMCS Code: 1057-040

For instructions on removal and installation, see the Service Manual, "Disassembly and Assembly".

1. Remove the exhaust bypass valve.

WARNING

The exhaust bypass valve cover is under spring compression. To prevent personal injury, use caution when removing the cover.

2. Disassemble the valve.

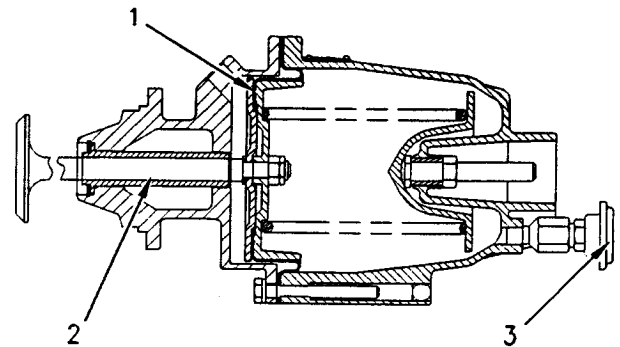


Illustration 76

g00781274

Exhaust bypass valve

- (1) Diaphragm
- (2) Valve stem
- (3) Breather

3. Inspect diaphragm (1). If the diaphragm is worn or cracked, replace the diaphragm.
4. Inspect valve stem (2) and the valve guide. If the parts are excessively worn, replace the parts.
5. Clean breather (3).
6. Assemble the valve.
7. Install the valve.

i00721010

Exhaust Piping - Inspect

SMCS Code: 1061-040

WARNING

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

Inspect the components of the exhaust system. Repair the components or replace the components if any of the following conditions occur:

- Damage
- Cracks
- Leaks
- Loose connections

Consult your Caterpillar dealer for assistance.

Water Cooled Exhaust Manifolds

The water cooled exhaust manifolds do not require maintenance unless excessive deposits build up in the exhaust passages. Buildup of deposits cause an increase in back pressure that will cause the following conditions:

- Increased fuel consumption
- Reduced boost pressure

If excessive deposits build up in the exhaust passages, clean the passages in order to remove the deposits.

i00796401

Fuel Filtration System - Service

SMCS Code: 1260

Engines that use bio-gas require special equipment for processing the fuel. Service the fuel filtration system according to the instructions that are provided by the OEM of the equipment.

i01505536

Fuel System Fuel Filter Differential Pressure - Check

SMCS Code: 1261-535

A fuel filter differential pressure gauge must be installed in order to determine when the fuel filter requires service. This gauge and the fuel filter are supplied by the customer.

A fuel filter differential pressure gauge indicates the difference in fuel pressure between the inlet side and the outlet side of the fuel filter. The differential pressure increases as the fuel filter becomes plugged.

Operate the engine at the rated speed and at the normal operating temperature. Check the fuel filter differential pressure. Service of the fuel filter depends on the pressure of the fuel system:

- For low pressure gas fuel systems, service the fuel filter when the fuel filter differential pressure reaches 1.7 kPa (0.25 psi).
- For high pressure gas fuel systems, service the fuel filter when the fuel filter differential pressure reaches 34 kPa (5 psi).

For instructions, see Special Instruction, SEHS9298, "Installation and Maintenance of Gaseous Fuel Filters". Consult your Caterpillar dealer for assistance.

i01642143

Gas Pressure Regulator - Check

SMCS Code: 1270-535

Check the fuel pressure before the gas pressure regulator. Table 43 lists the fuel pressure that is required for the gas pressure regulator.

Table 43

Requirements for Fuel Pressure To the Gas Pressure Regulator	
Fuel System	Pressure
Low pressure gas	10.3 to 34 ± 2 kPa (1.50 to 5 ± 0.25 psi)
High pressure gas Standard Engine	172 to 207 ± 3.5kPa (25 to 30 ± 0.5psi)
High pressure gas LE Engine	242 to 275 ± 3.5 kPa (35 to 40 ± 0.5psi)

Fuel Differential Pressure of the Fuel Supply To the Carburetor

The gas pressure regulator maintains a pressure differential between the boost and the fuel that is supplied to the carburetor. After setting, the gas pressure regulator will maintain the pressure differential in response to changes in the boost pressure.

Use a water manometer for measuring the pressure differential. Obtain the measurement when the engine is operating at high idle rpm. After a load is applied, the fuel pressure will usually decrease by approximately 0.1 to 0.25 kPa (0.50 to 1 inches of H₂O). If the performance of the gas pressure regulator is erratic, the gas pressure regulator may require service.

Natural Gas

Set the differential of the fuel supply to a maximum of 1 to 1.2 kPa (4 to 4.5 inches of H₂O).

Check the differential pressure in order to maintain the correct pressure for the fuel that is being burned and the application of the engine. Refer to the engine's Systems Operation/Testing and Adjusting.

i01642256

Gas Pressure Regulator Condensation - Drain

SMCS Code: 1270-543

To collect condensation, drip legs should be installed in the following locations:

- Supply line for the gas pressure regulator
- Balance line for the gas pressure regulator
- Supply line to the gas shutoff valve

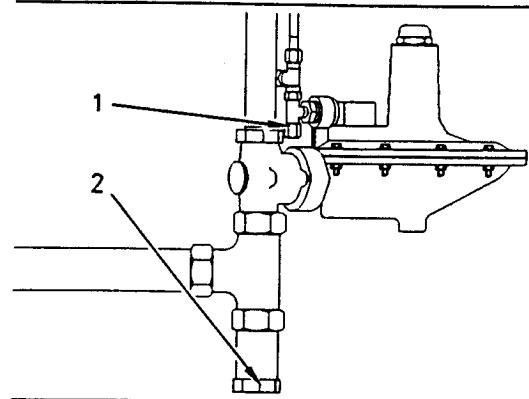


Illustration 77

g00829869

- (1) Cap on the drip leg for the balance line
(2) Cap on the drip leg for the gas supply line to the gas pressure regulator

1. Close the main gas supply valve.
2. Remove caps (1) and (2) from the drip legs.
3. Allow the moisture to drain into a suitable container. Inspect the drip legs for debris. Clean the drip legs, if necessary.
4. Clean the caps. Install the caps.
5. Perform Step 2 through Step 4 for the drip leg on the supply line to the gas shutoff valve.
6. Open the main gas supply valve.

i00907072

Hoses and Clamps - Inspect/Replace

SMCS Code: 7554-040; 7554-510

Inspect all hoses for leaks that are caused by the following conditions:

- Cracking
- Softness
- Loose clamps

Replace hoses that are cracked or soft. Tighten any loose clamps.

NOTICE

Do not bend or strike high pressure lines. Do not install bent or damaged lines, tubes or hoses. Repair any loose or damaged fuel and oil lines, tubes and hoses. Leaks can cause fires. Inspect all lines, tubes and hoses carefully. Tighten all connections to the recommended torque.

Check for the following conditions:

- End fittings that are damaged or leaking
- Outer covering that is chafed or cut
- Exposed wire that is used for reinforcement
- Outer covering that is ballooning locally
- Flexible part of the hose that is kinked or crushed
- Armoring that is embedded in the outer covering

A constant torque hose clamp can be used in place of any standard hose clamp. Ensure that the constant torque hose clamp is the same size as the standard clamp.

Due to extreme temperature changes, the hose will heat set. Heat setting causes hose clamps to loosen. This can result in leaks. A constant torque hose clamp will help to prevent loose hose clamps.

Each installation application can be different. The differences depend on the following factors:

- Type of hose
- Type of fitting material
- Anticipated expansion and contraction of the hose
- Anticipated expansion and contraction of the fittings

Replace the Hoses and the Clamps**⚠ WARNING**

Pressurized System: Hot coolant can cause serious burns. To open the cooling system filler cap, stop the engine and wait until the cooling system components are cool. Loosen the cooling system pressure cap slowly in order to relieve the pressure.

1. Stop the engine. Allow the engine to cool.

2. Loosen the cooling system filler cap slowly in order to relieve any pressure. Remove the cooling system filler cap.

Note: Drain the coolant into a suitable, clean container. The coolant can be reused.

3. Drain the coolant from the cooling system to a level that is below the hose that is being replaced.

4. Remove the hose clamps.

5. Disconnect the old hose.

6. Replace the old hose with a new hose.

Note: For torques on hose clamps, see this Operation and Maintenance Manual, "Torque Specifications" (Maintenance Section).

7. Install the hose clamps with a torque wrench.

Note: For the proper coolant to use, see this Operation and Maintenance Manual, "Coolant Recommendations" (Maintenance Section).

8. Refill the cooling system.

9. Clean the cooling system filler cap. Inspect the cooling system filler cap's gaskets. Replace the cooling system filler cap if the gaskets are damaged. Install the cooling system filler cap.

10. Start the engine. Inspect the cooling system for leaks.

i01642332

**Ignition System Spark Plugs -
Check/Adjust/Replace**

SMCS Code: 1555-535

⚠ WARNING

Ignition systems can cause electrical shocks. Avoid contacting the ignition system components and wiring.

Do not attempt to remove the valve covers when the engine is operating. The transformers are grounded to the valve covers. Personal injury or death may result and the ignition system will be damaged if the valve covers are removed during engine operation. The engine will not operate without the valve covers.

