KNOW YOUR COOLING SYSTEM

CATERPILLAR®

Contents

Contents

Foreword

Diesel engine manufacturers have increased engine operating temperatures to improve engine efficiency. This increase in temperature means proper cooling system maintenance is especially important. Overheating, overcooling, pitting, cavitation-erosion, cracked heads, piston seizures, and plugged radiators are classic cooling system failures.

Proper coolant selection and maintenance are your choice, and coolant is vital to successful engine service life. In fact, coolant is as important as the quality of your fuel and lubricating oil.

This booklet tells the coolant story: its composition, contamination, and typical consequences. This booklet also offers preventive measures to help you avoid the costly effects of coolant related failures.

NOTE: Always check the latest Service Information for updates to ensure that the most current specifications and test procedures are used.

Understanding Cooling Systems

Proper cooling system design and maintenance is an important part of the satisfactory operation and service life of an engine. Understanding how the cooling system works can help reduce owning and operating costs.

Function

The temperature of burning fuel in Caterpillar Engines can reach 1927° C (3,500° F). However, only about 33% of this total heat is converted into crankshaft horsepower. Approximately 30% is expelled through exhaust, while another 7% is radiated directly into the atmosphere from engine surfaces. The remaining 30% must be dissipated through a carefully designed cooling system.

The cooling system must remove heat in order to keep the engine at the correct operating temperature. The cooling system must not remove too much heat or the engine will run cold.

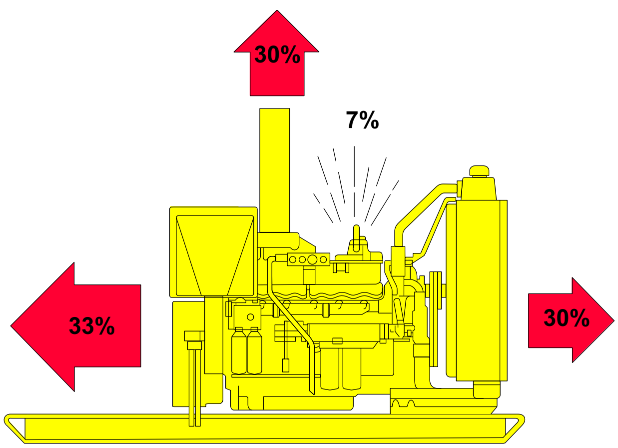


Fig. 1: Proportional amount of heat dissipated from engine.

In addition to removing heat generated from fuel combustion, in some applications, the cooling system must also remove heat from other sources.

Other components that transfer heat to the coolant include:

- transmission oil coolers
- hydraulic oil coolers
- aftercoolers
- water-cooled exhaust manifolds
- water-cooled turbocharger shields and housings
- marine gear oil coolers
- torque converter/retarder coolers

The cooling system has a direct effect on the operation and service life of the engine. Overheating or overcooling can result from the following conditions:

- The cooling system is not the correct size
- Poor maintenance of the cooling system
- Incorrect operation of the engine

Overheating or overcooling can shorten the engine service life. Overheating or overcooling can also cause poor engine performance. Find the cause of any problem in the cooling system and correct the problem immediately.

Thus, the function of the cooling system is to remove the proper amount of heat to keep the engine running at correct operating temperatures. This function is vital to the operation of an internal combustion engine.

Function of Components

There are many types of cooling systems. Most cooling systems use a radiator and a fan to remove the heat from the engine and other systems on a machine. Other types of cooling systems use a heat exchanger, keel coolers, or cooling towers to remove heat.

Figure 2 shows the basic components of most cooling systems. These basic components are: coolant, the water pump, the engine oil cooler, water temperature regulators in the thermostat housing, the fan, and the radiator. In normal operation, the water pump pushes coolant through the engine oil cooler and into the cylinder block. The coolant then flows through the cylinder block and into the cylinder head or heads where it flows to the hot areas of the cylinder head. After flowing through the cylinder head or heads, the coolant goes into the thermostat housing.

When the engine is cold, the temperature regulators prevent the flow of coolant to the radiator and direct the coolant back to the water pump. As the temperature of the coolant becomes warmer, the temperature regulators begin to open and permit some flow of coolant to the radiator.

The regulator opens to maintain the correct engine temperature. The amount that the regulator opens and the percent of coolant flow to the radiator depends on the temperature of the coolant that in turn is determined by the load on the engine and the outside air temperature.

The fan pushes or pulls air through the radiator and around the tubes and fins that go from the top to the bottom of the radiator. (Some machines, such as lift trucks and highway trucks, can have cross flow radiator cores.)

When the hot coolant goes through the tubes in the radiator, the flow of air around the tubes and fins lowers the temperature of the coolant. The coolant then flows back through the water pump.

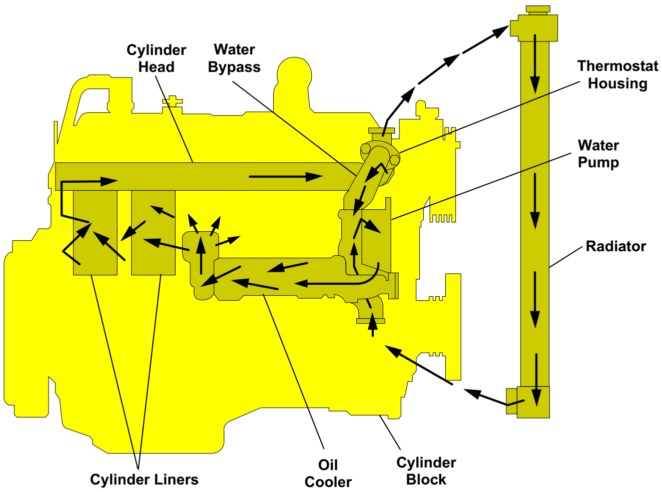


Fig 2: Typical Cooling System.

In many applications, there are other components that transfer heat to the coolant. These components can be aftercoolers, water cooled exhaust manifolds, water cooled turbocharger shields and housings, transmission oil coolers, torque converters, and marine transmission oil coolers.

In some cooling systems, a shunt line is used to maintain a positive water pressure at the water pump inlet. The shunt line also provides a path for filling the cooling system.

Some cooling systems use a radiator cap that seals the opening in the top tank or overflow tank and limits the pressure in the cooling system. Other cooling systems have a separate pressure relief valve to limit the pressure in the cooling system.

An orifice may be used between the thermostat and the radiator top tank for flow balance. If your cooling system is equipped with this system, it must not be changed or removed.

Most marine engines have an expansion tank and keel cooler or a heat exchanger instead of a radiator or fan. A second water pump is used to push sea water through the heat exchanger and, in some applications, through an aftercooler.

In heat exchanger cooling systems, an expansion tank and heat exchanger perform the same function as the radiator. However, instead of transferring heat into the air, a heat exchanger system transfers coolant heat to an external water supply. In marine applications, a keel or skin cooler is used as an outboard heat exchanger. This cooler is either attached to the submerged part of a vessel's hull or built as part of the hull.

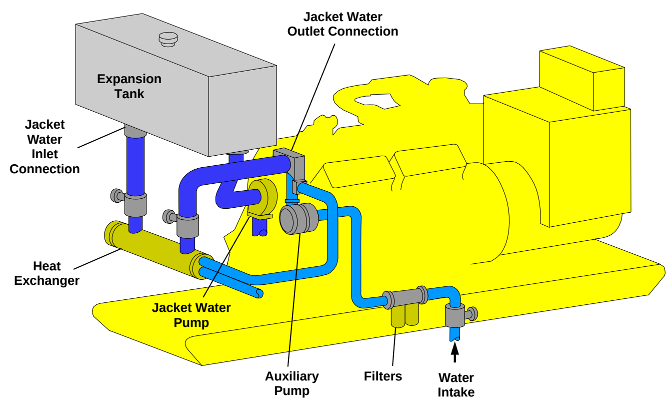
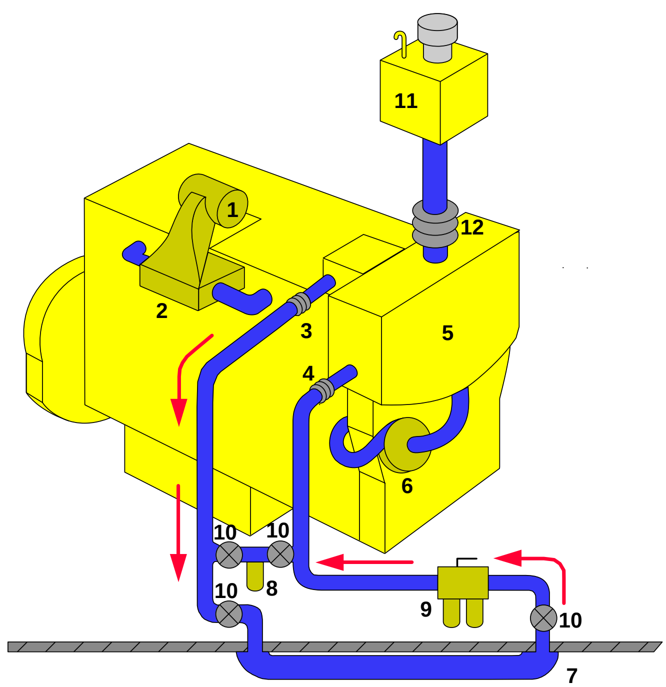


Fig. 3: Schematic of typical heat exchanger cooling system.



1. turbocharger
2. aftercooler, jacket water cooled
3. jacket water outlet connection
4. jacket water inlet connection
5. expansion tank
6. jacket water pump
7. keel cooler
8. bypass filter
9. duplex full-flow strainer
10. shut-off valve
11. auxiliary expansion tank
12. flexible connection

Fig. 4: Schematic of typical keel cooler cooling system.

Some machines use other cooler cores (radiators) to lower the temperature of transmission oil, hydraulic oil or air conditioning refrigerant. In most cases, the cores are upstream of the air flow to the radiator to get the coolest air. The additional cores increase the temperature of the air that passes through the radiator as well as increase the resistance to air flow. The additional cores also make it more difficult to thoroughly clean the radiator core. Recent design changes on some machines allow these additional cores to be easily swung to the side to allow better access to clean the radiator core.

Cooling System Temperature

Cooling systems are designed to keep an engine operating within a desired temperature range. The temperature of the coolant must remain high to allow the engine to operate efficiently. However, the temperature must stay low enough to prevent the coolant from boiling.

A cooling system regulates temperature by transferring heat from the engine to the coolant and, eventually, into the air (or external water supply). How quickly the system transfers heat from the coolant into the air directly affects the system's temperature. This rate of heat transfer at the radiator depends on many different factors.

A major factor of heat transfer is the difference between the temperature of coolant inside the radiator and the temperature of surrounding air. When the difference between coolant temperature and ambient temperature increases, the rate of heat transfer increases. Alternatively, when this temperature differential decreases, the rate of heat transfer declines.

If the coolant starts to boil or steam, coolant is pushed out of the radiator's pressure relief valve. This action lowers the level of coolant and leads to engine overheating. Once overheating begins, continued operation only worsens the condition.

Three factors can change the boiling temperature of the coolant.

- The amount and type of coolant
- The pressure in the cooling system
- The altitude or barometric pressure

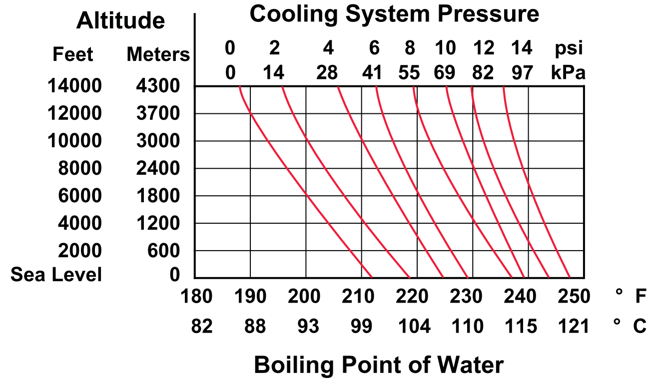


Fig 5: Pressure/temperature chart.

Increasing the pressure of the cooling system raises the boiling point of the coolant. For this reason, most cooling systems are designed to operate under pressure. The maximum amount of pressure is controlled by a valve in the radiator cap or the pressure relief valve.

A higher altitude causes a lower boiling point. Figure 5 shows the relationship of the altitude and the pressure in the cooling system with the boiling point. This chart is for water with no coolant.

For example, at 1800 meters (6,000 feet) above sea level, water boils at 93°C (200°F). But at 3700 meters (12,000 feet), water boils at only 88°C (190°F).

Boiling Point of Coolant at Varying Glycol Concentrations	
% Concentration	Temperature at which Coolant with Ethylene Glycol Will Boil(1)
20	103° C (217° F)
30	104° C (219° F)
40	106° C (223° F)
50	108° C (226° F)
60*	111° C (232° F)

(1) At sea level
* Caterpillar Recommends not to exceed 60% concentration

Fig 6: Coolant boiling point concentration chart.

Along with altitude and pressure, the type and the amount of coolant that is added to water also changes the boiling point. The boiling point is higher with higher concentrations of ethylene glycol in water when compared to propylene glycol based antifreeze in water. However, ethylene glycol is less effective than water at transferring heat. Use the correct concentration of ethylene glycol because of the effects on boiling point and heat transfer.

Factors That Affect the Cooling System

The rate of heat transfer from the radiator to the air is directly related to the difference between the coolant and air temperatures. High ambient air temperature causes the coolant temperature to be higher. Air density decreases as the altitude increases. Therefore, the rate of heat transfer to the air will decrease as the altitude increases. Because of this, higher altitudes cause higher coolant temperatures. However, ambient air temperatures normally decrease at higher altitudes, so the effects often counterbalance one another.

Sources of Heat

Operation of the machine in an overload condition can also cause overheating. The correct selection of gears is very important. If the machine is operated for a long period in a speed range that is near the stall speed of the torque converter, the cooling system can overheat. Under such conditions a large amount of heat is generated by the engine and/or torque converter while the speed of the fan and water pump are decreased.

Fuel combustion creates heat in all internal combustion engines. How much heat is determined by the API density and the amount of fuel used.

Cooling systems are generally designed to maintain proper operating temperature of the engine at full load conditions. If the load is increased with a drop in the rpm of the engine or if the rpm of the engine is decreased with no change in the load, the cooling system can overheat. In many applications, the cooling system must absorb heat from several other sources. Among those sources are: Engine Oil Coolers, Aftercoolers, Transmission or Torque Converter Oil Coolers, Retarder Coolers, Water Cooled Exhaust Manifolds, Water Cooled Turbocharger Shields, and Hydraulic Oil Coolers.

Fig. 7: Typical engine oil cooler.

Oil Coolers

Many engines, especially engines with turbochargers, have engine oil coolers. Most of the heat in the oil comes from oil that is sprayed on the bottom side of the pistons. The coolant must absorb enough heat in the oil cooler to prevent the oil from overheating. High temperature of pistons is caused by high inlet air temperatures, wrong injection timing, incorrect fuel settings, or low turbocharger boost, all of which increase the temperature of the oil.

Fig. 8: One type of aftercooler.

Aftercoolers

The air at the outlet of the turbocharger is at a higher temperature than the air at the inlet of the turbocharger. Some engines have an aftercooler to lower the temperature of turbocharger outlet air. Coolant is used in many aftercoolers to absorb the heat from the turbocharged air. If the aftercooler core has dirt or oil in it, the coolant cannot absorb as much heat as it does normally. This can raise piston temperature and lower engine horsepower.

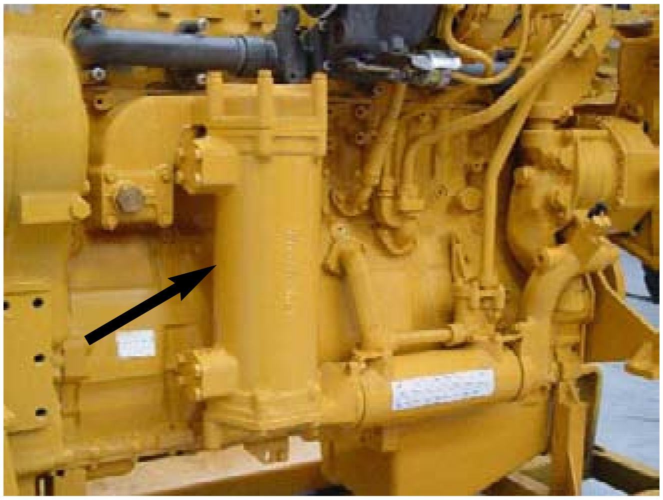


Fig. 9: Typical transmission oil cooler.

Transmission, Marine Transmission or Torque Converter Oil Coolers

The operation of transmissions, marine transmissions, and torque converters generates heat. Most of the heat in transmissions and marine transmissions is caused by the churning of oil. Normally, the amount of heat will increase with load, because some heat is generated by gears meshing. For torque converters, much of the heat is caused by shearing of oil between moving parts. The greatest amount of heat is generated when the torque converter operates near stall speed. A significant amount of heat is also generated in the torque converter when the machine runs at high speed with no load - usually downhill.

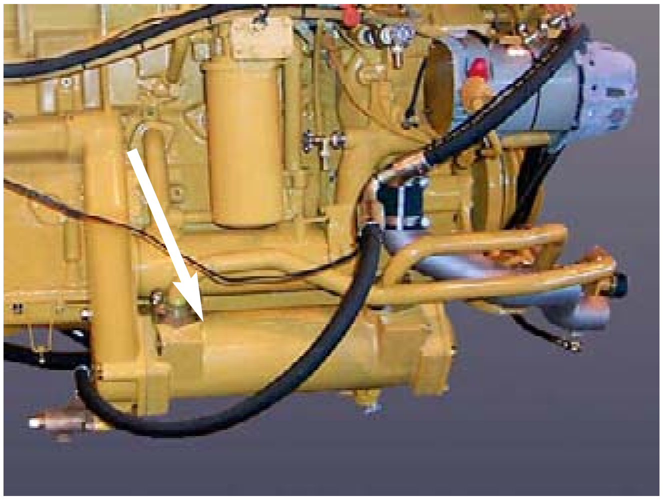


Fig. 10: Combination retarder/transmission oil cooler.

Retarder Coolers

Some machines have a retarder that can be used to help slow the machine on a downslope. Use of this retarder causes heat in the retarder oil. It is important that proper engine speed and transmission speed range are used when using the retarder.

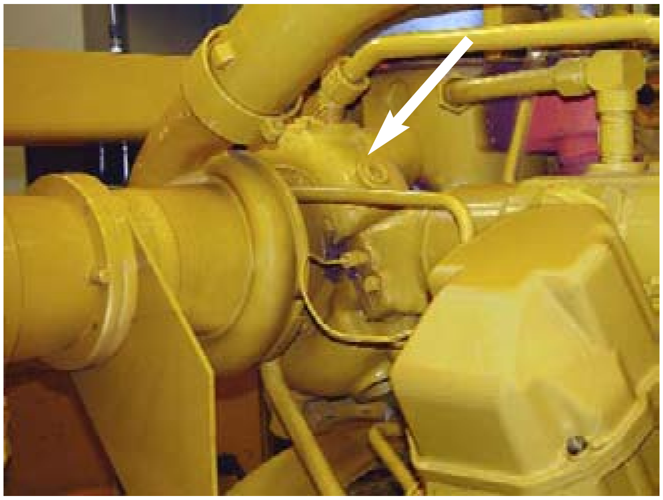


Fig 11: Water cooled turbocharger.

Water Cooled Exhaust Manifolds and Water Cooled Turbocharger Shields

Some engines, especially marine engines, are equipped with water-cooled exhaust manifolds and/or water-cooled turbocharger shields. Incorrect fuel settings or injection timing, excessive load on the engine, high inlet air temperature, or restrictions in the inlet or exhaust air flow can cause high exhaust temperatures and high coolant temperatures.

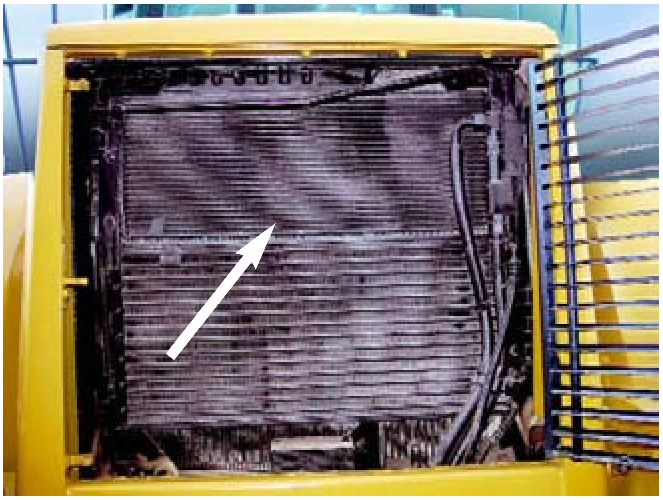


Fig 12: Hydraulic oil coolers.

Hydraulic Oil Coolers

Some machines have hydraulic oil coolers. Generally, these are radiator-type coolers. On some machines, the cooler core is between the fan and the radiator. The air must pass through the cooler before it goes through the radiator. If the hydraulic oil overheats, so can the cooling system. Hot hydraulic oil is normally the result of a cycle time that is too rapid, the relief valve pressure set too low or exceeded, or the hydraulic system operated in an overload condition.

Safety Recommendations

Always wear eye protection when you perform any service work on a cooling system.

Fig. 13: Care must be taken during removal of the radiator cap.

Release the pressure in the cooling system before performing any service work. If the pressure in the cooling system is not released or the temperature of the system is not permitted to cool, steam or hot water may be released when you remove the radiator cap. This may cause personal injury. To release the pressure in a cooling system, let the system cool, put a heavy cloth over the cap and loosen it SLOWLY.

- Do not allow undiluted corrosion inhibitors or diluted/undiluted radiator cleaners to come in contact with the skin or eyes.
- Do not use chromate corrosion inhibitors or any other cooling tower treatment chemistries in an engine cooling system. The use of these inhibitors in the cooling system can produce deposits that will lead to poor heat transfer.
- Always follow the manufacturer's instructions when handling corrosion inhibitors, radiator cleaners, or antifreeze. Be especially sure to follow the manufacturer's recommendations concerning toxicity.
- Glycol may catch fire when it is hot or exposed to an open flame. Do not weld, cut or use an open flame near leaking coolant that contains antifreeze.
- Do not use alcohol in place of antifreeze. Alcohol has a lower boiling temperature and flash point.
- Do not operate a machine or perform any service work around the area of the fan with the fan guards removed. Moving fan blades can cause personal injury. Moreover, anything that may fall into a moving fan can be thrown out with force.
- Do not work near fan belts with the engine running.
- Do not attempt to tighten any hose clamps while the cooling system is hot or under pressure. If there is a failure of the hose clamp when it is tightened, a sudden loss of hot coolant or steam could result.

Cooling System Maintenance

Coolant

Coolant generally consists of water combined with corrosion inhibitors or water combined with antifreeze and corrosion inhibitors. The correct selection of coolant has a direct effect on the efficiency and/or service life of both the cooling system and the engine. Coolant must be able to transfer heat from hot engine components to a radiator or heat exchanger where the heat is dissipated.

Heat Transfer

Heat transfer describes the tendency of heat to move from a hot area to a cooler area. Rate of heat transfer is measured by the specific heat properties of a given liquid. (Specific heat is the ratio of the quantity of heat required to raise the temperature of an amount of a specific liquid 1° compared to that required to raise the temperature of an equal mass of water 1°). In coolant, the rate of heat transfer also depends on the temperature difference between the outside air and the coolant itself, plus the conductive properties of the material that surrounds the coolant.

A coolant mixture of 50% ethylene glycol, which has a specific heat of .880, and 50% water, will increase the atmospheric boiling temperature of the mixture to approximately 107°C (225°F). The heat transfer of an ethylene glycol mixture is less than the heat transfer of water. The temperature at which the glycol mixture will boil is higher. This means some loss in cooling capability is recovered by obtaining a higher temperature in the radiator top tank without loss of coolant because of boiling.

Protection Against Freezing of the Coolant

The best protection against coolant freezing is the correct mixture/ratio of the coolant. Use the correct mixture/ratio of ethylene glycol and water or the correct mixture/ratio of propylene glycol and water as a coolant. The most common antifreezes that are available use ethylene glycol to provide freeze protection.

NOTE: Use a mixture of water, ethylene glycol (antifreeze), and cooling system conditioner. Pure, undiluted antifreeze will freeze at -23°C (-9°F).

Corrosion Resistance

The coolant must prevent the formation of rust and pits in the engine and other components. Since all water can cause corrosion, water should not be used alone. Any type of water is unacceptably corrosive when corrosion inhibitors or antifreeze are not added.

Always add Cat SCA (Supplemental Cooling Additive), or equivalent to the water antifreeze mixture at the time of the initial fill of the cooling system. [Adding Cat SCA is not necessary when using Cat ELC (Extended Life Coolant) or Cat DEAC (Diesel Engine Antifreeze/Coolant). The Caterpillar formula in these products includes all necessary inhibitors for initial fill.]

NOTE: Do NOT use conventional SCA with Cat ELC. Use only Cat ELC Extender with Cat ELC.

NOTE: Conventional Coolants DO require periodic additions of SCA to maintain cooling system protection.

Water alone is corrosive. If water alone is used (not recommended), it is extremely important that Cat SCA be added. Refer to this publication, "Water and Supplemental Coolant Additive" topic.

Scale and Deposits

The general characteristics of the water used as a coolant determine scale and deposit formations. It is impossible to inhibit "poor" water completely so as to make it usable as a coolant mixture. The water must be pretreated.

Compatibility

The coolant must not damage seals, hoses or any of the materials used in the construction of cooling systems such as copper, aluminum, and steel. Inhibitors in Cat ELC, Cat DEAC, and Cat SCA are designed to protect these materials.

Non foaming

The coolant used in a system must not foam or make sludge that can damage the cooling system.

Sediment

The coolant must be clear and not have mud or an oil residue in it.

Cylinder Wall Pitting

Proper cooling system maintenance helps to control cylinder wall pitting. Cylinder wall pitting is the result of the combined action of cavitation-erosion and corrosion. Essentially, during the normal course of engine operation, the cylinder wall flexes causing small air bubbles to form on the coolant side of the wall. Cavitation occurs when these bubbles break or implode and remove the cylinder wall's protective oxide film. Once this film is removed, corrosion is free to develop and eventually the cylinder wall surface deteriorates.

Erosion-corrosion is a combination of mechanical and chemical or electrochemical action that cause corrosion. Cavitation is a particular type of erosion-corrosion and a common cause of cylinder wall pitting.

Cylinder wall pitting can be controlled if the cooling system is regularly replenished with Cooling System Conditioner. If, however, conditioner is not added at the proper intervals (see page 24) and in the correct quantities, pitting will worsen, ultimately allowing coolant to penetrate the combustion chamber and cause major engine damage.

Coolant Properties

General Coolant Information

NOTICE

These recommendations are subject to change without prior notice. Contact your local Caterpillar Dealer for the most up to date recommendations.

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 caused by freezing coolant.

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 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. Removing the regulators allows some coolant to bypass the radiator, potentially causing overheating.

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, or 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

All Caterpillar diesel engines equipped with air-to-air aftercooling (ATAAC) require a minimum of 30 percent glycol to prevent water pump cavitation.

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 seawater.

If distilled water or deionized water is not available, use water that meets or exceeds the minimum acceptable water requirements listed in Figure 14.

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" ‘D4327"
Total Hardness	170 mg/L (10 grains/US gal)	"D1126"
Total Solids	340 mg/L (20 grains/US gal)	Federal Method (1) ‘2540B"
Acidity	pH of 5.5 to 9.0	"D1293"

(1) Total dissolved solids dried at 103-105°C, "Standard Method for the Elimination of Water and Wastewater", American Public Health Association, etal, 1015 15th Street, N.W. Washington, DC 20005

Fig. 14: Caterpillar Minimum Acceptable Water Requirements.

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
- Foaming of the coolant

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

Additives must be added at the proper concentration. Over concentration 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
- Water pump cavitation (ATAAC equipped engines)

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 Figures 15 and 16.

Ethylene Glycol		
Concentration	Freeze Protection	Boil Protection[1]
50 Percent	-37° C (-35° F)	106° C (223° F)
60 Percent	-52° C (-62° F)	111° C (232° F)

(1) Boiling protection is increased with the use of a pressurized radiator.

Fig. 15: Ethylene Glycol Concentration Chart.

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. Do not use ethylene glycol in concentrations that exceed 60 percent glycol.

Propylene Glycol		
Concentration	Freeze Protection	Boil Protection[1]
50 Percent	-32° C (-26° F)	106° C (223° F)

(1) Boiling protection is increased with the use of a pressurized radiator.

Fig. 16: Propylene Glycol Concentration Chart.