Maintenance of the spark plugs is required in order to achieve the following benefits:

- Normal fuel consumption
- Normal level of emissions
- Maximum service life of the spark plugs

The service life of the spark plugs is affected by fouling due to deposits from the oil and by peak voltage. Maintenance of the ignition system is also affected by voltage. Higher voltage is required by higher inlet manifold air pressure and a higher compression ratio. Higher voltage reduces the service life of components such as spark plugs, wires, and transformers.

Removing the Spark Plug

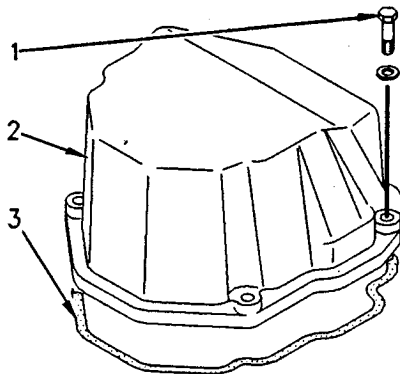


Illustration 78

g00787369

- (1) Bolt
(2) Valve cover
(3) O-ring seal

Note: Do not use an impact wrench to remove the cover bolts and do not use an impact wrench to install the cover bolts.

1. Remove bolts (1). Remove valve cover (2). Inspect O-ring seal (3). If the seal appears to be worn or damaged, discard the seal and use a new seal for assembly.

NOTICE

Pulling on the wiring harness may break the wires. Do not pull on the wiring harness.

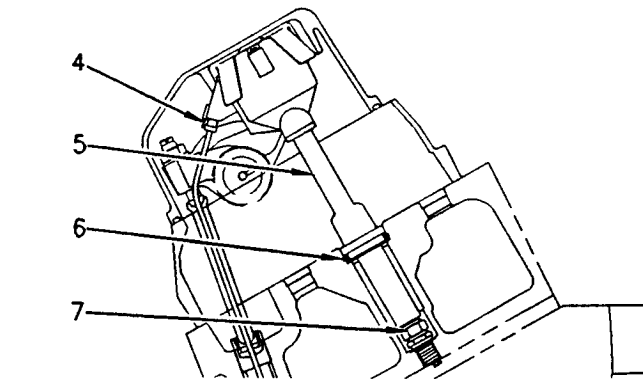


Illustration 79

g00787367

- (4) Wiring harness
(5) Transformer
(6) Lip seal
(7) Spark plug

2. Disconnect wiring harness (4) from transformer (5). Be careful to completely depress the retainer clip away from the connector. Remove transformer (5).

Note: Excessive buildup of oil in the spark plug well is an indication of a damaged lip seal on the transformer. If this condition is found, clean the surface of the seal groove. Replace the seal.

3. Inspect lip seal (6). If the seal is worn or damaged, discard the seal and use a new seal for assembly.

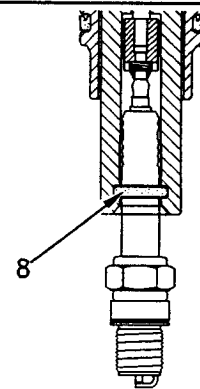


Illustration 80

g00787371

- (8) O-ring seal

4. Inspect O-ring seal (8). If the seal is hard or cracked, use a new seal for assembly.

WARNING

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

5. Debris may have collected in the spark plug well. Thoroughly remove any debris. Use compressed air. The maximum air pressure for cleaning purposes must be below 207 kPa (30 psi). Ensure that the area around the spark plug is clean and free of dirt and debris.
6. Use a 22.23 mm (0.875 inch), 4C-4601 Spark Plug Socket and an extension to loosen spark plug (7). After the spark plug has been loosened, remove the spark plug by hand in order to detect problems with the threads. After the spark plug has been removed, discard the used spark plug gasket.

NOTICE

Do not use a thread tap. A thread tap will remove metal unnecessarily. The threads could be stripped and the cylinder head could be damaged.

If the spark plug resists removal by hand, apply penetrating oil to the threads. Use the wrench and apply steady pressure to the spark plug until the spark plug is loose.

If the spark plug can not be removed by hand, clean the threads with 9U-7511 Spark Plug Seat Cleaner. This tool scrapes debris from the seat and from the threads in the cylinder head. Be sure to clean any debris from the cylinder.

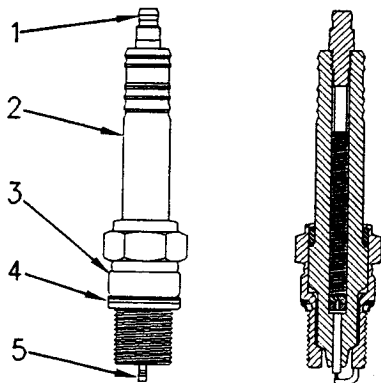
Inspecting the Spark Plug

Illustration 81

g00787368

- (1) Terminal post
- (2) Insulator
- (3) Shell
- (4) Gasket
- (5) Electrode

Inspect the spark plug closely for damage. The condition of the spark plug can indicate the operating condition of the engine.

Terminal post (1) must not move. If the terminal post can be moved by hand, carefully tighten the post into the threads of the insulator. If the post cannot be tightened, discard the spark plug.

Inspect insulator (2) for cracks. If a crack is found, discard the spark plug.

Faint marks may extend from shell (3) onto the insulator. The marks may be a result of corona that forms at the top of the shell. The conductor will develop a corona when a very high voltage potential ionizes the air. This is a normal condition. This is not an indication of leakage between the shell and the insulator.

Inspect shell (3) for damage. Cracks can be caused by overtightening the spark plug. Overtightening can also loosen the shell. Discard any spark plug that has a shell that is cracked or loose.

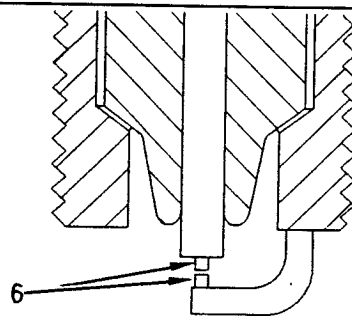


Illustration 82

g00787372

(6) Precious metal tips on the electrode and the ground strap

Caterpillar spark plugs have precious metal tips (6) on the electrode and the ground strap. This material will gradually erode. Use extreme care when you set the electrode gap. Maintain even spacing and proper alignment between the two precious metal surfaces.

Replace the spark plug if the precious metal is worn off.

A light brown deposit or a beige deposit around the electrode is produced by normal operation.

Deposits that are gray or black may be caused by the following substances:

- Excessive oil
- Use of the wrong oil
- A substance that is introduced through the fuel system or the air system

A spark plug can operate despite a buildup of ash. However, a buildup of ash can cover the electrode gap. This will cause misfire. Large deposits may retain heat which can cause premature fuel ignition. This can lead to uncontrollable detonation.

Cleaning the Spark Plug

Thoroughly clean the spark plug. Do not use a wire brush. Glass beads are the preferred method for cleaning.

Follow these guidelines for using glass beads:

- Always use clean glass beads.
- Use new glass beads for each set of spark plugs.
- Use care in order to clean only the electrode and the insulator near the electrode.
- Do not use glass beads on the outside of the shell or on the upper part of the insulator.

Checking the Spark Plug

After the spark plug is clean, measure the spark plug's resistance. If the resistance is correct, make sure that the electrode gap is correct before you install the spark plug.

Note: A standard ohmmeter cannot be used for measuring the resistance of a used spark plug.

Use the 142-5055 Insulation Tester Group to measure the resistance of the spark plug. Follow the warnings and instructions that are provided with the tool.

Connect the red lead of the tester to terminal post (1). Because the ground strap is close to electrode (5), you will need to connect a smaller lead to the center electrode. Then connect the black lead of the tester to the smaller lead. Use the tester's "KΩ" scale. The correct resistance depends on the spark plug that is used:

- For the 146-2588 Spark Plug, the correct resistance is approximately 1000 ohms.
- For the 194-8518 Spark Plug, the correct resistance is approximately 500 ohms.

If the resistance is greater than the specification, discard the spark plug and obtain a new spark plug.

Installing the Spark Plug

Note: Use the 9U-7516 Spark Plug Gauge to measure the electrode gap. Do not use a flat feeler gauge for measuring the electrode gap of used spark plugs. A feeler gauge will incorrectly measure the actual electrode gap because the used precious metal tips are curved.

1. Before installing the spark plug, set the electrode gap. The electrode gap depends on the engine's compression ratio.
 - a. For compression ratios that are greater than 9:1, set the electrode gap to 0.29 ± 0.03 mm (0.011 ± 0.001 inch).
 - b. For compression ratios of 9:1 or less, set the electrode gap to 0.35 ± 0.03 mm (0.014 ± 0.001 inch).

Adjust the electrode gap, if necessary. Bend the ground strap at the existing bend. Then bend the strap near the weld in order to achieve proper alignment and even spacing between the two precious metal surfaces. Measure the electrode gap after the alignment. Correct the electrode gap, if necessary.

Note: Do not use anti-seize compound on spark plugs. Most of the heat is transferred through the threads and the seat area of the spark plug. The surfaces must be in contact in order to provide the heat transfer that is required.