NOTE: Propylene glycol coolant that is used in the cooling systems for Caterpillar diesel engines must meet "ASTM D6210-04," "Fully-Formulated Glycol-Based Engine Coolant for Heavy-Duty Engines." When propylene glycol coolant is used in heavy-duty diesel engines, a regular addition of SCA is required for protection against liner cavitation. Consult your Caterpillar dealer for additional information.

Testing Glycol Concentration

To check the concentration of glycol, use the 245-5829 Coolant/Battery Tester/Refractometer. The tester gives readings that are immediate and accurate in both degrees Celsius and degrees Fahrenheit. The tester can be used with ethylene or propylene glycol.

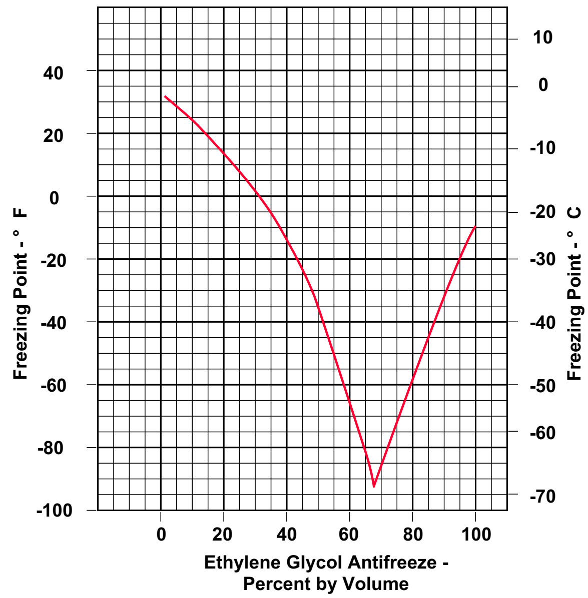


Fig. 17: Freezing point curve for typical ethylene glycol solution.

Freeze Protection Temperatures for Antifreeze Concentrations[1]	
Protection to:	Concentration
-15° C (5° F)	30% glycol, 70% water
-24° C (-11° F)	40% glycol, 60% water
-37° C (-35° F)	50% glycol, 50% water
-52° C (-62° F)	60% glycol, 40% water

(1) Ethylene glycol-based antifreeze

Fig. 18: Protection Temperatures for Antifreeze Concentrations.

Coolant Recommendations

The following two types of coolants may be used in Caterpillar diesel engines.

Preferred – Cat ELC (Extended Life Coolant) or a commercial extended life coolant that meets the Caterpillar EC-1 specification

Acceptable – Cat DEAC (Diesel Engine Antifreeze/Coolant) or a commercial heavy-duty coolant/antifreeze that meets "ASTM D4985" or "ASTM D6210" specifications

NOTICE

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

Use only the coolant/antifreeze that is recommended.

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

NOTE: Cat DEAC does not require a treatment with an SCA at the initial fill. However, a commercial heavy-duty coolant/antifreeze that only meets the "ASTM D4985" specification WILL require a treatment with an SCA at the initial fill. A commercial heavy-duty coolant/antifreeze that meets the "ASTM D6210" specifications will NOT require a treatment with an SCA at the initial fill. Read the label or the instructions that are provided by the manufacturer of the commercial heavy-duty coolant/antifreeze.

NOTE: These coolants WILL require a treatment with a supplemental coolant additive on a maintenance basis.

In stationary engine applications and marine engine applications that do not require anti-boil protection or freeze protection, a mixture of supplemental coolant additive and water is acceptable. **Caterpillar recommends a six percent to eight percent concentration of Cat SCA in those cooling systems.** Distilled water or deionized water is preferred. If distilled water or deionized water is not available, use water that meets or exceeds the minimum acceptable water requirements listed in Figure 14.

NOTICE

All Caterpillar diesel engines equipped with air-to-air aftercooling (ATAAC) require a minimum of 30 percent glycol to prevent water pump cavitation.

NOTE: Caterpillar recommends a minimum of 30 percent glycol in diesel engine cooling systems. Refer to engine specific Operation and Maintenance Manuals for exceptions.

Coolant Service Life	
Coolant Type	**Service Life(1)(2)**
Cat ELC	12000 Service Hours (3) or Six Years
Commercial Coolant that meets the Caterpillar EC-1 Specification	6000 Service Hours (4) or Six Years
Cat DEAC	3000 Service Hours or Three Years
Commercial Heavy-Duty Coolant/Antifreeze that meets "ASTM D6210"	3000 Service Hours or Two Years
Commercial Heavy-Duty Coolant/Antifreeze that meets "ASTM D4985"	3000 Service Hours or One Year
Cat SCA(5) and Water(6)	3000 Service Hours or Two Years
Commercial supplemental coolant additive(7) and Water(6)	3000 Service Hours or One Year

(1) Use the interval that occurs first.

(2) Refer to the specific engine Operation and Maintenance Manual, "Maintenance Interval Schedule" for the correct interval for replacement of the Cooling System Water Temperature Regulator.

(3) Cat ELC Extender must be added at 6000 service hours or one half of the service life for the ELC.

(4) Requires the addition of an extender at 3000 hours or one half of the service life for the coolant.

(5) The Cat SCA concentration in a cooling system that uses Cat SCA and water should be 6 to 8 percent by volume.

(6) Refer to this publication, "General Coolant Information" under the section that discusses water for requirements.

(7) Consult the supplier for the commercial SCA for instructions on usage. Also, refer to this Special Publication, "Water and Supplemental Coolant Additive" topic for additional information.

Fig. 19: Coolant Service Life Chart.

NOTE: These coolant changes are only achievable with the annual S•O•S Services Level 2 coolant sampling and analysis.

Cat ELC can be recycled into conventional coolants.

Containers of several sizes are available.

Coolant Part Numbers		
Description	**Size**	**Part Number[1]**
Cat DEAC (Concentrate)	Bulk	2P-9868 or 156-2649
	208.2 L (55 US gal)	8C-3686 238-8653*
	3.8 L (1 US gal)	8C-3684 238-8651*
Cat ELC (50/50 Premix)	Bulk	156-2653
	208.2 L (55 US gal)	101-2845 238-8650*
	18.9 L (5 US gal)	129-2151 238-8649*
	3.8 L (1 US gal)	101-2844 238-8648*
Cat ELC (concentrate)	3.8 L (1 US gal)	119-5150 238-8647*
Cat ELC Extender	0.946 L (1 qt) 3.8 L (1 gal)	119-5152 210-0786

* With embitterment. Embitterment makes the coolant taste bad. This is done in order to deter accidental human or animal ingestion of the coolant/antifreeze.

[1] The availability of part numbers will vary by region. Consult your Caterpillar dealer.

Fig. 20: Coolant Part Numbers Chart.

Recommended Coolant/Antifreeze for Caterpillar Gas Engines

NOTICE

Do not use Extended Life Coolant (ELC) with Caterpillar Gas Engines.

ELC was not formulated for use in Caterpillar Gas Engines.

Use only the coolant/antifreeze that is recommended.

Preferred - Caterpillar Natuaral Gas Engine Coolant (NGEC).

Alternatively, use Caterpillar Diesel Engine Antifreeze/Coolant (DEAC) or a commercail heavy-duty coolant/antifreeze that meets "ASTM D6210" or ASTM D4985" specifications.

The preferred coolant antifreeze can contain either ethylene glycol or propylene glycol. The coolant/antifreeze must be low in silicates. The coolant/antifreeze must be mixed with water that meets the properties that are listed in the table in the "General Coolant Information" topic. The coolant/antifreeze must also have the correct concentration of Supplemental Coolant Additive (SCA).

NOTICE

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

Use only the coolant/antifreeze that is recommended.

Cat ELC (Extended Life Coolant)

Caterpillar provides Cat ELC for use in the following applications:

- Heavy-duty diesel engines
- Automotive applications

When Cat ELC is compared to conventional coolants the Cat ELC anti-corrosion package is based on a totally different additive system. Cat ELC has been formulated with the correct amounts of additives in order to provide superior corrosion protection for all metals that are in engine cooling systems.

Cat ELC extends the service life of the coolant to 12000 service hours or six years. Cat ELC does not require a frequent addition of a SCA (Supplemental Coolant Additive). An Extender is the only additional maintenance that is needed at 6000 service hours or one half of the ELC service life.

Cat ELC is available in a 1:1 premixed cooling solution with distilled water. The Premixed ELC provides freeze protection to -37°C (-34°F). The Premixed ELC is recommended for the initial fill of the cooling system. The Premixed ELC is also recommended for topping off the cooling system.

ELC Concentrate is also available. ELC Concentrate can be used to lower the freezing point to -52°C (-62°F) for arctic conditions.

See Page 18 for available quantities and part numbers.

NOTE: Caterpillar developed the EC-1 specification. The EC-1 specification is an industry standard. The EC-1 specification defines all of the performance requirements that are needed for an engine coolant to be sold as an extended life coolant for Caterpillar engines. Cat ELC can be used in most OEM engines of the following types: diesel and gasoline. Cat ELC meets the performance requirements of "ASTM D4985" and "ASTM D6210" for heavy-duty low silicate antifreeze/coolants, but does not require treatment with conventional SCA. Cat ELC also meets the performance requirements of "ASTM D3306" for automotive applications.

Cat ELC Cooling System Maintenance

NOTICE

Use only Caterpillar products or commercial products that have passed Caterpillar's EC-1 specification for pre-mixed or concentrated coolants.

Use only Cat ELC Extender with Cat ELC.

Do NOT use conventional SCA with Cat ELC. Mixing Cat ELC with conventional coolants and/or conventional SCA reduces the Cat ELC service life.

Do NOT mix brands or types of coolant. Do NOT mix brands or types of SCA. Different brands or types may use different additive packages to meet the cooling system requirements. Different brands or types may not be compatible.

Failure to follow the recommendations can reduce cooling system components life unless appropriate corrective action is performed.

In order to maintain the correct balance between the antifreeze and the additives, you must maintain the recommended concentration of ELC. Lowering the proportion of antifreeze lowers the proportion of additive. This will lower the ability of the coolant to protect the system from pitting, from cavitation, from erosion, and from deposits.

During daily maintenance, use the premixed Cat ELC as a cooling system top-off. This action will bring the coolant up to the proper level. Check the specific gravity of the coolant system with the 245-5829 Coolant/Battery Tester/Refractometer. This tester gives readings that are immediate and accurate in both degrees Celsius and degrees Fahrenheit. Use Cat ELC Concentrate to restore the proper glycol concentration in the coolant system. This action should be done before the engine is exposed to freezing temperatures.

NOTICE

Do not use a conventional coolant to top-off a cooling system that is filled with Cat ELC.

Do not use standard conventional SCA or an SCA maintenance element. Only use Cat ELC Extender in cooling systems that are filled with Cat ELC.

Cat ELC Extender

Cat ELC Extender is added to the cooling system halfway through the Cat ELC service life. Treat the cooling system with Cat ELC Extender at 6000 hours or one half of the coolant service life. A 119-5152 Container (0.946 L) (1 qt.) or a 210-0786 Container (3.79L) (1 gal) of Cat ELC Extender are available for convenient use. Containers are available in metric liter sizes. Consult your Caterpillar dealer for the part numbers.

Use the formula in Figure 21 to determine the proper amount of Cat ELC Extender for your cooling system. Refer to Operation and Maintenance Manual, "Refill Capacities and Recommendations" in order to determine the capacity of the cooling system.

Formula for Adding Cat ELC Extender to Cat ELC
V x 0.02 = X
V is the capacity of the cooling system. X is the amount of Cat ELC Extender that is required

Fig. 21: Formula for Adding Cat ELC Extender to Cat ELC.

Figure 22 is an example for using the formula that is in Figure 21.

Example of The Equation for Adding Cat ELC Extender to Cat ELC		
Total Volume of the Cooling System (V)	Multiplication Factor	Amount of Cat ELC Extender that is Required (X)
946 L (250 US gal)	x 0.02	19 L (5 US gal)

Fig. 22: Example for using Formula for Adding Cat ELC Extender to Cat ELC.

NOTICE

When using Cat ELC, do not use conventional SCA's or SCA maintenance elements. To avoid SCA contamination of an ELC system, remove the SCA element base and plug off or by-pass the coolant lines.

Cat ELC Cooling System Cleaning

NOTE: If the cooling system is already using Cat ELC, cleaning agents are not required to be used at the specified coolant change interval. Cleaning agents are only required if the system has been contaminated by the addition of some other type of coolant or by cooling system damage.

Clean water is the only cleaning agent that is required when Cat ELC is drained from the cooling system.

Cat ELC can be recycled into conventional coolants. The drained coolant mixture can be distilled in order to remove the ethylene glycol and the water. The ethylene glycol and the water can be reused. This distilled material does not contain the additives that are required to be classified as either Cat ELC or Cat DEAC. Consult your Caterpillar dealer for more information.

After the cooling system is drained and after the cooling system is refilled, operate the engine while the cooling system filler cap is removed. Operate the engine until the coolant level reaches the normal operating temperature and until the coolant level stabilizes. As needed, add the coolant mixture in order to fill the system to the proper level.

Changing to Cat ELC

To change from heavy-duty coolant/antifreeze to the Cat ELC, perform the following steps:

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 Dealer Service Tool Catalog" and to Special Publication , GECJ0001 "Cat Shop Supplies and Tools" guide for tools and supplies suitable to collect and contain fluids on Caterpillar products.

Dispose of all fluids according to local regulations and mandates.

---

1. Drain the coolant into a suitable container.
2. Dispose of the coolant according to local regulations.
3. If equipped, remove the empty SCA maintenance element and remove the element base. Plug the coolant lines or bypass the coolant lines.

NOTICE

Do not leave an empty SCA maintenance element on a system that is filled with ELC.

The element housing may corrode and leak causing an engine failure.

Remove the SCA element base and plug off or by-pass the coolant lines.

---

4. Flush the system with clean water in order to remove any debris.
5. Use Caterpillar cleaner for cooling systems in order to clean the system. Follow the instruction on the label.
6. Drain the cleaner into a suitable container. Flush the cooling system with clean water.

NOTE: Deposits that remain in the system may be loosened and removed by the Cat ELC.

7. In systems with heavy deposits, it may be necessary to disconnect the hoses. Clean the deposits and debris from the hoses and the fittings. Install the hoses and tighten the hose fittings. Refer to Specifications, SENR3130, "Torque Specifications" for the proper torques. Pipe threads may also need to be cleaned and sealed. Seal the threads with 5P-3413 Pipe Sealant.
8. Fill the cooling system with clean water and operate the engine until the engine is warmed to 49°C to 66°C (120°F to 151°F).

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.

---

9. Drain the cooling system into a suitable container and flush the cooling system with clean water.

NOTICE

The cooling system cleaner must be thoroughly flushed from the cooling system. Cooling system cleaner that is left in the system will contaminate the coolant. The cleaner may also corrode the cooling system.

10. Repeat Steps 8 and 9 until the system is completely clean.
11. Fill the cooling system with Cat ELC.
12. Operate the engine until the engine is warmed. While the engine is running, inspect the engine for leaks. Tighten hose clamps and connections in order to stop any leaks.
13. Attach the Special Publication, PEEP5027, "Label" to the cooling system filler for the engine in order to indicate the use of Cat ELC.

NOTE: Clean water is the only flushing agent that is required when Cat ELC is drained from the cooling system.

Cat ELC Cooling System Contamination

NOTICE

Mixing ELC with other products reduces the effectiveness of the ELC and shortens the ELC service life. Use only Caterpillar products or commercial products that have passed the Caterpillar EC-1 specification for premixed or concentrate coolants. Use only Cat ELC Extender with Cat ELC. Do NOT mix brands or types of coolants. Failure to follow these recommendations can result in shortened cooling system component life.

Cat ELC cooling systems can withstand contamination to a maximum of ten percent of conventional heavy-duty coolant/antifreeze and/or SCA before the advantages of Cat ELC are reduced. If the contamination exceeds ten percent of the total system capacity, perform ONE of the following procedures:

- If cooling system contamination is caused by cooling system damage, follow the procedures under the "Changing to Cat ELC" heading. Also follow the procedures under the "Changing to Cat ELC" heading if the engine has been operated since being contaminated with more than ten percent conventional heavy-duty coolant/antifreeze and/or SCA. Certain types of cooling system contamination may require cooling system tear-down and manual cleaning of system components.

- If the cooling system is contaminated with more than ten percent conventional heavy-duty coolant/antifreeze and/or SCA, but the engine hasn't been operated, drain the cooling system into a suitable container. Dispose of the coolant according to local regulations. Thoroughly flush the system with clean water. Fill the system with Cat ELC.

- Maintain the system as a conventional DEAC (Diesel Engine Antifreeze/Coolant) or other conventional coolant. If the SCA concentration is less than three percent, treat the system with an SCA. Maintain three to six percent SCA concentration in the coolant. Change the coolant at the interval that is recommended for Cat DEAC or at the interval that is recommended for the conventional commercial coolants."

Commercial Extended Life Coolant

If Cat ELC is not used, then select a commercial extended life coolant that meets the Caterpillar specification of EC-1 and the "ASTM D6210" specification. Do not use an extended life coolant that does not meet the EC-1 specification. Follow the maintenance guide for the coolant from the supplier of the commercial extended life coolant. Follow the Caterpillar guidelines for the quality of water and the specified coolant change interval.

Diesel Engine Antifreeze/Coolant and Coolant Additives

Cat DEAC (Diesel Engine Antifreeze/Coolant)

Caterpillar recommends using Cat DEAC for cooling systems that require a high performance conventional heavy-duty coolant/antifreeze. Cat DEAC is an alkaline single-phase ethylene glycol type antifreeze that contains corrosion inhibitors and antifoam agents.

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

Containers of several sizes are available. See page 18 for available quantities and part numbers.

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

NOTE: The concentrated Cat DEAC and the recommended water must be thoroughly mixed prior to filling the cooling system.

Supplemental Coolant Additive

The use of SCA (supplemental coolant additive) helps to prevent the following conditions from occurring:

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

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

Cat SCA maintenance elements and containers of Cat SCA are available in several sizes. See page 24 for available quantities and part numbers.

NOTE: Do not exceed six percent maximum concentration of SCA.

Conventional Coolant/Antifreeze Cooling System Maintenance

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 Coolant/Battery Tester/Refractometer (245-5829). The tester gives readings in both degrees Celsius and degrees Fahrenheit that are immediate and accurate. The tester can be used with ethylene or with propylene glycol.

Caterpillar engine cooling systems should be tested at 250 hour intervals or at the PM level 1 intervals for the concentration of Supplemental Coolant Additive (SCA). SCA test kits are available from your Caterpillar dealer. Test the concentration of SCA or submit a coolant sample to your Caterpillar dealer at 250 hour intervals or at the intervals for PM Level 1. Refer to this publication "S·O·S Services Coolant Analysis" for more information on this topic.

Additions of SCA are based on the results of the test or based on the results of the coolant analysis. An SCA that is liquid or a maintenance element for an SCA (if equipped) may be needed at 250 hour intervals or at the intervals for PM Level 1.

Figure 23 lists the amount of Cat SCA that is needed at the initial fill in order to treat coolant/antifreeze. These amounts of Cat SCA are for systems that use heavy-duty coolant/antifreeze.

Figure 23 also lists additions of supplemental coolant additive for liquid and for maintenance elements at 250 hour intervals or at the intervals for PM Level 1. The additions are required for Cat DEAC and for commercial coolant/antifreezes.

NOTE: Conventional heavy-duty coolant/antifreeze of all types REQUIRE periodic additions of SCA.

Caterpillar SCA Requirements for Heavy-Duty Coolant			
Cooling System Capacity in L (US Gal)	Caterpillar Liquid SCA		Spin-on Element at 250 Service Hour or Intervals for PM Level 1
	Initial Fill(1)	250 Service Hour or Intervals for PM Level 1(2)	
22 to 30 L (6 to 8)	0.95 L (32 fl oz)	0.24 L (8 fl oz)	111-2370(3)
31 to 38 L (9 to 10)	1.18 L (40 fl oz)	0.36 L (12 fl oz)	111-2369(3)
39 to 49 L(11 to 13)	1.42 L (48 fl oz)	0.36 L (12 fl oz)	111-2369(3)
50 to 64 L (14 to 17)	1.90 L (64 fl oz)	0.47 L (16 fl oz)	9N-3368(3)
65 to 83 L (18 to 22)	2.37 L (80 fl oz)	0.60 L (20 fl oz)	111-2371(3)
84 to 114 L (23 to 30)	3.32 L (112 fl oz)	0.95 L (32 fl oz)	9N-3718(3)
115 to 163 L (31 to 43)	4.75 L (160 fl oz)	1.18 L (40 fl oz)	two units 111-2371(3)
164 to 242 L (44 to 64)	7.20 L (256 fl oz)	1.90 L (64 fl oz)	two units 9N-3718(3)

(1) When the coolant system is first filled, the SCA is not required to be used with Cat DEAC or with fully formulated coolants that meet the "ASTM D6210-04" specification.

(2) Do not exceed the six percent maximum concentration. Check the concentration of SCA with an SCA test kit, or check the concentration of SCA with Cat SOS Coolant Analysis.

(3) Do not use the maintenance element for the SCA and the liquid for the SCA at the same time.

Fig. 23: Caterpillar SCA Requirements for Heavy-Duty Coolant.

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

Refer to Figure 23 and Figure 24 for part numbers and for quantities of SCA maintenance elements and liquid SCA.

Caterpillar Liquid SCA(1)	
Part Number	Size of Container
6V-3542	0.24 L (8 oz)
8T-1589	0.47 L (16 oz)
3P-2044	0.94 L (32 oz)
217-0616	1 L (34 oz)
237-7673	5 L (1.3 US gal)
8C-3680	19 L (5.0 US gal)
217-0617	20 L (5.3 US gal)
5P-2907	208 L (55 US gal)
217-0618	208 L (55 US gal)

(1) The availability of part numbers will vary from one region to another region.

Fig. 24: Caterpillar Liquid SCA container sizes.

Cooling Systems with Larger Capacities

Adding the Supplemental Coolant Additive to Conventional Coolant/Antifreeze at the Initial Fill

NOTE: When the coolant system is first filled, the SCA is not required to be used with Cat DEAC or with fully formulated coolants that meet the "ASTM D6210-04" specification.

NOTE: Do not exceed six percent maximum concentration. Check the concentration of SCA with an SCA test kit, or check the concentration of SCA with CAT S•O•S coolant analysis.

Commercial heavy-duty coolant/antifreeze that meets only the "ASTM D4985" specification WILL require adding supplemental coolant additive at the initial fill. Read the label or the instructions that are provided by the manufacturer of the commercial heavy-duty coolant/antifreeze.

Use the equation that is in Figure 25 to determine the amount of Cat SCA that is required when the cooling system is initially filled with fluids that meet the following specification: "ASTM D4985"

Equation for Adding the Cat SCA to Conventional Coolant / Antifreeze at the Initial Fill
V x 0.045 = X
V is the total volume of the cooling system.
X is the amount of Cat SCA that is required

Fig. 25: Equation for Adding the Cat SCA at Initial Fill.

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

Example of the Equation for Adding the Cat SCA to Conventional Coolant / Antifreeze at the Initial Fill		
Total Volume of the Cooling System (V)	Multiplication Factor	Amount of Cat SCA that is Required (X)
946 L (250 US gal)	x 0.045	43 L (11 US gal)

Fig. 26: Example of Equation for adding CAT SCA at Initial Fill.

Adding the supplemental coolant additive to Conventional Coolant/Antifreeze for Maintenance

Heavy-duty coolant/antifreeze of all types REQUIRE periodic additions of a supplemental coolant additive.

Test the coolant/antifreeze periodically for the concentration of supplemental coolant additive. For the interval, see the Operation and Maintenance Manual, Maintenance Interval Schedule for your engine.

Supplemental coolant additive test kits are available from your Caterpillar dealer. Test the concentration of supplemental coolant additive or submit a coolant sample to your Caterpillar dealer. Refer to, in this publication, "S·O·S Services Coolant Analysis" topic.

Additions of supplemental coolant additive 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 supplemental coolant additive that is needed.

Use the equation that is in Figure 27 to determine the amount of Cat SCA that is required, if necessary.

Equation for Adding the Cat SCA to Conventional Coolant / Antifreeze for Maintenance
V x 0.014 = X
V is the total volume of the cooling system.
X is the amount of Cat SCA that is required

Fig. 27: Equation for Adding the Cat SCA for Maintenance.

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

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

Figure 24 lists part numbers and the sizes of containers for Cat SCA that is available from your Caterpillar dealer

Example of the Equation for Adding the Cat SCA to Conventional Coolant / Antifreeze for Maintenance		
Total Volume of the Cooling System (V)	Multiplication Factor	Amount of Cat SCA that is Required (X)
946 L (250 US gal)	x 0.014	13 L (4 US gal)

Fig. 28: Example of the Equation for Adding the Cat SCA for Maintenance.

Cleaning of Heavy-Duty Coolant/Antifreeze Systems

Before Caterpillar's supplemental coolant additive can be effective, the cooling system must be free from rust, scale and other deposits. Preventive cleaning helps avoid downtime caused by expensive out-of-service cleaning required for extremely dirty and neglected cooling systems.

Caterpillar Cooling System Cleaner - Standard:

- Dissolves or depresses mineral scale, corrosion products, light oil contamination, and sludge.
- Cleans the cooling system after used coolant is drained or before the cooling system is filled with new coolant.
- Cleans the cooling system whenever the coolant is contaminated or whenever the coolant is foaming.
- Cleans engine while still in service.
- Reduces downtime and cleaning costs.
- Avoid costly repairs from pitting and other internal problems caused by improper cooling system maintenance.
- Can be used with glycol-based antifreeze.
- For the recommended service interval, refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule" for your engine.

Caterpillar Cooling System Cleaner - Standard is designed to clean the system of harmful scale and corrosion without taking the engine out of service. The cleaners , both "Standard" and "Quick Flush," can be used in all Caterpillar Engine cooling systems. Contact your Caterpillar dealer for part numbers.

NOTE: These cleaners must not be used in systems that have been neglected or have heavy scale buildup. These systems require a stronger commercial solvent available from local distributors.

Follow label directions for proper usage.

Commercial Heavy-Duty Coolant/Antifreeze and Supplemental Coolant Additive

If Cat DEAC is not used, select a coolant/antifreeze with low silicate content for heavy-duty applications that meets "ASTM D6210" or "ASTM D4985" specifications.

When a heavy-duty coolant/antifreeze is used, treat the cooling system with three to six per cent Cat SCA by volume. Maintain a concentration level of SCA in the cooling system that is between three percent and six percent. For more information refer to, in this publication, "Conventional Coolant/Antifreeze Cooling System Maintenance" topic.

If Cat SCA is not used, select a commercial supplemental coolant additive. The commercial supplemental coolant additive must provide a minimum of 1400 mg/L or 1400 ppm (82 grains/US gal) of nitrites in the final coolant mixture.

Maintain a concentration level of nitrates in the cooling system that is between 1200 ppm (70 grains/US gal) and 2400 ppm (140 grains/US gal).

Coolant/antifreeze for heavy-duty applications that meet only the "ASTM D4985" specification WILL require treatment with supplemental coolant additive at the initial fill. These coolants WILL require treatment with supplemental coolant additive on a maintenance basis.

Coolant/antifreezes for heavy-duty applications that meet the "ASTM D6210" specification do not require treatment with supplemental coolant additive at the initial fill. Treatment with supplemental coolant additive WILL be required 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, in this publication, "General Coolant Information" topic.

Water and Supplemental Coolant Additive

NOTICE

All Caterpillar diesel engines equipped with air-to-air aftercooling (ATAAC) require a minimum of 30 percent glycol to prevent water pump cavitation.

NOTE: Caterpillar recommends a minimum of 30 percent glycol in diesel engine cooling systems. Refer to engine specific Operation and Maintenance Manuals for exceptions.

NOTICE

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

In engine cooling systems that use water alone, Caterpillar recommends the use of Cat SCA. Cat SCA helps to prevent the following conditions from occurring:

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

If Cat SCA is not used, select a commercial supplemental coolant additive. The commercial supplemental coolant additive 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, use the recommended water properties in this publication, "General Coolant Information" topic for water that meets the minimum requirement.

A cooling system that uses a mixture of supplemental coolant additive and water only needs more supplemental coolant additive than a cooling system that uses a mixture of glycol and water. The supplemental coolant additive concentration in a cooling system that uses supplemental coolant additive and water should be six to eight percent by volume. Refer to Figure 29 for the amount of supplemental coolant additive that is required for various capacities of the cooling system.

Refer to Figure 30 for part numbers and for container sizes of SCA.