2. Ensure that the spark plug is clean and free of dirt and oil.
3. Always use a new gasket when a spark plug is installed. If a used spark plug is installed, place a new 9Y-6792 Spark Plug Gasket on the spark plug. Orient the tabs of the gasket toward the electrode. Otherwise, the gasket may not seat properly. Do not increase the torque on the spark plug in order to improve the seal. Do not reuse the gasket. Install a new gasket.

NOTICE

Do not overtighten the spark plug. The shell can be cracked and the gasket can be deformed. The metal can deform and the gasket can be damaged. The shell can be stretched. This will loosen the seal that is between the shell and the insulator, allowing combustion pressure to blow past the seal. Serious damage to the engine can occur.

Use the proper torque.

4. Install the spark plug by hand until the spark plug bottoms out. Tighten the spark plug to 68 ± 4 N·m (50 ± 3 lb ft).
5. Ensure that the transformer and the extension are clean and free from dirt and oil. Lubricate O-ring seal (8) (Illustration 80) with one of the following lubricants:
 - 4C-9504 Dielectric Grease
 - 5N-5561 Silicone Lubricant
 - 8T-9020 Dielectric Grease

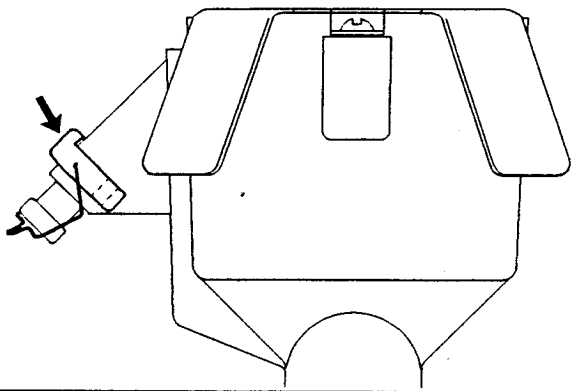


Illustration 83

g00838130

Retainer on the transformer's connector for the wiring harness

6. Install the transformer. Orient the transformer toward the wiring harness. Carefully align the socket of the transformer with the wiring harness connector. Connect the wiring harness.

Note: If the connector's locking tab or the transformer's connector are damaged, install a retainer onto the transformer's connector for the wiring harness. For connectors with a width of 22.3 mm (0.88 inch), use the 178-0565 Retainer. For connectors with a width of 17.1 mm (0.67 inch), use the 179-1500 Retainer.

7. Install the valve cover.

i01005974

Ignition System Timing - Check/Adjust

SMCS Code: 1550-025; 1550-535

After maintenance has been performed on the ignition system, check the timing of the ignition system. Adjust the timing, if necessary.

The optimum ignition timing for a gas engine varies according to several factors:

- Compression ratio of the engine
- Inlet air temperature
- Methane number of the gas

For the proper timing, see the Engine Performance publication for the engine.

Adjust the timing according to the Service Manual, "Systems Operation/Testing and Adjusting" module. Consult your Caterpillar dealer for assistance.

i01113853

Inlet Air System - Inspect

SMCS Code: 1058-040; 1071-040; 1087-040

Inspect the components of the air inlet system for the following conditions:

- Cracks
- Leaks
- Loose connections

Inspect the following components:

- Piping between the air cleaner and the turbocharger
- Turbocharger
- Piping between the turbocharger and the aftercooler
- Aftercooler
- Connection of the aftercooler to the air plenum
- Connection of the air plenum to the cylinder head

Ensure that all of the connections are secure. Ensure that the components are in good condition.

Make repairs, if necessary. For information regarding removal and installation of the components, see the Service Manual, "Disassembly and Assembly" module. Consult your Caterpillar dealer for assistance.

i01642396

Overhaul (Major)

SMCS Code: 7595-020-MJ

Scheduling a Major Overhaul

Note: For information on estimating operating hours before an overhaul, see Maintenance Management Schedules, SEBU6127.

Generally, a major overhaul is performed at the sixth top end overhaul. The need for a major overhaul is determined by several factors. Some of those factors are the same factors that determine the in-frame overhaul:

- An increase of oil consumption
- An increase of crankcase blowby
- A decrease and variation of cylinder compression

Other factors must also be considered for determining a major overhaul:

- The service hours of the engine
- The wear metal analysis of the lube oil
- An increase in the levels of noise and vibration

An increase of wear metals in the lube oil indicates that the bearings and the surfaces that wear may need to be serviced. An increase in the levels of noise and vibration indicates that rotating parts require service.

Note: It is possible for oil analysis to indicate a decrease of wear metals in the lube oil. The cylinder liners may be worn so that polishing of the bore occurs. Also, the increased use of lube oil will dilute the wear metals.

Monitor the engine as the engine accumulates service hours. Consult your Caterpillar dealer about scheduling a major overhaul.

Note: The driven equipment may also require service when the engine is overhauled. Refer to the literature that is provided by the OEM of the driven equipment.

Major Overhaul Information

A major overhaul includes all of the work that is done for top end overhauls and in-frame overhauls. A major overhaul includes additional parts and labor. Additional parts and labor are required in order to completely rebuild the engine. In some cases, the engine is relocated for disassembly.

For the major overhaul, all of the bearings, seals, gaskets, and components that wear are disassembled. The parts are cleaned and inspected. If necessary, the parts are replaced. The crankshaft is measured for wear. The crankshaft may require regrinding. Alternatively, the crankshaft may be replaced with a Caterpillar replacement part.

Your Caterpillar dealer can provide these services and components. Your Caterpillar dealer can ensure that the components are operating within the appropriate specifications.

If you elect to perform an overhaul without the services of a Caterpillar dealer, be aware of the following recommendations.

Replacing of Components

Replace the following components during the major overhaul.

- Camshaft bearings
- Connecting rod bearings
- Coupling (tandem engines)
- Cylinder liners
- Piston rings
- Cylinder heads, gaskets, and bolts
- Gaskets and seals
- Gear train bearings
- Main bearings
- Oil temperature regulators
- Water temperature regulators
- Wiring harnesses

Rebuilding or Replacing of Components

Rebuild the following components during the major overhaul.

- Carburetor
- Crankshaft vibration damper 1.
- Exhaust bypass
- Gas regulator
- Prelube pump
- Starting motor
- Turbochargers
- Water pumps

Note: 1. Replace the crankshaft vibration damper if the damper cannot be rebuilt.

Inspecting Components

Inspect the following components according to the instructions that are in Caterpillar reusability publications. Refer to Guidelines for Reusable Parts and Salvage Operations, SEBF8029, "Index of Publications on Reusability or Salvage of Used Parts".

- Aftercooler
- Camshafts
- Camshaft followers
- Connecting rods
- Crankshaft
- Gear train
- Governor
- Inlet air piping
- Oil cooler
- Oil pump
- Pistons
- Transformers

Overhaul (Top End)

SMCS Code: 7595-020-TE

Scheduling a Top End Overhaul

Note: For information on estimating operating hours before an overhaul, see Maintenance Management Schedules, SEBU6127.

Top end overhauls are scheduled according to the recession of the exhaust valve stems. This measurement provides an accurate indication of the rate of valve wear. This measurement can be used to predict when a cylinder head requires replacement.

Measure the projection of the exhaust valve stems within the first 1000 service hours. This measurement is the baseline. The baseline is a reference for subsequent measurements. Continue to periodically measure the projection.

Plan for the top end overhaul as the valve stem projection approaches the maximum limit 1.8 mm (0.07 inch). Perform the top end overhaul when the valve stem projection has increased by a total of 2.3 mm (0.09 inch). Do not allow the projection of the exhaust valve stems to exceed this limit.

Note: Generally, cylinder heads wear out at different rates. In some cases, servicing the cylinder heads at different times may be the most economic decision. This depends on the valve stem projection of the individual cylinders. However, this decision must include the costs of additional downtime that is caused by this procedure. Perform an economic analysis in order to determine if cylinder heads should be serviced as a group or divided into smaller groups.

Note: The generator or the driven equipment may also require service when the engine overhaul is performed.

Top End Overhaul Information

A top end overhaul involves servicing the cylinder heads and turbochargers. Also, some other engine components are inspected.

Top end overhauls require more tools than preventive maintenance. The following tools are needed for restoring the engine to factory specifications:

- Torque wrenches
- Dial indicators

- Accurate measurement tools
- Cleaning equipment
- Rebuilding equipment

Caterpillar dealers are equipped with these tools. Caterpillar dealers can provide a flat rate price for a top end overhaul.

Unexpected problems may be found during a top end overhaul. Plan to correct these problems, if necessary.

- Buildup in the cylinders from excessive oil consumption
- Buildup in the cylinders from contamination of the fuel
- Plugging of the aftercooler from coolant that is poorly maintained
- Plugging of the aftercooler from contamination of the inlet air
- Degradation of the oil cooler from hydrogen sulfide in the fuel

Inspect the following components according to the instructions that are in Caterpillar reusability publications. Refer to Guidelines for Reusable Parts and Salvage Operations, SEBF8029, "Index of Publications on Reusability or Salvage of Used Parts".

Your Caterpillar dealer can provide these services and components. Your Caterpillar dealer can ensure that the components are operating within the appropriate specifications.

If you elect to perform an overhaul without the services of a Caterpillar dealer, be aware of the following recommendations.

Replacing of Components

Replace the following components during a top end overhaul.