Caterpillar SCA Requirements for Cat SCA and Water Cooling Systems		
Cooling System Capacity	Cat SCA at Initial Fill	Cat SCA at 250 Hours[1]
22 to 30 L (6 to 8 US gal)	1.75 L (64 fl oz)	0.44 L (15 fl oz)
31 to 38 L (9 to 10 US gal)	2.30 L (80 fl oz)	0.57 L (20 fl oz)
39 to 49 L (11 to 13 US gal)	3.00 L (100 fl oz)	0.75 L (25 fl oz)
50 to 64 L (14 to 17 US gal)	3.90 L (128 fl oz)	0.95 L (32 fl oz)
65 to 83 L (18 to 22 US gal)	5.00 L (168 fl oz)	1.25 L (42 fl oz)
84 to 110 L (23 to 29 US gal)	6.60 L (224 fl oz)	1.65 L (56 fl oz)
111 to 145 L (30 to 38 US gal)	8.75 L (296 fl oz)	2.19 L (74 fl oz)
146 to 190 L (39 to 50 US gal)	11.50 L (392 fl oz)	2.88 L (89 fl oz)
191 to 250 L (51 to 66 US gal)	15.00 L (512 fl oz)	3.75 L (128 fl oz)

[1] Do not exceed the eight percent maximum concentration. Check the concentration of Cat SCA with a test kit for supplemental coolant additive or perform an SOS Coolant Analysis.

Fig. 29: Caterpillar SCA Requirements for Cat SCA in Water.

Caterpillar Liquid SCA[1]	
Part Number	Size of Container
6V-3542	0.24 L (8 oz)
8T-1589	0.47 L (16 oz)
3P-2044	0.94 L (32 oz)
217-0616	1 L (34 oz)
237-7673	5 L (1.3 US gal)
8C-3680	19 L (5.0 US gal)
217-0617	20 L (5.3 US gal)
5P-2907	208 L (55 US gal)
217-0618	208 L (55 US gal)

[1] The availability of part numbers will vary from one region to another region.

Fig. 30: Caterpillar Liquid SCA Container Sizes.

Maintain the Cat SCA in the same way as you would maintain a cooling system that uses heavy-duty coolant/antifreeze. Adjust the maintenance for the amount of Cat SCA additions. See Figure 29 for the amount of Cat SCA that is required.

Cooling Systems with Larger Capacities

Adding the Cat SCA to Water at the Initial Fill

Use the equation that is in Figure 31 to determine the amount of Cat SCA that is required at the initial fill. This equation is for a mixture of only Cat SCA and water.

Equation for Adding the Cat SCA to Water at the Initial Fill
V x 0.07 = X
V is the total volume of the cooling system.
X is the amount of Cat SCA that is required

Fig. 31: Equation for CAT SCA at the Initial Fill.

Figure 32 is an example for using the equation that is in Figure 31.

Example of The Equation for Adding Cat SCA to Water at the Initial Fill		
Total Volume of the Cooling System (V)	Multiplication Factor	Amount of Cat SCA that is Required (X)
946 L (250 US gal)	x 0.07	66 L (18 US gal)

Fig. 32: Example of the Equation for Adding the Cat SCA at the Initial Fill.

Adding the Cat SCA to Water for Maintenance

For the recommended service interval, refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule" for your engine.

Submit a coolant sample to your Caterpillar dealer. See, in this publication, S·O·S Services Coolant Analysis.

Additions of Cat SCA are based on the results of the coolant analysis. The size of the cooling system determines the amount of Cat SCA that is required.

Use the equation that is in Figure 33 to determine the amount of Cat SCA that is required for maintenance, if necessary:

Equation for Adding the Cat SCA to Water for Maintenance
V x 0.023 = X
V is the total volume of the cooling system.
X is the amount of Cat SCA that is required

Fig. 33: Equation for adding Cat SCA to Water for Maintenance.

Figure 34 is an example for using the equation that is in Figure 33.

Example of the Equation for Adding Cat SCA to Water for Maintenance		
Total Volume of the Cooling System (V)	Multiplication Factor	Amount of Cat SCA that is Required (X)
946 L (250 US gal)	x 0.023	22 L (6 US gal)

Fig. 34: Example of the Equation for adding Cat SCA to Water for Maintenance.

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

Figure 30 lists part numbers and the sizes of containers for Cat SCA that are available from your Caterpillar dealer.

S·O·S Service Coolant Analysis

Testing the engine coolant is important to ensure that the engine is protected from internal cavitation and corrosion. The analysis also tests the ability of the coolant to protect the engine from boiling and freezing. S·O·S coolant analysis can be done at your Caterpillar dealer. Caterpillar S·O·S coolant analysis is the best way to monitor the condition of your coolant and your cooling system. S·O·S coolant analysis is a program based on periodic samples.

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.

New, Refilled, and Converted Systems

Perform an S·O·S coolant analysis (Level 2) at the following maintenance intervals.

- Every Year
- Initial 500 service hours

Perform this analysis at the interval that occurs first for new systems, for refilled systems, or for converted systems that use Cat ELC or use Cat DEAC. This 500 hour check will also check for any residual cleaner that may have contaminated the system.

Recommended Interval for S·O·S Coolant Sampling

Recommended Interval		
Type of Coolant	Level 1	Level 2
CAT DEAC	Every 250 hours (1)	Yearly (1) (2)
CAT ELC	Optional (2)	Yearly (2)

(1) This is the recommended coolant sampling interval for all conventional heavy duty coolant/anti-freeze. This is also the recommended coolant sampling interval for commercial coolants that meet Cat EC-1(Engine Coolant specifications - 1).

(2) The Level 2 Coolant Analysis should be performed sooner if a problem is suspected or identified.

Fig. 35: Recommended Interval for S•O•S Coolant Sampling.

NOTE: Check the SCA (Supplemental Coolant Additive) of the conventional coolant at every oil change or at every 250 hours. Perform this check at the interval that occurs first.

S·O·S Coolant Analysis (Level 1)

A coolant analysis (Level 1) is a test of the properties of the coolant.

The following properties of the coolant are tested:

- Glycol concentration for freeze protection and boil protection
- Ability to protect from erosion and corrosion
- pH
- Conductivity
- Visual analysis
- Odor analysis
- Water hardness

The results are reported, and appropriate recommendations are made.

S·O·S Coolant Analysis (Level 2)

A coolant analysis (Level 2) 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 S·O·S coolant analysis has the following features:

- Full coolant analysis (Level 1)
- 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 the possibility of electrolysis within the cooling system of the engine

The results are reported, and appropriate recommendations are made.

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

Caterpillar Conditioner Elements

NOTE: Do NOT use SCA precharge or SCA maintenance elements with Cat ELC. Do NOT use liquid SCA with Cat ELC.

When using Cat DEAC, no precharge elements are required. Caterpillar DEAC contains the necessary amount of supplemental coolant additives at initial fill. However, maintenance elements are still available. Using the wrong size element can result in over-concentration of additives.

Supplemental coolant additive maintenance element assemblies are also available from Caterpillar for use instead of liquid coolant additives in some applications. Element assemblies are in a dried state. The contents of these element assemblies dissolve into the coolant when the coolant passes through the element. Use precharge elements at original fill, and use other elements as maintenance items at specific service intervals. Elements can be identified by part number or element length. In marine applications, Caterpillar recommends using a liquid supplemental coolant additive.

Fig. 36: Supplemental Coolant Additive Element Assembly.

At original fill, precharge elements can be used with commercial coolants that meet only the "ASTM D4985" specifications for heavy-duty coolants that require a precharge with SCA. The precharge establishes a protection level between a minimum of 0.030 liter per 3.8 liters (1.0 ounce per gallon) and a maximum of 0.059 liter per 3.8 liters (2.0 ounces per gallon). Use precharge elements only at original fill or after the system has been drained and refilled.

Precharge elements are necessary at original fill and after the system has been drained and refilled because maintenance elements do not supply sufficient amounts of coolant additives. If the cooling system lacks the necessary concentration of coolant additives, some surfaces have protection against corrosion and pitting at the expense of other surfaces.

Supplemental Coolant Additive Elements By Capacity				
Cooling System Capacity liter (gal)	Initial[1] Precharge Element	Qty	250 Hour Maintenance Element	Qty
22-30 (6-8)	112-0926	1	111-2370	1
31-38 (9-10)	111-2373	1	111-2369	1
39-49 (11-13)	9N-6123	1	111-2369	1
50-64 (14-17)	9N-3366	1	9N-3368	1
65-83 (18-22)	9N-3367	1	111-2371	1
84-114 (23-30)	9N-3367	1	9N-3718	1
117-163 (31-43) or	9N-3367	2	111-2371	2
117-163 (31-43)	1W-5518	1	111-2371	2
166-242 (44-64)	9N-3367	2	9N-3718	2

(1) When using Caterpillar Antifreeze, no precharge elements are required

Fig. 37: Supplemental Coolant Additive Elements by Capacity.

NOTE: One 9N-3668 base assembly is required for all capacities listed, except for 117-163 liters (31- 43 gallons) and 166-242 liters (44-64 gallons), each of which require two base assemblies. Also, all capacities require two 9N-3666 Valve Assemblies.

A 3% to 6% concentration of liquid supplemental coolant additive is required during the original fill of the cooling system mixture. This initial concentration of supplemental additive is vital. If the concentration of additive is too high, insoluble salts form and can cause wear on water pump seal surfaces. Engine damage can also result when the concentration of supplemental coolant additive or antifreeze exceeds recommended levels,

NOTE: Higher aluminum content engines require silicates to protect aluminum surfaces. Supplemental coolant additive used on these engines must pass the following tests:

ASTM D1384 - Glassware corrosion test

ASTM D2809 - Cavitation Erosion Of Aluminum

ASTM D4340 - Hot Surface Corrosion Of Aluminum

In addition, the additives must control cast iron cylinder liner and block pitting, and cavitation erosion.

Fig. 38: Water Pump Seal Deterioration.

Over a period of time, the concentration of coolant additives is depleted. This depletion occurs because additives deplete during the coating of metal surfaces, and from continuously neutralizing acids that form in the system. Therefore, to maintain constant protection, it is necessary to periodically replenish the additive concentration. Either replace the initial precharge element with the maintenance element or add 0.47 liter (1 pint) of additive for every 75.8 liters (20 U.S. gallons) of coolant at recommended intervals.

Normal recommended intervals are 16,000 to 19,000 kilometers (10,000 to 12,000 miles), or at 250 Service Meter Hours. Follow container instructions for the correct concentration

Supplemental Coolant Additive Precharge Element Assemblies Available from Caterpillar			
Part No.	Description	Amount of Additive	Length of Element
9N-3366	Precharge Element	453 g (16 oz)	175 mm (6.9")
9N-3367	Precharge Element	906 g (32 oz)	201 mm (7.9")
9N-6123	Precharge Element	340 g (12 oz)	175 mm (6.9")
1W-5518	Precharge Element	907 g (32 oz)	263 mm (10.4")
111-2371	Precharge Element	141 g (5 oz)	133 mm (5.25")
111-2373	Precharge Element	280 g (10 oz)	175 mm (6.9")
112-0926	Precharge Element	227 g (8 oz)	175 mm (6.9")

Supplemental Coolant Additive Maintenance Element Assemblies Available from Caterpillar			
Part No.	Description	Amount of Additive	Length of Element
9N-3368	Maintenance Element	113 g (4 oz)	133 mm (5.25")
9N-3718	Maintenance Element	226 g (8 oz)	175 mm (6.9")
111-2369	Maintenance Element	85 g (3 oz)	133 mm (5.25")
111-2370	Maintenance Element	57 g (2 oz)	133 mm (5.25")

Fig. 39: Coolant Additives and Element Assemblies Chart.

NOTE: Soluble oil must not be used as a supplemental coolant additive in Caterpillar engines. Soluble oil damages the radiator hoses and certain engine seals. Also, soluble oil does not lubricate pump bearings or protect engine parts from damage caused by cavitation erosion.

Functional Effects

Without careful selection and maintenance of coolant, certain functional effects can cause problems in the cooling system. Coolant mixtures must be formulated to minimize the possibility of problems like:

- pitting and cavitation-erosion
- rust
- acidity
- alkalinity imbalance
- galvanic and electrolytic corrosion
- scale and deposit formation
- aeration

Using acceptable water and correct additives helps prevent these functional effects.

Fig. 40: Cylinder liner walls with heavy external scale may have areas that are free of scale and are experiencing cavitation-erosion induced pitting corrosion.

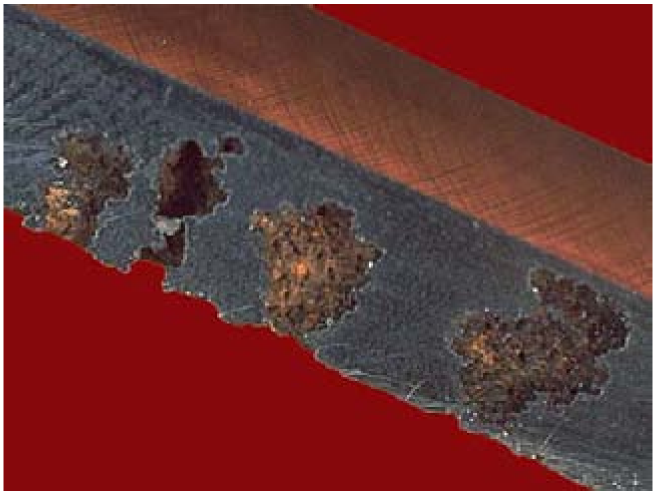


Fig. 41: Careful examination of what appears to be small surface pits in Fig. 37 will reveal large underlying holes in the liner wall. This is called concentration cell pitting corrosion.

Fig. 42: Rust and scale deposits, due to the absence of supplemental coolant additive, caused temperature regulators to fail.

Fig. 43: Corrosion on a water pump passage due to lack of supplemental coolant additive in the cooling system.

NOTE: CAT ELC does not require treatment with SCA in order to provide cooling system protection.

Conventional coolants DO require periodic additions of SCA to maintain cooling system protection

Corrosion is a chemical or electrochemical action that gradually wears away metal surfaces in the cooling system. In some instances, corrosion can eventually destroy an engine. All cooling system components need protection from corrosion. Supplemental coolant additives are used to protect metal surfaces. They coat these surfaces and prevent the formation of scale, rust, and cavitation erosion.

Types of cooling system corrosion are pitting and cavitation erosion, rust, acidity-alkalinity imbalance caused erosion, and galvanic and electrolytic corrosion. Other functional effects of coolants with no, or low, levels of supplemental coolant additives are aeration and the formation of scale and deposits.

Fig. 44: Example of cylinder wall cavitation-erosion.

Pitting and Cavitation-Erosion

Electrical current flow in a localized area is one of the causes of pitting corrosion. Pitting is the most damaging type of corrosion. After pitting has progressed for any appreciable length of time, there is no practical way to stop pitting before perforation takes place. Because one ampere of current flowing for thirty hours removes one ounce of iron, current flow concentrated on a small area is very destructive. Therefore, prevention is the best policy.

Erosion-corrosion is a combination of mechanical and chemical or electrochemical action that causes corrosion. Cavitation is a particular type of erosion-corrosion and a common cause of cylinder wall pitting.

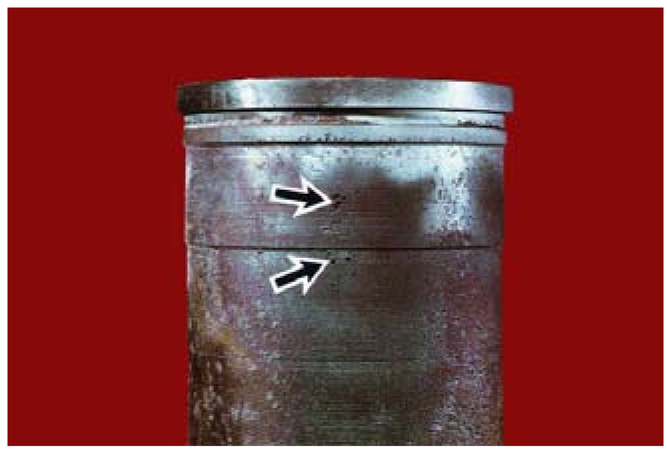


Fig. 45: Example of cylinder wall cavitation-erosion.

Cavitation of the cylinder wall begins when air bubbles remove the wall's protective oxide film. Flexing of the cylinder wall after the fuel mixture explodes in the combustion chamber causes cylinder wall vibration and creates air bubbles in the coolant. Concentration of air bubbles increases when cooling system pressure is low or when the system leaks. Also, increased vibration amplifies the quantity of air bubbles. Vibration multiplies when the engine is run cold, because of increased piston-to-cylinder clearance. Vibration also multiplies when the engine is lugged.

These air bubbles form on the outside of the cylinder wall (perpendicular to the wrist pin) and then explode inward (implode). When air bubbles continue to implode, sufficient energy is released to physically attack the cylinder wall and remove the oxide film.

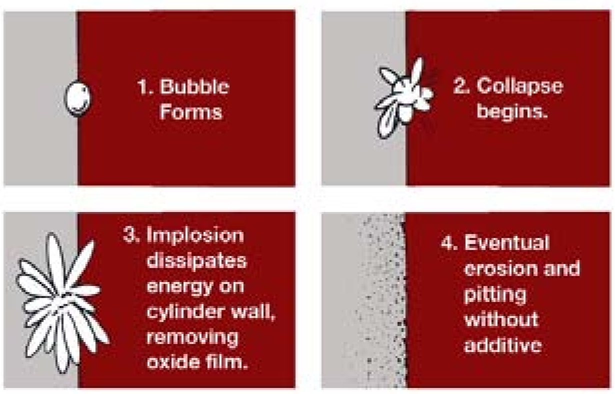


Fig. 46: Progression of cavitation and pitting on cylinder wall.

Corrosion and pitting then take place at a high rate.

Eventually, a pit can become deep enough to break through the cylinder wall and allow coolant to leak into the cylinder. This coolant leak contaminates the lubricating oil.

Fig. 47: Eventually, a pit can penetrate the cylinder wall and allow coolant to leak into the cylinder.

Supplemental coolant additives coat metal surfaces and control cavitation-erosion and pitting. Unfortunately, small particles or ferrous scale often shield the surfaces underneath from the protective action of coolant additives. If this condition persists, pits can form. Keeping your cooling system clean, along with regularly replenishing your coolant additives, helps prevent pitting. However, if coolant additives are not added at the proper intervals and in correct quantities (see page 24), cavitation erosion and pitting intensifies. Eventually, coolant can penetrate the cylinder wall and cause major damage to the engine.

Cat SCA helps prevent pitting when the system is filled with either Cat DEAC or commercial heavy-duty coolant/antifreeze that contains a minimum of 1200 ppm Nitrite.

Cat ELC does not require the addition of Caterpillar supplemental coolant additives. Do not use supplemental coolant additives with Cat ELC.

Fig. 48: Effects of improperly treated cooling system.

Fig. 50: Rust deposits on outside of cylinder wall surface.

Fig. 49: Corrosion/erosion of aluminum Water Pump Adapter .

Fig. 51: Rusting inside water pump.

Rust

Rust is caused by oxidation within the cooling system. Heat and moist air accelerate this process. Rusting leaves residual scale deposits that can clog the cooling system. This causes accelerated wear and reduces the efficiency of heat transfer.

Cat SCA helps prevent rust in cooling system passages.

Acidity-Alkalinity Imbalance

A coolant mixture's acidity-alkalinity content is measured by its pH level. The pH level, ranging from 1 to 14, indicates the degree of acidity or alkalinity and the coolant's corrosiveness. For best results, the cooling system's pH level should be maintained between 8.5 and 10.5. When the pH level is above 11.0, the coolant attacks aluminum and copper, or non-ferrous materials. When the pH level is below 7.0, the coolant becomes acidic and attacks ferrous materials. When the pH level is below 7.0, or above 11.0, the coolant mixture is unsuitable.

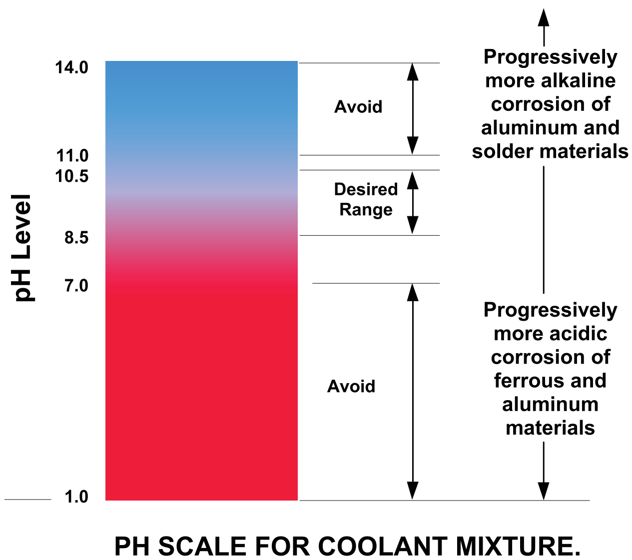


Fig. 52: pH scale for coolant mixture.

Supplemental coolant additives used in the coolant mixture must contain buffering agents to properly maintain the pH level and to neutralize acids produced by blow-by gases.

Galvanic and Electrolytic Corrosion

Electrical current flowing through coolant between different metals causes galvanic corrosion. The coolant acts as an electrical conductor between metals that are coupled together. An electromotive force or a potential voltage that exists between the two dissimilar metals allows current to flow. Galvanic corrosion occurs on the least resistant metal.

In marine applications where sea water is highly conductive, sacrificial material (rods) are placed in seawater flow passages to absorb current flow. Typically, this wear material is either magnesium or zinc. Rods must be inspected regularly and replaced when necessary. Caterpillar recommends inspecting rods every 50 hours until a wear rate is established.

In truck, earthmoving, and other non-marine applications, if galvanic corrosion occurs, immediately drain, flush, and refill the coolant mixture. The source of voltage must be determined to prevent continued corrosion.

Corrosion can also occur when the source of current flow through the coolant is external. To help prevent this electrolytic corrosion, electrical systems must be designed so that no continuous electrical potential is imposed upon any cooling system components. Despite coolant mixture quality, the presence of an electrical potential can cause materials in the cooling system to be damaged by electrolytic corrosion.

Soundness of ground connections should be checked with a volt/ohm meter. Typically, measured resistance between an electrical component on the engine and battery negative should be less than 0.3 ohms. All grounds should be tight and free of corrosion.

Aluminum material parts are susceptible to electrolytic corrosion. Aluminum requires only about one-half the electrical potential as iron to produce the same damaging effect. With the aluminum components of newer engines, greater care is required to ensure proper grounding to prevent electrical potential differences.

Troubleshooting these types of corrosion is extremely complicated. The source of electrical current must be located. Common sources of stray current are improper grounding of electrical components or corroded ground strap connections.

Scale and Deposit Formation

The general characteristics of water - including pH level, calcium and magnesium hardness, total hardness, and temperature determine scale and deposit formation. Use of supplemental coolant additive is a major factor in preventing scale and deposit formation. Common scale deposits in a cooling system include:

- calcium carbonate
- calcium sulfate
- iron
- copper
- silica
- lead

Fig. 53: Rust deposits on water pump impeller caused by lack of supplemental coolant additive.

Scale and deposit formations are detrimental to the cooling system because they act as insulators and barriers to heat transfer. Thus, scale and deposit formations reduce the cooling system's efficiency. Only 1.6MM (1/16") of scale has the same insulating potential as approximately 101 mm (4") of cast iron. This thin scale deposit can reduce heat transfer by 40%. In many cases, severe damage to the engine results.

It is impossible to completely eliminate poor water characteristics. However, water must be pretreated to meet the manufacturer's specifications for the cooling system. (See page 15).

Used in proper concentration, Cat SCA helps prevent the formation of scale and deposits.

Aeration

Air leakage into the cooling system often results in coolant foaming. Foaming promotes pitting, particularly around water pump impellers. Pitting and corrosion increase significantly when exhaust gases enter the cooling system, introducing bubbles, foam, and acid forming compounds.

To help prevent such problems, foam suppressant additives must be added to the coolant mixture. Cat SCA contains de-foaming agents and helps prevent the formation of air bubbles.

Coolant-Related Failures

Because of the cooling system's vital function in regulating temperature, coolant-related problems, such as corrosion or aeration in the cooling system, can ultimately lead to failure of the engine. Temperatures that are excessively high or low lead to engine failure. Overheating typically causes cracking of cylinder heads and cylinder blocks and seizure of pistons. Excessively low operating temperatures lead to other types of problems such as sludge formation and carbon build-up.

Overheating can be traced to many different sources:

- slow hydraulically driven fan
- low coolant level
- plugged radiator core
- broken or leaking coolant hoses
- loose fan belts
- excessive engine load
- failure of water pump or water temperature regulator
- restriction of inlet or exhaust air flow
- engine operation with no temperature regulator
- cooling system (heat exchanger, cooler, or radiator) that is defective or too small

Many of these causes are related to coolant. Examples of coolant-related failure symptoms are cracked or warped cylinder heads, cylinder block damage, piston seizure, and cold operating temperatures.

Cracked or Warped Cylinder Heads

When an engine overheats, stress in the cylinder head increases. This can cause the cylinder head to become warped or cracked.

Fig. 54: Coolant-related overheating caused this crack in the cylinder head at the nozzle hole.

Fig. 55: Further inspection of the crack shows extension into the valve seat area.

Cylinder Block

The cylinder block represents another potentially vulnerable area. Cavitation-erosion and excessive pitting in the water passage around the cylinder liner can cause holes in the cylinder wall. Pitting and cavitation-erosion often result from incorrect cooling system maintenance. These types of problems can be prevented by properly maintaining the cooling system, which includes regular additions of Cat SCA as required.

Piston Seizure

Piston damage, in varying amounts, is typical of overheating failure. Normally, several pistons have seizure damage (scuffing), while the skirts of the remaining pistons are polished or have normal appearance. Usually, more severe damage occurs on pistons in one or more of the rear cylinders.

Fig. 56: Piston damage on this direct-injection engine resulted from improper cylinder jacket cooling. As shown by the middle piston, seizure usually begins in the skirt area while the top land escapes damage. The piston on the right shows further progression after skirt seizure.

Seizure damage from improper cylinder jacket cooling usually begins in the piston's skirt area on direct injected fuel system engines. On precombustion fuel system engines, piston seizure often begins at the top land.

Cold Operating Temperatures

Overcooling can damage an engine, just as overheating can. Correct operating temperature is critical to engine performance. Engines must reach a specific operating temperature to run efficiently and prevent failures.

Continued engine operation at cold temperatures can result in sludge formation in the crankcase. Sludge can gum valve lifters, valve stems, pistons, and piston rings. Also, when using fuels with high sulfur content, sulfuric acid can form more readily and accelerate corrosion.

Cold operating temperatures can also lead to carbon buildup. Carbon buildup is a result of over-lubrication or cold engine operation. Correct temperatures help reduce carbon deposits from forming on valves.

Fig. 57: Excessive carbon buildup on an intake valve. Carbon buildup can be caused by engine operating at cold temperatures.

All Caterpillar Engines are equipped with temperature regulators (thermostats) for temperature control. Regulators can vary according to engine application. Make sure the recommended regulator has been installed and is operating correctly.

Service and Periodic Maintenance

Periodic Maintenance

Periodic maintenance is necessary for the cooling system to operate efficiently. The following maintenance practices extend both cooling system and engine service life.

NOTE: These are general recommendations. For specific requirements, consult the engine manufacturer's owner's guide.

⚠ WARNING

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

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

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

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

INITIAL FILL

1. If Cat ELC or Cat DEAC will not be used, select proper water, supplemental coolant additive, and coolant.
2. Before the cooling system is filled, close all drain plugs.
3. Before adding to the cooling system, always premix water, supplemental coolant additive, and coolant concentrate, or use fully formulated premixed coolant. Premixed coolants that are not fully formulated may require a precharge of coolant additive. Consult manufacturers label.
4. Do not fill the cooling system faster than 20 liters (5 gallons) per minute. Air pockets can form in the cooling system if the cooling system is filled at a faster rate. Air pockets result in an incomplete fill and could possibly cause damaging steam.
5. After filling the cooling system, run the engine for several minutes with the radiator cap off. Next, install the radiator cap and run the engine at low idle until the coolant becomes warm.
6. Inspect coolant level in top tank. If necessary, add coolant. Examine all cooling system components for leaks. If none are found, the engine is ready for service.

10-HOUR OR DAILY CHECK

1. Inspect the coolant level in the top tank or the overflow tank.
2. Remove foreign material and dirt from outside the radiator core (and between the panels of folded core radiators).

50-HOUR INTERVAL

1. Perform all 10-hour maintenance.
2. Inspect zinc or magnesium rods if so equipped.

250-HOUR OR MONTHLY CHECK

1. Perform all 10 and 50-hour maintenance.
2. Inspect the condition and tension of all fan belts. If necessary, adjust or replace any belts.
3. Add supplemental coolant additive, or change element assemblies if so equipped.
4. Test the coolant for freeze protection.
5. Inspect the radiator or overflow tank cap gasket.
6. Inspect all hoses for leaks.
7. Inspect/check all engine grounds.