- Cylinder heads and gaskets
- Oil temperature regulators
- Water temperature regulators

Rebuilding of Components

Rebuild the following components during a top end overhaul:

- Carburetor
- Exhaust bypass
- Gas regulator
- Prelube pump
- Starting motor
- Turbochargers
- Water pumps

Note: Periodic inspection of the turbocharger is recommended for determining when the turbocharger will require an overhaul. In a few applications, the turbocharger may require rebuilding prior to the top end overhaul. An example is an application with loads that vary frequently. In these cases, rebuilding the turbocharger normally occurs separately from rebuilding the cylinder heads. Some applications can operate longer before the turbocharger requires rebuilding. Only experience can determine the actual need.

Inspecting of Components

Clean the aftercooler core and the oil cooler core. Pressure test the components. Replace the components.

Note: It is difficult to clean the aftercooler core when proper maintenance is not performed. The tank that is opposite of the inlet port and the outlet port can not be removed for cleaning.

Note: This procedure may be used for cleaning both the aftercooler core and the oil cooler core.

1. Remove the core. For the procedure, see the Service Manual, "Disassembly and Assembly" module.
2. Turn the core upside-down in order to remove debris.

NOTICE

Do not use a high concentration of caustic cleaner to clean the core. A high concentration of caustic cleaner can attack the internal metals of the core and cause leakage. Only use the recommended concentration of cleaner.

3. Back flush the core with cleaner.

Caterpillar recommends the use of Hydrosolv liquid cleaner. Hydrosolv liquid cleaners are available from your Caterpillar dealer.

Use a two to five percent concentration of the cleaner at temperatures up to 93 °C (200 °F). Refer to Application Guide, NEHS0526 or consult your Caterpillar dealer for more information.

4. Steam clean the core in order to remove any residue. Flush the fins of the core. Remove any other trapped debris.
5. Wash the core with hot, soapy water. Rinse the core thoroughly with clean water.

! WARNING

Personal injury can result from air pressure.

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

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

6. Dry the core with compressed air. Direct the air in the reverse direction of the normal flow.

Note: The test pressure for the oil cooler is 790 kPa (115 psi). The maximum differential pressure of water for the aftercooler is 44 kPa (6 psi). The maximum differential pressure of air for the aftercooler is 5.1 kPa (0.74 psi).

7. Inspect the core in order to ensure cleanliness. Pressure test the core. Many shops that service radiators are equipped to perform pressure tests. If necessary, repair the core.
8. Install the core. For the procedure, see the Service Manual, "Disassembly and Assembly" module.

For more information on cleaning the cores, consult your Caterpillar dealer.

Coupling

For tandem engine arrangements, inspect the coupling for the engines according to the information that is provided by the OEM of the coupling. Check the bolts for proper torque.

Governor

Inspect the governor for proper operation. Make any repairs that are necessary.

Transformers

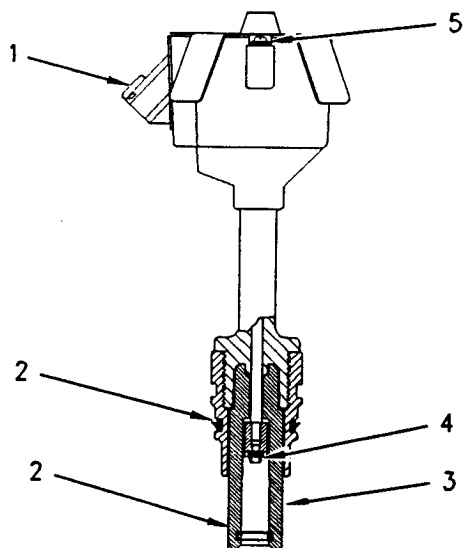


Illustration 84

g00850303

The transformers produce a voltage increase. For good operation, the connections must be clean and secure. Inspect the transformers for the following conditions:

- 1. Damaged connector
- 2. Damaged O-rings
- 3. Dirty insulator
- 4. Loose connections
- 5. Loose screws in the top ground spring
- Moisture

Test the resistance of the transformers according to the Electronic Troubleshooting, SENR6413, "G3500 Engines". Consult your Caterpillar dealer for assistance.

Oil Suction Screen

! WARNING

Hot oil and components can cause personal injury.

Do not allow hot oil or components to contact skin.

Clean the oil suction screen after the oil has been drained.

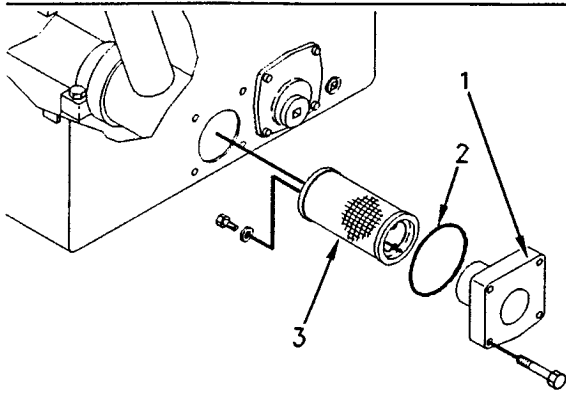


Illustration 85

g00787412

- (1) Cover
(2) O-ring seal
(3) Screen assembly

Note: Approximately 1 L (1 qt) of oil will remain in the housing after the sump has been completely drained. This oil will pour out of the housing when cover (1) is removed. Prepare to catch the oil in a pan. Clean up any spilled oil with absorbent pillows or towels. DO NOT use absorbent particles to clean up the oil.

1. Loosen the bolts from cover (1). Remove cover (1) and O-ring seal (2). Discard the seal. Remove screen assembly (3).
2. Wash screen assembly (3) in clean nonflammable solvent. Allow the screen assembly to dry before installation.
3. Remove the side covers from the engine block and clean the inside of the oil pan. Install the side covers.
4. Inspect screen assembly (3) for good condition. Obtain a new screen assembly, if necessary. Install the screen assembly. Install a new O-ring seal (2). Install cover (1).

i01604264

Overhaul Considerations

SMCS Code: 7595-043

Overhaul Information

An overhaul is replacing the major worn components of the engine. An overhaul is a maintenance interval that is planned. The engine is rebuilt with certain rebuilt parts or new parts that replace the worn parts.

An overhaul also includes the following maintenance:

- Inspection of all the parts that are visible during the disassembly
- Replacement of the seals and gaskets that are removed
- Cleaning of the internal passages of the engine and the engine block

Most owners will save money by overhauling the engine at the intervals that are recommended in the Operation and Maintenance Manual. It is not practical to wait until the engine exhibits symptoms of excessive wear or failure. It is not less costly to wait. A planned overhaul before failure may be the best value for the following reasons:

- Costly unplanned downtime can be avoided.
- Many original parts can be reused according to the guidelines for reusable parts.
- The service life of the engine can be extended without the risk of a major catastrophe due to engine failure.
- Achieve the best cost/value relationship per hour of extended service life.

Overhaul Intervals

Note: For information on estimating operating hours before an overhaul, refer to Maintenance Management Schedules, SEBU6127.

Top end overhauls are determined by the projection of exhaust valve stems. In-frame overhauls are determined by cylinder compression, crankcase blowby, and oil consumption. Major overhauls are determined by the in-frame tests, and by results of S-O-S oil analysis.

Some other factors that are important for determining the overhaul intervals include the following considerations:

- Performance of preventive maintenance
- Use of recommended lubricants
- Use of recommended coolants
- Use of recommended fuels
- Proper installation
- Operating conditions
- Operation within acceptable limits
- Engine load

- Engine speed

Note: To avoid oil problems, engines that are turbocharged and aftercooled must be operated at a minimum of 60 percent of rated load.

Generally, engines that are operated at a reduced load and/or speed achieve more service life before an overhaul. However, this is for engines that are properly operated and maintained.

Overhaul Inspection

Refer to the Service Manual for the disassembly and assembly procedures that are necessary in order to perform the required maintenance on the items that are listed. Consult your Caterpillar dealer for assistance.

To determine the reusability publications that are needed to inspect the engine, refer to Guidelines for Reusable Parts and Salvage Operations, SEBF8029, "Index of Publications on Reusability or Salvage of Used Parts".

The Guidelines For Reusable Parts and Salvage Operations is part of an established Caterpillar parts reusability program. These guidelines were developed in order to assist Caterpillar dealers and customers reduce costs by avoiding unnecessary expenditures for new parts. If the engine parts comply with the established inspection specifications, the parts can be reused. New parts are not necessary if the old parts can be reused, repaired, or salvaged.

If the parts are not within the inspection specifications, the parts should be salvaged, repaired, replaced, or exchanged. The use of out-of-spec parts could result in unscheduled downtime and/or costly repairs. The use of out-of-spec parts can also contribute to increased fuel consumption and reduction of engine efficiency.

Your Caterpillar dealer can provide the parts that are needed to rebuild the engine at the least possible cost.

Overhaul Programs

An economical way to obtain most of the parts that are needed for overhauls is to use Caterpillar remanufactured parts. Caterpillar remanufactured parts are available at a fraction of the cost of new parts. These parts have been rebuilt by Caterpillar and certified for use. The following components are examples of the remanufactured parts:

- Alternators
- Connecting rods

- Crankshafts
- Cylinder heads
- Oil Pumps
- Starting motors
- Turbochargers
- Water pumps

Consult your Caterpillar dealer for details and for a list of the remanufactured parts that are available.