3000 HOURS OR 24 MONTHS (whichever occurs first)

1. Perform all 10, 50, and 250-hour maintenance.
2. Add Cat ELC Extender if filled with Commercial ELC.
3. Drain, clean, and refill the cooling system if filled with Cat DEAC, commercial heavy-duty coolant/antifreeze, or supplemental coolant additive and water. (See page 63, Caterpillar Cooling System Cleaners.)
4. Inspect the condition of fan blades and guards. Inspect the condition of hoses and clamps. Tighten all clamps.
5. Obtain a coolant analysis.

6000 HOURS OR 6 YEARS (whichever occurs first)

1. Perform all 10, 50, and 250-hour maintenance.
2. Add Cat ELC Extender if filled with Cat ELC. See page 20 for the amount of Cat ELC Extender to add.
3. Drain, clean, and refill the cooling system if filled with commercial coolant that meets the Caterpillar EC-1 specifications.
4. Inspect the condition of fan blades and guards. Inspect the condition of hoses and clamps. Tighten all clamps.
5. Obtain a coolant analysis.

12,000 HOURS OR 6 YEARS with CAT ELC Only. (whichever occurs first)

1. Perform all 10, 50, and 250-hour maintenance.
2. Drain, clean, and refill the cooling system if filled with Cat ELC only.
3. Inspect the condition of fan blades and guards. Inspect the condition of hoses and clamps. Tighten all clamps.

Troubleshooting Checklist

Three basic problems are typical of cooling systems:

- overheating
- overcooling
- loss of coolant

A cooling system problem should first be diagnosed by visual inspection. If the problem cannot be diagnosed, tools must be used to find the cause.

Caterpillar has published booklets that contains the following service information in extensive detail:

- Cooling system inspection, test and troubleshooting procedures
- Overheating and overcooling problems and causes
- Steps to clean and recondition cooling systems
- Components that affect cooling systems

Refer to the "Reference Material" section at the back of this publication.

Troubleshooting Overheating

Visual Inspections for Overheating

If an overheating problem is suspected, first check to see if an overheating problem actually exists.

... Look for radiator clogging, low coolant level and low fan rpm.

... Check for coolant leaks or steam coming out of the overflow on the radiator when the engine is stopped.

If no problem is found after these simple visual checks, more accurate ways to check cooling system components are necessary.

... Ensure that the coolant temperature gauge is accurate. Use a 4C6500 Digital Thermometer Group or other temperature testing tools shown on pages 68 and 69 to check the temperature of the coolant. Most coolant temperature gauges for pressurized cooling systems are calibrated to show overheating at approximately 108°C (226°F).

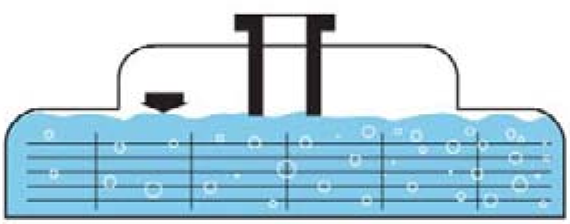


Fig. 58: Correct coolant level in radiator.

... Check the level of the coolant in the radiator. Ensure that the coolant is cool first. A low coolant level can cause overheating. A low coolant level can also be the result of overheating. If the coolant begins to boil, the pressure relief valve in the radiator top tank or filler cap will open. The cooling system pressure remains constant, but coolant is lost. If the level of the coolant is low, add more coolant as needed. See the appropriate Operation and Maintenance Guide for the amount of coolant to add. If the engine overheats again, the low coolant level was not the cause of overheating.

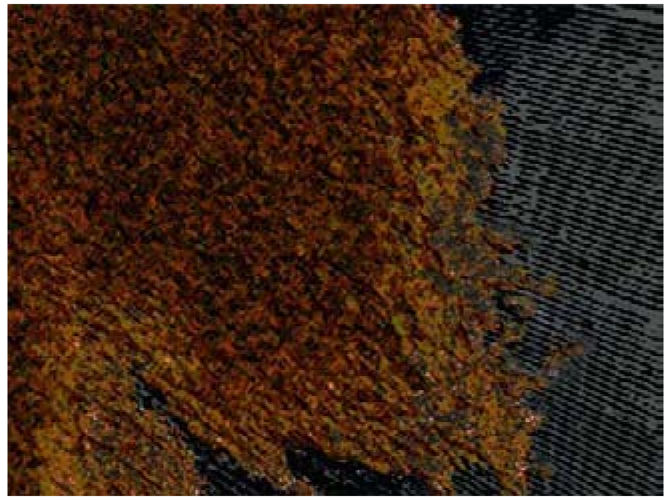


Fig. 59: Dirt in the radiator core.

... Check for restrictions that can stop the flow of air through the radiator. Look for dirt in the cores, especially outside of the fan blast area. Use a light to check for plugged areas in the core. Lower light on one side of the radiator and visually inspect the opposite side.

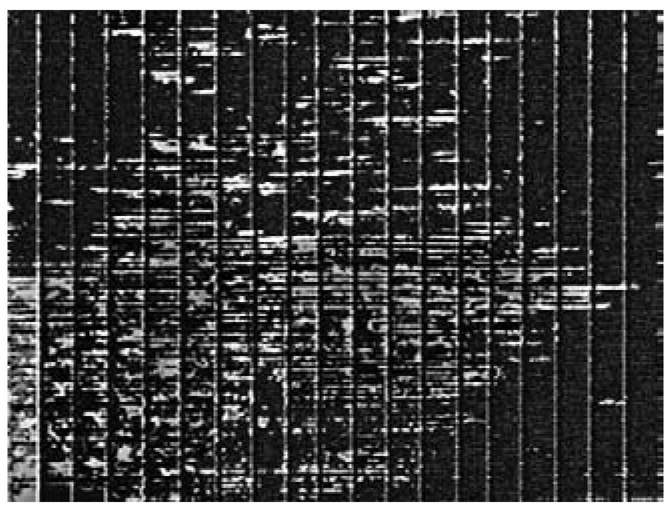


Fig. 60: Radiator with bent cooling fins.

... Check for radiator fins that are bent, damaged, or show signs of leakage from the radiator. On truck engines that have shutters on the radiator, check to see if the shutters are stuck in a closed position.

... Check engine high idle speed. If necessary, adjust until the correct high idle speed is reached.

... Check for correct shutter opening temperature. The relationship between the thermostat and shutter operating temperature must be defined.

... Check fan belts and pulley grooves. Loose belts will wear at a faster rate and cause damage to pulleys. It is also possible for loose fan belts to slip and cause the fan to turn at a slower rate. This too can cause overheating.

... Make sure there is no oil or grease on the fan belts or pulleys. Oil or grease will cause the belts to slip. The outside diameter of a new fan belt must extend beyond the edge of the pulley a small amount. If the fan belt is even with the outside diameter of the pulley, either the fan belt or pulley is worn. Check the inside surface of the fan belts for cracks. Cracks on the inside surface of the fan belt will cause the belt to break after a period of time. Replace fan belts in sets. A new fan belt will stretch a small amount after several days of operation. A new fan belt and a used fan belt used together will cause excessive stress on the new fan belt. When an adjustment is made to the belts, the new belt will tighten before the used belt and thus carry all of the load.

... Check fan speed of hydraulically driven fans. Low relief valve pressure setting or low fan pump flow can cause slow fan speed.

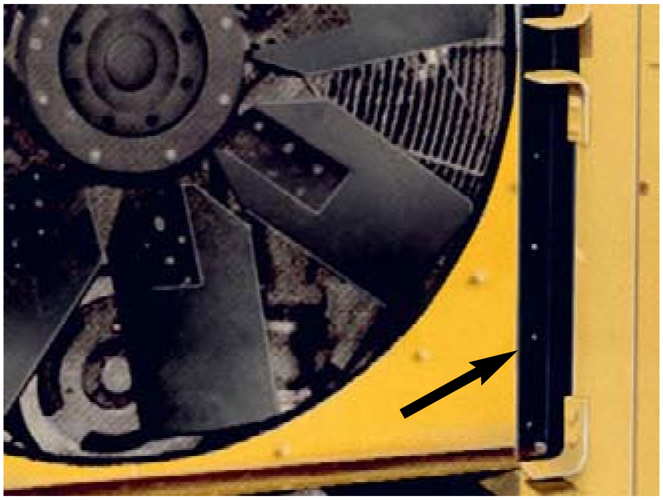


Fig. 61: Radiator Baffle.

... Check the fan blades for damage. Look for missing or damaged radiator baffles. The baffles prevent recirculation of air around the sides of the radiator. A missing or damaged baffle raises the temperature of the air that goes through the radiator.

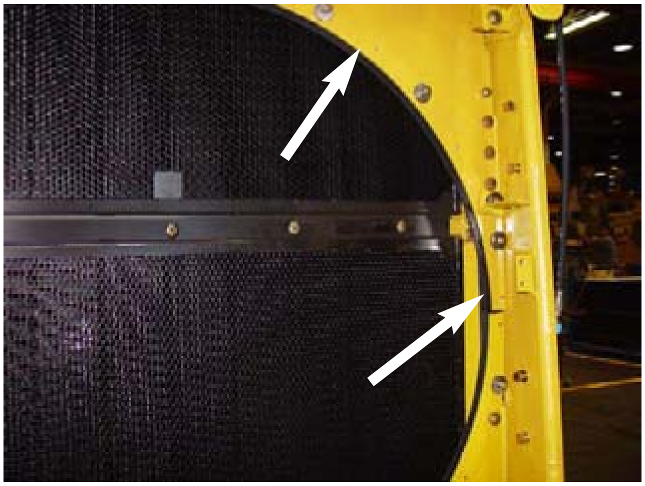


Fig. 62: Fan shroud.

... Check the condition of the shrouds. Make sure they are installed correctly. Also, make sure the rubber strips are in good condition. Fan and radiator shrouds increase the efficiency of the fan by helping to move air through the radiator. The fan shroud must be near the outer edges of the fan blade to prevent recirculation of air around the ends of the fan.

... Check the air inlet system, If an industrial or marine engine is in a closed room and has an air inlet pipe that provides a supply of outside air to the engine, make sure the inlet pipe does not leak and that it is properly connected to the engine. The temperature of the air in the room will rise because of engine heat. If the inlet pipe is not connected correctly, the inlet air will be hot. Make sure there are no restrictions in the air cleaner, air inlet and exhaust lines, or to the flow of air through the cooling system.

... Check the condition of all hoses. A collapsed hose with the engine running, is an indication that the water pump cannot pump enough coolant because of a restriction in the radiator. If the hose is collapsed after shutoff and cool down, the system is not vented properly to allow pressures to equalize. Check the vented filler cap or the relief valve in older systems to assure the vacuum valve is functioning properly.

... Avoid installation where the radiator is significantly higher than the engine. Excess head pressure can cause pump seal leaks while the engine is stopped. For instance, if the engine is in the basement and the cooling tower is on the roof, the height differential cannot exceed 17.4 meters (57feet). If the height differential exceeds 17.4 meters, an auxiliary expansion tank should be incorporated to ensure the water pump seals and hoses do not leak.

... Check for leaks around the water pump. On all engines, there is a drain hole between the coolant seal and the bearing seal in the water pump. Without this drain hole, coolant can get into the oil if there is a failure of the seals in the water pump. Look for signs of coolant or oil leaks at the junction of the cylinder head and cylinder block. Leaks in this area are an indication of head gasket failure,

If no cause for overheating can be found, make these additional visual checks before cooling system tests are made:

Check the condition of the gasket in the radiator cap. If necessary, install a new gasket or radiator cap.

.. Check the radiator gasket sealing surface in the cap for gouges, nicks, or grooves. This surface must be smooth and even.

... If the radiator cap is held in position by a stud, tighten the cap and feel for contact between the gasket and the surface on the radiator top tank. If the stud is too long or damaged, the cap will not provide a complete seal.

Fig. 63: Type of radiator cap held by studs.

NOTICE

Do not disassemble the relief valve in the cooling system until the radiator cap has been removed from the radiator and the pressure in the cooling system is released. If there is pressure in the cooling system when the relief valve is removed, steam can be released. This can cause personal injury.

... Remove the relief valve and check its condition and the condition of the gasket surface for the relief valve. If the parts are in good condition, remove any rust or scale deposits and install the relief valve back in the top tank.

... Make sure the fan is installed correctly. A fixed-blade fan that is installed backwards can lose approximately 50% of its capacity.

... Check the governor seal to see if the fuel setting was changed. Make sure the machine is not used in an overload condition or is not operated near the stall speed of the torque converter.

... Check for transmission and steering clutch slippage.

... Make sure the brakes on the machine are not dragging.

... Check the retarder or BrakeSaver to see if it is fully disengaged.

... Check the glycol concentration of the coolant. The glycol should not exceed 50%.

Cooling System Tests

If the cause of overheating was not discovered during the visual inspections, cooling system tests must be made. Before any tests are made, let the engine temperature cool and install self sealing probe adapters in the following positions if not already installed:

1. Radiator top tank

2. Radiator bottom tank or water pump inlet

3. Water pump outlet or oil cooler inlet

4. Water temperature regulator housing

5. Torque converter oil outlet

6. Engine oil manifold or oil cooler outlet

NOTICE

Remove the radiator cap slowly to release the pressure in the cooling system. It is not necessary to drain the coolant if the engine is allowed to cool and probe adapters are already installed. If these steps are not taken, hot coolant can run out or spray out and cause personal injury.

Test Water Temperature Regulators

Increase the water temperature to the opening temperature of the regulator (this is stamped on the regulator). After several minutes at this temperature, quickly check the regulator to see if it has cracked open. Raise the water temperature approximately 15°C (25°F) above the opening temperature for approximately 10 minutes. Remove the regulator from the water and immediately measure the opening dimension. If the distance is less than the specified dimension in the Service Manual, replace the regulator.

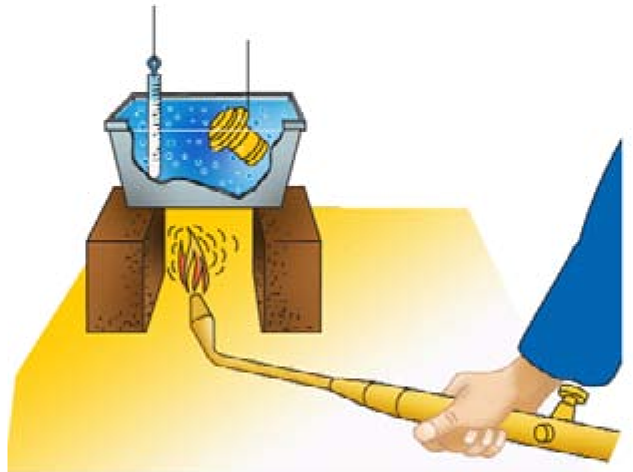


Fig. 64: Testing water temperature regulators.