Your Caterpillar dealer may be offering a variety of overhaul options.

A Flat Rate Overhaul guarantees the maximum price that you will pay for an overhaul. Flat rate prices on preventive maintenance programs or major repair options are available from many servicing dealers for all Caterpillar Engines. Consult your Caterpillar dealer in order to schedule a before failure overhaul.

Overhaul Recommendation

Caterpillar recommends a scheduled overhaul in order to minimize downtime. A scheduled overhaul will provide the lowest cost and the greatest value. Schedule an overhaul with your Caterpillar dealer.

Overhaul programs vary between dealers. To obtain specific information about the types of overhaul programs and services, consult your Caterpillar dealer.

101506009

Power Take-Off Clutch - Check/Adjust/Lubricate

SMCS Code: 3055-036; 3055-086

NOTICE

New power take-offs should have the clutch adjustment checked before being placed into service. The clutch adjustment should be checked again after the first ten hours of operation. New clutch plates have a "wear in" period, and the clutch may require several adjustments until the new plates are "worn in".

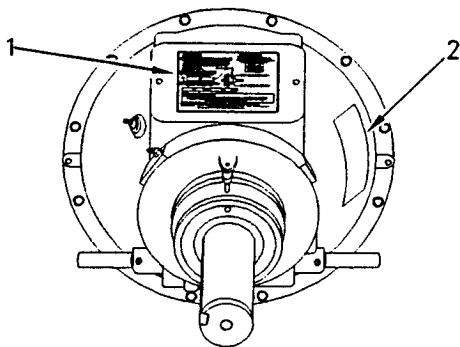


Illustration 86

g00781502

- (1) Instruction plate
- (2) Serial number plate

Check the clutch adjustment regularly after "wear in". Heavy-duty applications which have engagements that are frequent and relatively long periods of clutch slippage require more frequent adjustment than light-duty applications. The operating torque should be measured in order to determine if a clutch adjustment is required.

Refer to the OEM information and instruction plate (1) for instructions on lubrication, adjustment, and other recommendations for service. Perform the maintenance that is specified on the instruction plate.

! WARNING

Do not operate the engine with the Instruction Plate cover removed from the clutch. Personal injury may result.

If the clutch is damaged to the point of burst failure, expelled pieces can cause personal injury to anyone in the immediate area. Proper safeguards must be followed to help prevent accidents.

i01604510

Radiator - Clean

SMCS Code: 1353-070

Note: Adjust the frequency of cleaning according to the effects of the operating environment.

Inspect the radiator for these items: damaged fins, corrosion, dirt, grease, insects, leaves, oil, and other debris. Clean the radiator, if necessary.

! WARNING

Personal injury can result from air pressure.

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

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

Pressurized air is the preferred method for removing loose debris. Direct the air in the opposite direction of the fan's air flow. Hold the nozzle approximately 6 mm (0.25 inch) away from the fins. Slowly move the air nozzle in a direction that is parallel with the tubes. This will remove debris that is between the tubes.

Pressurized water may also be used for cleaning. The maximum water pressure for cleaning purposes must be less than 275 kPa (40 psi). Use pressurized water in order to soften mud. Clean the core from both sides.

Use a degreaser and steam for removal of oil and grease. Clean both sides of the core. Wash the core with detergent and hot water. Thoroughly rinse the core with clean water.

After cleaning, start the engine and accelerate the engine to high idle rpm. This will help in the removal of debris and drying of the core. Stop the engine. Use a light bulb behind the core in order to inspect the core for cleanliness. Repeat the cleaning, if necessary.

Inspect the fins for damage. Bent fins may be opened with a "comb". Inspect these items for good condition: welds, mounting brackets, air lines, connections, clamps, and seals. Make repairs, if necessary.

For more detailed information on cleaning and inspection, refer to Special Publication, SEBD0518, "Know Your Cooling System".

i01631430

Speed Sensor - Clean/Inspect

SMCS Code: 1907-040; 1907-070

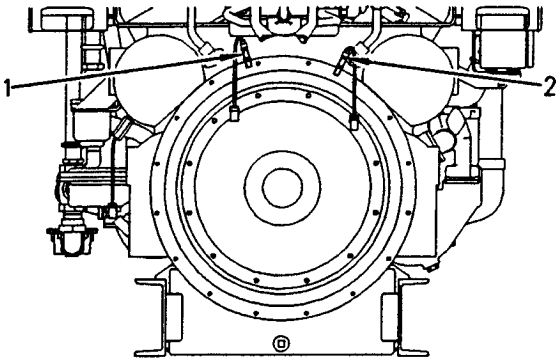


Illustration 87

g00845023

- (1) Speed sensor for the governor
(2) Speed sensor for the service meter

1. Remove the speed sensors from the flywheel housing. Inspect the condition of the ends of the sensors. Check for signs of wear and contaminants.
2. Clean the metal shavings and other debris from the faces of the sensors.

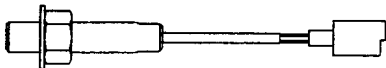


Illustration 88

g00318744

Speed sensor

3. Install the speed sensor in the flywheel housing. Turn the sensor clockwise until the sensor contacts the teeth of the flywheel ring gear.
4. Turn the sensor 1/2 of a turn (180 degrees) counterclockwise. Maintain a clearance of 0.56 mm (.022 inch) to 0.84 mm (.033 inch) between the sensor and the teeth of the flywheel ring gear. Tighten the locknut to 45 ± 7 N·m (33 ± 5 lb ft).

i01113939

Starting Motor - Inspect

SMCS Code: 1451-040; 1453-040

If the starting motor fails, the engine may not start in an emergency situation. A scheduled inspection of the starting motor is recommended.

The starting motor pinion and the flywheel ring gear must be in good condition in order for the engine to start properly. The engine will not start if the starting motor pinion does not engage the flywheel ring gear. The teeth of the starting motor pinion and the flywheel ring gear can be damaged because of irregular engagement.

Inspect the starting motor for proper operation. Listen for grinding when the engine is started. Inspect the teeth of the starting motor pinion and the flywheel ring gear. Look for patterns of wear on the teeth. Look for teeth that are broken or chipped. If damaged teeth are found, the starting motor pinion and the flywheel ring gear must be replaced.

Electric Starting Motor

Note: Problems with the electric starting motor can be caused by the following conditions: malfunction of the solenoid and malfunction of the electric starting system.

Inspect the electrical system for the following conditions:

- Loose connections
- Corrosion
- Wires that are worn or frayed
- Cleanliness

Make repairs, if necessary.

Air Starting Motor

WARNING

Personal injury or death can result from improperly checking for a leak.

Always use a board or cardboard when checking for a leak. Escaping air or fluid under pressure, even a pin-hole size leak, can penetrate body tissue causing serious injury, and possible death.

If fluid is injected into your skin, it must be treated immediately by a doctor familiar with this type of injury.

Inspect all of the components in the air circuit for the starting motor. Inspect all of the air lines and connections for leaks.

If the teeth of the starting motor pinion and/or the flywheel ring gear are damaged, the air circuit for the starting motor must be examined in order to determine the cause of the problem.

Removal and Installation of the Starting Motor

Refer to the Service Manual, "Disassembly and Assembly" module for information on removing the starting motor and installing the starting motor.

Consult your Caterpillar dealer for assistance.

i01454354

Turbocharger - Inspect

SMCS Code: 1052-040

Periodic inspection and cleaning is recommended for the turbocharger. Fouling of the turbine wheels can contribute to loss of engine power and overall loss of engine efficiency.

If the turbocharger fails during engine operation, damage to the turbocharger compressor wheel and/or to the engine may occur. Damage to the turbocharger compressor wheel could allow parts from the compressor wheel to enter an engine cylinder. This can cause additional damage to the pistons, the valves, and the cylinder head.

NOTICE

Turbocharger bearing failures can cause large quantities of oil to enter the air inlet and exhaust systems. Loss of engine lubricant can result in serious engine damage.

Minor leakage of a turbocharger housing under extended low idle operation should not cause problems as long as a turbocharger bearing failure has not occurred.

When a turbocharger bearing failure is accompanied by a significant engine performance loss (exhaust smoke or engine rpm up at no load), do not continue engine operation until the turbocharger is repaired or replaced.

An inspection of the turbocharger can minimize unscheduled downtime. Also, the chance for potential damage to other engine parts is reduced.

Note: Turbocharger components require clearances that are precise. The turbocharger cartridge must be balanced due to high rpm.

The following conditions can cause the turbocharger to be out-of-balance:

- The buildup of deposits
- Chipping and/or flaking of deposits

If the turbocharger must be removed for inspection, use caution. Do not break deposits from the turbine wheel. Do not attempt to clean the turbine wheel. For options regarding removal, installation, repair and replacement, see the Service Manual or consult your Caterpillar dealer.

1. Remove the exhaust outlet piping and remove the air inlet piping from the turbocharger. Visually inspect the piping for the presence of oil.
2. Turn the compressor wheel and the turbine wheel by hand. The assembly should turn freely. Inspect the compressor wheel and the turbine wheel for contact with the turbocharger housing. There should not be any visible signs of contact between the turbine wheel or compressor wheel and the turbocharger housing. If there is any indication of contact between the rotating turbine wheel or the compressor wheel and the turbocharger housing, the turbocharger should be reconditioned.

3. Check the compressor wheel for cleanliness. If only the inlet side of the wheel is dirty, dirt and/or moisture is passing through the air filtering system. If oil is found only on the back side of the wheel, there is a possibility of a failed turbocharger oil seal.

The presence of oil may be the result of extended engine operation at low idle. The presence of oil may also result from restriction of the inlet air (plugged air filters). This causes oil to leak past the seal for the turbocharger compressor.

If oil is found on the compressor wheel and/or at the air inlet, the source of the oil is the fuel compressor or the PCV system.

Note: Deposits of ash and silicone can accumulate on the turbine wheel. Turbine wheel will become unbalanced when the deposits flake off. The turbocharger cartridge must be replaced when this occurs. However, remove deposits from the housing. This will prevent wear on the blades of the new turbine wheel.

4. Inspect the turbine wheel and the nozzle for deposits of ash and silicone. If deposits of 1.6 mm (0.06 inch) thickness are found or if the turbine is in contact with the housing, the turbocharger must be disassembled and cleaned. Removal of the deposits can be difficult.
5. Inspect the bore of the turbine housing for corrosion and deposits.
6. Clean the turbocharger compressor housing with standard shop solvents and a soft bristle brush.
7. Fasten the air inlet piping and the exhaust outlet piping to the turbocharger housing.

- Measure the projection of the valve rotator above the cylinder head. It is not necessary to remove the rocker arms in order to obtain this measurement.

Measure the projection of the exhaust valve rotators with the 155 - 1536 Valve Recession Tool Group. Follow the instructions that are provided with the tool group.

Record the measurements on the Operation and Maintenance Manual, "Valve Data Sheet" (Reference Materials Section).

- Measure the projection of the exhaust valve rotators after 100 to 200 service hours. This measurement is the baseline. The baseline is a reference for subsequent measurements.
- Measure the projection of the exhaust valve rotators at the first 1000 service hours. Illustration 89 shows schedules for determining subsequent intervals.

i01492440

Valve Stem Projection - Measure/Record

SMCS Code: 1105-082

Valve Recession – The valves and the valve seats are worn over time. This causes the valves to recede into the cylinder head. This condition is called "valve recession".

The exhaust valves and valve seats show the greatest wear. The top end overhaul is scheduled according to the recession of the exhaust valves.

It is difficult to measure the actual valve recession in the cylinder head. A simpler method is used to determine the valve recession:

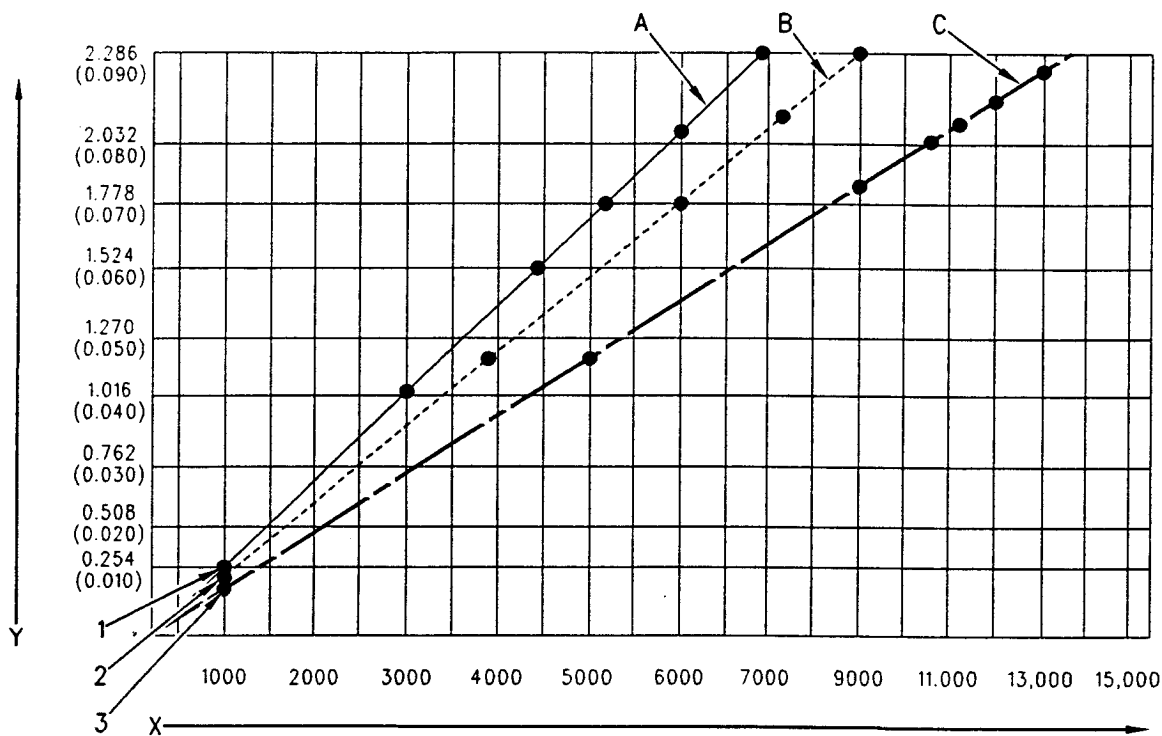


Illustration 89

g00792504

(A) Schedule
(B) Schedule
(C) Schedule

(Y) Valve recession in millimeters (inches)
(X) Hours of operation
(1) 0.254 mm (0.0100 inch)

(2) 0.218 mm (0.0086 inch)
(3) 0.152 mm (0.0060 inch)

To determine intervals, use the point on the graph in Illustration 89 that is closest to the measurement for each cylinder.

i01492446

For example, suppose that the measurement that was obtained at the initial 1000 hours shows a valve recession of approximately 0.152 mm (0.0060 inch). According to Schedule (C), the next interval for measuring that cylinder is at 5000 service hours. Another cylinder may have a valve recession of approximately 0.254 mm (0.0100 inch). According to Schedule (A), the next interval for measuring that cylinder is at 3000 service hours.

- After 70 percent of the maximum limit has been reached, measure the projection of the exhaust valve rotators at every 1000 hours of operation. The 70 percent is 1.60 mm (0.063 inch).
- Plan for the top end overhaul as the projection of the valve rotator approaches the maximum limit. Perform the top end overhaul when the projection of the valve rotator has increased by a total of 2.3 mm (0.09 inch). **Do not allow the recession of the exhaust valves to exceed this limit.** The valve head can break. This will cause severe damage in the combustion chamber.

Consult your Caterpillar dealer for assistance.

Walk-Around Inspection

SMCS Code: 1000-040

Inspect the Engine for Leaks and for Loose Connections

A walk-around inspection should only take a few minutes. When the time is taken to perform these checks, costly repairs and accidents can be avoided.

For maximum engine service life, thoroughly inspect the engine room before starting the engine. Look for items such as leaks, loose bolts, loose connections and trash buildup. Make repairs, as needed.

- The guards must be in the proper place. Repair damaged guards or replace missing guards.
- Wipe all caps and plugs before the engine is serviced in order to reduce the chance of system contamination.

NOTICE

For any type of leak, clean up the fluid. If leaking is observed, find the source and correct the leak. If leaking is suspected, check the fluid levels more often than recommended until the leak is found or fixed, or until the suspicion of a leak is proved to be unwarranted.

NOTICE

Accumulated grease and/or oil on an engine or deck is a fire hazard. Remove this debris with steam cleaning or high pressure water.

- Ensure that cooling lines are properly clamped. Check for leaks. Check the condition of all pipes.
- Inspect the water pumps for coolant leaks.

Note: The water pump seal is lubricated by coolant in the cooling system. It is normal for a small amount of leakage to occur when the engine cools and the parts contract.

Excessive coolant leakage may indicate the need to replace the water pump seal. For instructions on removal and installation of water pumps and/or seals, refer to the Service Manual, "Disassembly and Assembly" module for the engine or consult your Caterpillar dealer.

- Inspect the lubrication system for leaks at the front crankshaft seal, the rear crankshaft seal, the oil pan, the oil filters and the valve covers.



WARNING

NEVER use a flame to check for gas leaks. Use a gas detector.

An open flame can ignite mixtures of air and fuel. This will cause explosion and/or fire which could result in severe personal injury or death.

- Check the fuel system for leaks. Look for loose fuel line clamps.
- Inspect the piping for the air inlet system and the elbows for cracks and for loose clamps.
- Inspect the wiring and the wiring harnesses for loose connections and for worn wires or frayed wires.
- Inspect the ground straps for good connections and for good condition.
- Check the condition of the gauges. Replace any gauge that is damaged. Replace any gauge that can not be calibrated.

- Inspect the exhaust system for leaks. If a leak is found, make repairs.

i00991247

Walk-Around Inspection

SMCS Code: 1000-040

S/N: 6JW1-Up

S/N: 8PW1-Up

S/N: 9AW1-Up

A walk-around inspection should only take a few minutes. When the time is taken to perform these checks, costly repairs and accidents can be avoided.

For maximum service life of the equipment, make a thorough inspection of the installation before starting the engine. Look for items such as oil leaks or coolant leaks, loose bolts, worn belts, loose connections and trash buildup. Make repairs, as needed.

- Inspect the engine and the compressor according to the information that is provided by the OEM of the equipment.
- The guards must be in the proper place. Repair damaged guards or replace missing guards.
- Wipe all caps and plugs before the engine is serviced in order to reduce the chance of system contamination.

NOTICE

For any type of leak (coolant, lube, or fuel) clean up the fluid. If leaking is observed, find the source and correct the leak. If leaking is suspected, check the fluid levels more often than recommended until the leak is found or fixed, or until the suspicion of a leak is proved to be unwarranted.

NOTICE

Accumulated grease and/or oil on an engine or deck is a fire hazard. Remove this debris with steam cleaning or high pressure water.

- Ensure that cooling lines are properly clamped. Check for leaks. Check the condition of all pipes.
- Inspect the equipment for dirt and debris.

Inspecting During Operation

After starting the chiller, listen for excessive noise and/or unusual noise. Inspect the gearbox for oil leaks and for excessive vibration.

Monitor the Gauges

During operation, monitor the following parameters:

- Aftercooler inlet water temperature
- Engine rpm
- Gearbox oil temperature
- Gearbox oil pressure
- Inlet manifold air pressure
- Inlet manifold air temperature
- Jacket water temperature
- Pressure of the air control for the clutch

Maintain a log of the data as a permanent record. Compare the new data to the data that was previously recorded. Investigate any significant changes.

Check the Gearbox Oil Level

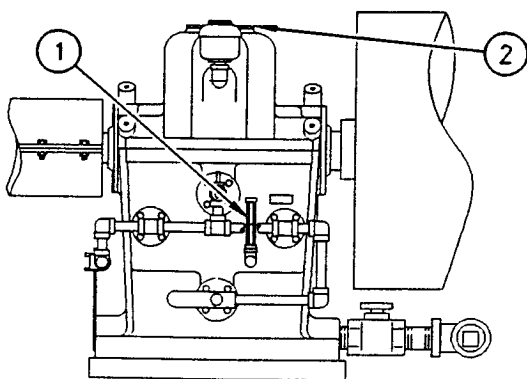


Illustration 90

g00505113

- (1) Sight gauge
(2) Cover

A sight gauge is mounted on the side of the gearbox. The sight gauge has an upper mark and a lower mark. Observe the oil level in the sight gauge.

When the chiller is NOT operating, the oil level should be approximately 2 cm (3/4 inch) above the upper mark.

When the chiller IS operating, the oil level should be between the upper mark and the lower mark.

Add oil, if necessary. The cover of the gearbox must be removed in order to add oil. If the equipment is operating, stop the operation. Attach a "DO NOT OPERATE" tag or a similar warning tag to the controls. Remove the cover of the gearbox and pour the correct amount of oil into the gearbox. For the correct oil to use, see this Maintenance Manual, "Lubricant Specifications" topic.

Inspect the Indicator for the Gearbox Oil Filter

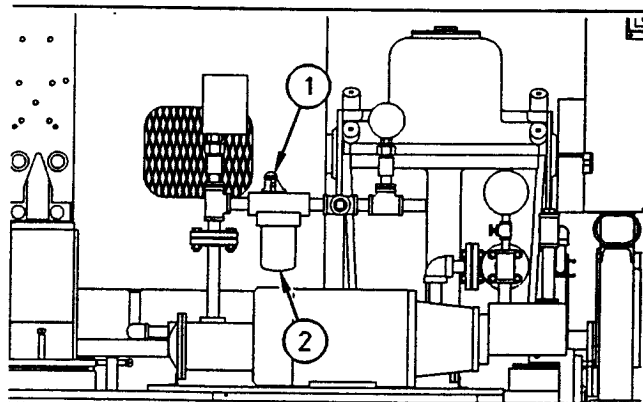


Illustration 91

g00500366

- (1) Indicator
(2) Filter

Change the filter when the plunger of the indicator rises to the red range. For instructions, see this Maintenance Manual, "Gearbox Oil and Oil Filter - Change" topic.

100524084

Water Pump - Inspect

SMCS Code: 1361-040

A failed water pump might cause severe engine overheating problems that could result in cracks in the cylinder head, a piston seizure or other potential damage to the engine.

Visually inspect the water pump for leaks. If leaking of the water pump seals is observed, replace all of the water pump seals. Refer to the Service Manual for the disassembly and assembly procedure.

Inspect the water pump for wear, cracks, pin holes and proper operation. Refer to the Service Manual or consult your Caterpillar dealer if repair is needed or replacement is needed.

i01665404

Water Temperature Regulator - Replace

SMCS Code: 1355-510

Replace the Water Temperature Regulators in the Water Temperature Regulator Housing and in the Thermostatic Valve

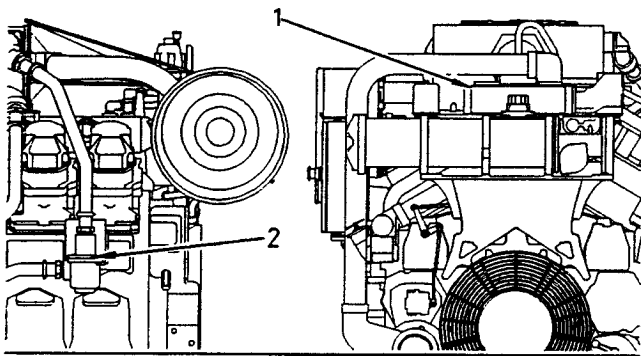


Illustration 92

g00787738

Replace the water temperature regulators before the water temperature regulators fail. This is a recommended preventive maintenance practice. Replacing the water temperature regulators reduces the chances for unscheduled downtime.

A water temperature regulator that fails in a partially opened position can cause overheating or overcooling of the engine.

A water temperature regulator that fails in the closed position can cause excessive overheating. Excessive overheating could result in cracking of the cylinder head or a seizure of the pistons.

A water temperature regulator that fails in the open position will cause the engine operating temperature to be too low during partial load operation. Low engine operating temperatures during partial loads could cause an excessive carbon buildup inside the cylinders. This excessive carbon buildup could result in an accelerated wear of the piston rings and wear of the cylinder liner. Also, a low temperature can allow moisture to condense in the oil. This can form damaging acids.

NOTICE

Failure to replace the water temperature regulator on a regularly scheduled basis could cause severe engine damage.

Never operate an engine without the water temperature regulator installed.

If the water temperature regulator is installed incorrectly, the engine may overheat, causing cylinder head damage. Ensure that the new water temperature regulator is installed in the original position.

For the procedure to replace the water temperature regulators, see the Service Manual, "Disassembly and Assembly" module. Consult your Caterpillar dealer for assistance.

Note: If only the water temperature regulators are replaced, drain the coolant from the cooling system to a level that is below the water temperature regulator housing.

Reference Information Section

Customer Service

Customer Assistance

i01452711

SMCS Code: 1000

USA and Canada

When a problem arises concerning the operation of an engine or concerning the service of an engine, the problem will normally be managed by the dealer in your area.

Your satisfaction is a primary concern to Caterpillar and to Caterpillar dealers. If you have a problem that has not been handled to your complete satisfaction, follow these steps:

1. Discuss your problem with a manager from the dealership.
2. If your problem cannot be resolved at the dealer level without additional assistance, use the phone number that is listed below to talk with a Field Service Coordinator:

1-800-447-4986

The normal hours are from 8:00 to 4:30 Monday through Friday Central Standard Time.

3. If your needs have not been met still, submit the matter in writing to the following address:

Caterpillar Inc.
Manager, Customer Service, Engine Division
Mossville Bldg A
P.O. Box 600
Peoria, Illinois 61552-0600

Please keep in mind: probably, your problem will ultimately be solved at the dealership, using the dealership's facilities, equipment, and personnel. Therefore, follow the steps in sequence when a problem is experienced.

Outside of the USA and of Canada

If a problem arises outside the USA and outside Canada, and if the problem cannot be resolved at the dealer level, consult the appropriate Caterpillar office.

Latin America, Mexico, Caribbean
Caterpillar Americas Co.
701 Waterford Way, Suite 200
Miami, FL 33126
USA
Phone: 305-476-6876
Fax: 305-476-6850

Europe, Africa, and Middle East
Caterpillar Overseas S.A.
76 Route de Frontenex
P.O. Box 6000
1211 Geneva 6
Switzerland
Phone: 22-849-4444
Fax: 22-849-4544

Far East
Caterpillar Asia Pte. Ltd.
7 Tractor Road
Jurong, Singapore 627968
Republic of Singapore
Phone: 65-662-8333
Fax: 65-662-8302

China
Caterpillar China Ltd.
37/F, The Lee Gardens
33 Hysan Avenue
Causeway Bay, Hong Kong
China
Phone: 852-2848-0333
Fax: 852-2848-0440

Japan
Shin Caterpillar Mitsubishi Ltd.
Setagaya Business Square Tower
10-1, Yoga 4-chome
Setagaya, Tokyo
Japan
Phone: 81-3-5717-1121
Fax: 81-3-5717-1177

Japan
Caterpillar Power Systems, Inc.
Japan Branch Sanno Grand Bldg.
2-14-2 Nagatacho
Chiyoda-ku, Tokyo, 100
Japan
Phone: 81-335-93-3237
Fax: 81-335-93-3238

Australia and New Zealand
Caterpillar of Australia Ltd.
1 Caterpillar Drive
Private Mail Bag 4
Tullamarine, Victoria 3043
Australia
Phone: 03-9339-9333
Fax: 03-9335-3366

i01028392

Ordering Replacement Parts

SMCS Code: 7567

WARNING

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

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

Quality Caterpillar replacement parts are available from Caterpillar dealers throughout the world. Caterpillar dealers' parts inventories are up-to-date. The parts stocks include all of the parts that are normally needed to protect your Caterpillar engine investment.

When you order parts, please specify the following information:

- Part number
- Part name
- Quantity

If there is a question concerning the part number, please provide your dealer with a complete description of the needed item.

When a Caterpillar engine requires maintenance and/or repair, provide the dealer with all the information that is stamped on the Information Plate. This information is described in this Operation and Maintenance Manual (Product Information Section).

Discuss the problem with the dealer. Inform the dealer about the conditions of the problem and the nature of the problem. Inform the dealer about when the problem occurs. This will help the dealer in troubleshooting the problem and solving the problem faster.

Reference Materials

- Owner's receipts
- Maintenance log

i00912149

Maintenance Records

SMCS Code: 1000

Caterpillar Inc. recommends the retention of accurate maintenance records. Accurate maintenance records can be used for the following purposes:

- Determine operating costs.
- Establish maintenance schedules for other engines that are operated in the same environment.
- Show compliance with the required maintenance practices and maintenance intervals.

Maintenance records can be used for a variety of other business decisions that are related to engine maintenance.

Maintenance records are a key element of a maintenance program that is well managed. Accurate maintenance records can help your Caterpillar dealer to fine tune the recommended maintenance intervals in order to meet the specific operating situation. This should result in a lower engine operating cost.

Records should be kept for the following items:

Fuel Consumption – A record of fuel consumption is essential in order to determine when the load sensitive components should be inspected or repaired. Fuel consumption also determines overhaul intervals.

Service Hours – A record of service hours is essential to determine when the speed sensitive components should be inspected or repaired.

Documents – These items should be easy to obtain, and these items should be kept in the engine history file. All of the documents should show this information: date, service hours, fuel consumption, unit number, and engine serial number. The following types of documents should be kept as proof of maintenance or repair for warranty:

Keep the following types of documents as proof of maintenance for warranty. Also, keep these types of documents as proof of repair for warranty:

- Dealer work orders and itemized bills
- Owner's repair costs

i00769479

Valve Data Sheet

SMCS Code: 1000

Table 45

Engine Model		Serial Number	Service Hours		Authorization	
Cylinder	Cylinder Pressure	Valve Location	Current Measure	Stem Baseline	Rotator Baseline	Wear
1		Pushrod Side				
		Exhaust Manifold				
2		Pushrod Side				
		Exhaust Manifold				
3		Pushrod Side				
		Exhaust Manifold				
4		Pushrod Side				
		Exhaust Manifold				
5		Pushrod Side				
		Exhaust Manifold				
6		Pushrod Side				
		Exhaust Manifold				
7		Pushrod Side				
		Exhaust Manifold				
8		Pushrod Side				
		Exhaust Manifold				
9		Pushrod Side				
		Exhaust Manifold				
10		Pushrod Side				
		Exhaust Manifold				
11		Pushrod Side				
		Exhaust Manifold				
12		Pushrod Side				
		Exhaust Manifold				
13		Pushrod Side				
		Exhaust Manifold				
14		Pushrod Side				
		Exhaust Manifold				
15		Pushrod Side				
		Exhaust Manifold				
16		Pushrod Side				
		Exhaust Manifold				

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Reference Material

SMCS Code: 1000

The following literature can be obtained through any Caterpillar dealer.

Lubricants

- Data Sheet, PEHP0002, "Multipurpose Lithium Complex Grease with Molybdenum (MPGM)"
- Data Sheet, PEHP0003, "Multipurpose Lithium Complex Grease (MPG)"
- Data Sheet, PEHP0017, "Special Purpose Grease (SPG) Bearing Lubricant"
- Special Publication, PECP6026, "One Safe Source"
- Special Publication, PEDP7036, "S·O·S Fluid Analysis"
- Special Publication, PEHP6001, "How To Take A Good Oil Sample"

Fuels

- Application and Installation Guide, LEKQ7256, "Fuels, Fuel Systems"
- Application and Installation Guide, LEKQ7260, "Low Energy Fuels"

Coolants

- Data Sheet, PEHP7057, "Coolant Analysis"
- Special Publication, PECP6026, "One Safe Source"
- Special Publication, PEDP7036, "S·O·S Fluid Analysis"
- Special Publication, SEBD0518, "Know Your Cooling System"
- Special Publication, SEBD0970, "Coolant and Your Engine"

Miscellaneous

- Application and Installation Guide, LEKQ7250, "Air Intake"
- Application and Installation Guide, LEKQ7260, "Low BTU Engines"

- Engine Performance, LEBQ6117, "G3500 Industrial"
- Engine Performance, LEBQ6169, "G3500 Generator Set"
- Electronic Troubleshooting, SENR6413, "G3500 Engines"
- Disassembly and Assembly, SENR6419, "G3500 Engines"
- Electronic Troubleshooting, SENR6517, "G3500 Air/Fuel Ratio Control"
- Maintenance Management Schedules, SEBU6127, "Schedules for Industrial and EPG Spark Ignited Gas Engines"
- Service Manual, REG1139F, "Service Manual Contents Microfiche"
- Software Program, LEKQ6378, "Methane Number Program"
- Specifications, SENR3130, "Torque Specifications"
- Specifications, SENR6411, "G3500 Engines"
- Specifications, SENR6417, "G3500 Engine Attachments"
- Special Instruction, GMG00694, "Analyzing Cylinder Condition By Measuring Air Flow"
- Special Instruction, REHS0128, "Using the 147-5482 Indicator Gauge For Valve Lash and Valve Bridge Adjustment"
- Special Instruction, SEHS7332, "Do Not Operate Tag"
- Special Instruction, SEHS7633, "Battery Test Procedure"
- Special Instruction, SEHS7768, "Use of the 6V-2150 Starting/Chargineg Analyzer"
- Special Instruction, SEHS8622, "Using the FT-1984 Air-To-Air Aftercooler Leak Test Group"
- Special Instruction, SEHS8712, "Using the 8T-2700 Blowby/Airflow Indicator Group"
- Special Instruction, SEHS9031, "Storage Procedure for Caterpillar Products"
- Special Instruction, SEHS9298, "Installation and Maintenance of Gaseous Fuel Filters"

- Special Instruction, SEHS9769, "Installation and Initial Start-Up Procedure for G3500 Engines"
- Special Publication, NEHS0526, "Service Technician Application Guide"
- Special Publication, NENG2500, "Caterpillar Tools and Shop Products Guide"
- Special Publication, SEBF8029, "Index to Guidelines for Reusable Parts and Salvage Operations"
- Special Publication, SEBF8062, "Procedure to Inspect and Clean Air Filters"
- Systems Operation/Testing and Adjusting, SENR6412, "G3500 Engines"
- Systems Operation/Testing and Adjusting, SENR6418, "G3500 Engine Attachments"
- Systems Operation/Testing and Adjusting, SENR6420, "Remote Control Panel (Status)"

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Additional Reference Material

SMCS Code: 1000

The "EMA Lubricating Oils Data Book" can be obtained from the following locations: local technological society, local library, and local college. If necessary, consult EMA at the following address:

Engine Manufacturers Association
401 N. Michigan Ave.
Chicago, IL, USA 60611
Telephone: (312) 644-6610 ext. 3626

The "Society of Automotive Engineers (SAE) Specifications" can be found in your SAE handbook. This publication can also be obtained from the following locations: local technological society, local library, and local college. If necessary, consult SAE at the following address:

SAE International
400 Commonwealth Drive
Warrendale, PA, USA 15096-0001
Telephone: (724) 776-4841

The "American Petroleum Institute Publication No. 1509" can be obtained from the following locations: local technological society, local library, and local college. If necessary, consult API at the following address:

American Petroleum Institute
1220 L St. N.W.
Washington, DC, USA 20005
Telephone: (202) 682-8000

The International Organization for Standardization (ISO) offers information and customer service regarding international standards and standardizing activities. ISO can also supply information on the following subjects that are not controlled by ISO: national standards, regional standards, regulations, certification, and related activities. Consult the member of ISO in your country.

International Organization for Standardization (ISO)
1, rue de Varembe
Case postale 56
CH-1211 Genève 20
Switzerland
Telephone: +41 22 749 01 11
Facsimile: +41 22 733 34 30
E-mail: central@iso.ch
Web site: <http://www.iso.ch>

European classifications are established by the Conseil International Des Machines a Combustion (CIMAC) (International Council on Combustion Engines).

CIMAC Central Secretariat
Lyoner Strasse 18
60528 Frankfurt
Germany
Telephone: +49 69 6603 1567
Facsimile: +49 69 6603 1566

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Warranty Information

SMCS Code: 1000

Engine Protection Plans

Extended Warranties and Service Contracts

A wide variety of protection plans are available for Caterpillar Engines. Consult your Caterpillar dealer for detailed information on the specific programs and coverages that are available.

Consult your Caterpillar dealer for information on a plan that is tailored in order to fit your requirements.

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