Do not operate the engine without the water temperature regulators installed. Removing the regulator(s) opens the water pump bypass allowing most of the coolant to bypass the radiator, compounding any potential overheating. In some applications, removing the regulators can be a time consuming task. In these cases it may be easier to determine regulator opening in the engine. This can be done by measuring water temperatures and comparing differential temperatures.

Measure temperatures at the locations specified in "Cooling System Tests." The regulator is not fully open if the radiator temperature drop is considerably higher than the engine temperature rise. The regulator is fully open when both temperature differentials are the same. if the engine and the radiator temperature differentials are greatly different when the engine reaches maximum temperature, it is likely the regulator is not opening properly.

The source of the overheating problem can usually be identified by determining engine temperature rise and radiator temperature drop during the overheating condition. Engine heat rejection and jacket water pump flow can be obtained from the Technical Marketing Information Files (TMI).

This information can be used to calculate the proper temperature differentials at full load. If the measured temperature differentials are much higher than calculated, a water flow problem exists. The heat transfer capacity of the radiator (heat exchanger) is too low if the engine overheats when the temperature differentials are correct or less than the calculated value. Any number of problems can cause low cooling capacity. These problems could include: improper sizing (too small initial heat transfer capacity), airflow too low, excessive glycol concentration, over loaded engine, lug operation, etc.

Check Air Velocity

Before the air velocity is checked, put the transmission in the machine in neutral position. Put the parking brakes "ON" and lower all equipment. Make all checks at rated speed with the radiator grill swung out of the way.

NOTICE

Wear eye protection when working around a running engine.

Check the air velocity with a 8T2700 Blowby/Air Flow Indicator Group. Take several readings and average the results. Care must be taken when trying to pinpoint problem areas in the radiator core. On machines and trucks, it is normal for velocities at the center (fan hub area) and outside edges of the radiator to be as much as five times less than the velocity at the blade sweep area of the core. This meter not only measures air velocity but also helps pinpoint the location of any core clogging that can cause overheating. Use Special Instruction, Form SEHS8712, as a guide for using the 8T2700 Blowby/Air Flow Indicator Group.

NOTE: The air flow through commercial engine radiators is determined by the type of installation. Radiators, with fans located remotely, may have equal air velocities across the radiator and will NOT have higher velocity at the blade sweep area.

If the radiator core has no restrictions, check the fan speed with the 9U7400 Multitach II Tool Group. The complete test procedure is given in Special Instruction, Form NEHS0605.

Check for Air, Gases and Steam in the Cooling System

A cooling system that is not filled to the correct level or that is not filled correctly can cause air in the cooling system. Also, leaks in some components, such as aftercoolers and hoses, permit air to get into the cooling system, especially on the inlet side of the water pump.

Air in the cooling system causes foaming or aeration and affects the performance of the water pump. The air bubbles in the system act as insulation and reduce pump flow. Coolant cannot come in contact with different parts of the engine that have air bubbles, so "hot spots" develop on these different parts. To keep air out of the system, fill the cooling system slowly at the original fill and make sure all suction hose clamps are tight. Start the engine. Check the coolant level to make sure the radiator is still full.

Combustion gas leakage into the cooling system also causes foaming or aeration. Combustion gases can get into the cooling system through cylinder head gaskets that have internal cracks or defects. Most of the causes can be found by a visual check but some need disassembly or a simple test.

Gas in the cooling system is one cause of overheating which can be found by a test known as the "bottle test." For the bottle test, fill the cooling system to the correct level with coolant. Fasten a hose to the outlet relief valve in the radiator top tank or expansion tank. Put the other end of the hose in a jar of water. See Figure 65. Install the radiator cap and tighten it. Start the machine and run it at torque converter stall for three to five minutes. Make sure the temperature of the cooling system is between 85°C (185°F) and 99°C (210°F). This temperature can be checked by installing a thermistor probe in the regulator housing ahead of the regulator. This is a test for gas in the system, not steam, which can produce similar conditions if the temperature is permitted to increase. Look at the amount of bubbles in the glass jar. If an occasional bubble is visible there is no air or combustion gases in the cooling system. However, a constant violent flow of bubbles indicates the presence of air or combustion gases.

Loose precombustion chambers, defective precombustion chamber seals, a loose cylinder head, a cracked liner, or a damaged head gasket will also cause combustion gases in the cooling system.

Fig. 65: Bottle test used to check for air or combustion gases in the cooling system.

Check the Cooling System Relief Valve

The cooling system relief valve must open at the pressure level indicated in the appropriate Engine Specification Module. To check the pressure, install a pressure gauge in the radiator top tank. Tighten the radiator cap. Use an air pressure regulating valve or a 9S8140 Pressurizing Pump to put pressure in the cooling system. Any additional pressure above must go past the relief valve. With the air supply turned off, the system must hold the minimum pressure indicated in the Engine Specification Module.

Test During Machine Operation

If the cause of overheating is not discovered by visual checks and simple cooling system tests, a temperature measurement must be taken. Temperatures are measured at different locations on the machine and compared to see if they are normal. The 4C6500 Thermistor Thermometer Group is used to measure temperatures at the following locations:

- Radiator top tank
- Water pump outlet
- Water temperature regulator housing
- Torque converter oil (inlet and outlet) measured across cooler
- Engine oil cooler

The temperature in the radiator top tank must be below coolant boiling point. The difference between the temperature in the radiator top tank and the ambient air must not be more than 61°C (110°F) with the regulator fully open, full coolant flow through the radiator, and the engine at full load. The water pump outlet temperature must be approximately 4.5° to 11°C (8° to 20°F) below the temperature in the radiator top tank.

NOTICE

The regulator in most machines is fully open when the water temperature is approximately 93°C (200°F - 205°F). The regulators in some earlier commercial engines and engines with reduced emissions will fully open at higher water temperatures.

The cooler inlet oil temperature must not be more than 132°C (270°F). The normal temperature range for cooler inlet oil temperature is 6° to 11°C (10° to 20°F) over the radiator top tank temperature when a machine is operated under full load. The cooler outlet oil temperature will be 8° to 22°C (15° to 40°F) lower than the cooler inlet oil temperature.

Measure Manifold and Aftercooler Temperatures

The temperature of the oil in the oil manifold is approximately 17°C (30°F) higher than the water temperature at the pump outlet. If the temperature of the oil in the oil manifold is 19° to 22°C (35° to 40°F) higher than the water pump outlet temperature, then scaling may be the cause.

A dirty aftercooler will result in high inlet air temperature. For every 1° (Fahrenheit or Centigrade) increase in inlet air temperature the exhaust temperature increases 3° (Fahrenheit or Centigrade). A dirty aftercooler, contaminated with oil mist or corrosion, will not permit normal heat transfer. Where raw or sea water aftercoolers leak into the engine, salt corrosion and wear of engine parts can result.

SUMMARY OF OVERHEATING PROBLEMS AND CAUSES	
PROBLEM	**POSSIBLE CAUSES**
1. Low coolant level	A. External leaks caused by loose connections, radiator cap or cooling system relief valve with defects. B. Internal leaks caused by cracked cylinder head, cracked cylinder block, loose cylinder heads, damaged cooler core, damaged after cooler, damaged gaskets.
2. Reduced air flow through radiator	A. Plugged radiator core. B. Damaged or bent radiator fins. C. Low fan speed because of low engine high idle speed. D. Fan is damaged or installed backwards. E. Loose or worn fan belts and pulleys. F. Damaged fan shroud, wrong diameter fan or incorrect number of fan blades. G. Incorrect fan blade position. (Fan projection out of the shroud must be approximately 50%). H. Excessive fan tip to shroud clearance. Should be . 38" maximum clearance. I. Closed shutter (if equipped). J. Fluid coupling for fan not engaged.
3. Insufficient cooling system pressure	A. Defective pressure gauge. B. Defective radiator cap. C. Defective cooling system pressure relief valve. D. Defective radiator top tank neck or stud.
4. Coolant overflow	A. Air in cooling system because of incorrect cooling system fill. B. Combustion gases in cooling system from loose cylinder head, cracked cylinder head, loose or defective precombustion chamber, defective cylinder head gasket, worn cylinder liner counterbore. C. Steam in cooling system because of engine torque converter over load or low coolant level.
5. Insufficient coolant flow	A. Stuck water temperature regulator. B. Absence of water temperature regulator. C. Low engine high idle speed. D. Loose water pump impeller. E. Radiator plugged on inside.
6. High inlet air temperature or restriction	A. High ambient air temperature. B. Plugged openings in screens for engine compartment with a blower fan. C. Disconnected inlet air pipe in engine room. D. Dirty aftercooler core. F. Plugged air cleaner. G. Damaged or carbon packed turbocharger.
7. Low heat transfer	A. Insufficient flow of raw water through heat exchanger. B. Crusted over keel cooler. C. Hot air for radiator caused by overheating hydraulic oil cooler. D. Scale on cylinder liners or cylinder head.
8. Exhaust restriction	A. Plugged air cleaner. B. Damaged turbocharger. C. Restriction in exhaust pipes. D. Water in muffler. E. Loose baffle in muffler. F. Excessively long exhaust pipe.

Fig 66: Overheating Troubleshooting Chart

Troubleshooting Overcooling

Engine Overcooling

Overcooling can damage an engine just as overheating can. Overcooling occurs when the normal temperature at which the engine operates cannot be reached. This condition is most severe with the use of high sulfur fuel. High sulfur fuel increases wear if the temperature is not over 80°C (175°F). Overcooling is the result of coolant bypassing the water temperature regulators and flowing directly to the radiator.

Causes of Overcooling

Low ambient air temperature and light load application conditions may exist when overcooling occurs. A defective temperature gauge can give an indication of overcooling. The gauge can be checked for accuracy by comparing the actual temperature of the coolant in the water temperature regulator housing with the temperature indication on the gauge. Use a 4C6500 Digital Thermometer to check the temperature of the coolant. If necessary, install a new gauge.

The most common cause of overcooling is water temperature regulators that do not close or allow excess coolant leakage because of a defect. It is possible for coolant to flow around a water temperature regulator that is in good condition. This too will give an indication of overcooling.

Check the water temperature regulator the same way you would for an overheating problem. Even if the. regulator opens and closes correctly, check it for other defects. On bonnet-type regulators that are used in the full-flow bypass system, check the bonnets for wear grooves and dents. These can prevent the regulator from sealing correctly.

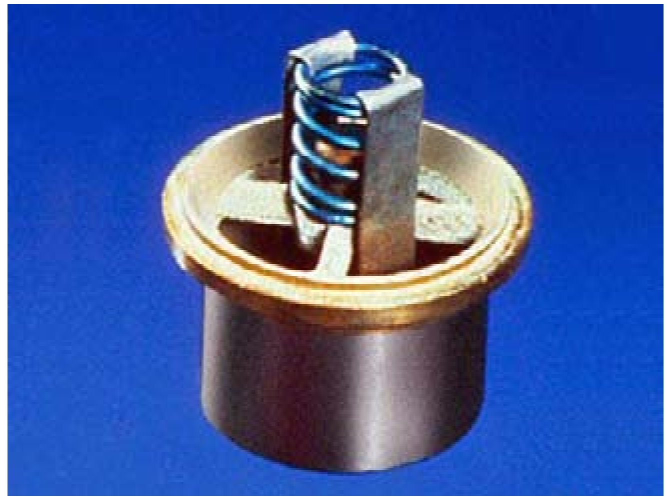


Fig. 67: Bonnet-type water temperature regulator.

After the water temperature regulators have been checked thoroughly, inspect the water temperature regulator housing. Check the counterbores that the regulators fit into. Make sure the surfaces of the counterbore are clean, smooth, and free of foreign material. Check the seal in the regulator housing and check for cocking which causes coolant to flow past the regulator and seal. Some housings have a bleed hole orifice to permit coolant flow to bleed air out of the cooling system when it is filled with coolant. Make sure this bleed hole is open. Do not enlarge this hole; it could cause overcooling. In some machinery, check valves are used to stop coolant flow through the bleed hole when the engine starts.

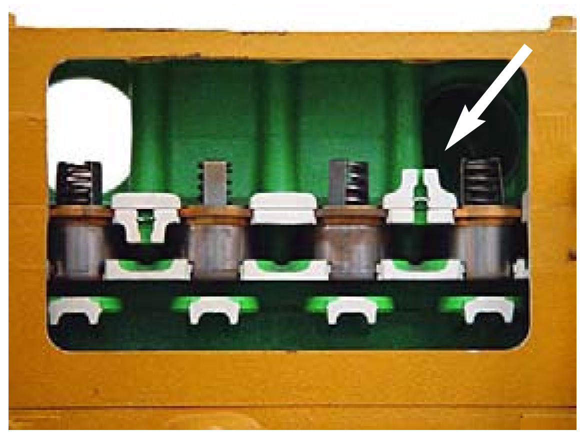


Fig. 68: Bleed hole in water temperature regulator housing.

Some engine installations use external vent lines to vent air. Excessive vent line flow can be controlled by adding a vent/check valve (i.e. 8N9071).

Caution: Do not alter highway truck vent lines on shunt type cooling systems.

Reconditioning the Cooling System

In the course of time, certain components in the cooling system will need reconditioning. The most common reasons for reconditioning are machine operating environment, normal wear of parts, or accidents. The following procedures and tips will assist you during reconditioning and repair of the cooling system.

Cleaning the Outside of a Standard Radiator Core

⚠ WARNING

Wear eye protection at all times when cleaning the cooling system. Always clean the radiator core with the engine stopped.

Remove the radiator grill from the machine. Find the direction of air flow from the fan. If the machine is equipped with a blower fan, the core must be cleaned from the side opposite the fan. If the machine is equipped with a suction fan, the core must be cleaned from the fan side of the radiator. The fan guards have to be removed to clean a radiator core that uses a suction fan. For normal debris such as dust, leaves, small twigs, nettles, cotton fluff, etc., use shop air or a compressor with a capacity of 1.4 to 1.7 cmm (50 to 60 cfm) at a pressure of 350 kPa (50 psi) to clean the core. Hold the air nozzle approximately 6 mm (1/4 ") from the fins. Slowly move the air nozzle from the top of the core to the bottom of the core in order to clean the debris from between the vertically positioned tubes in the radiator core.

Fig. 69: Cleaning the radiator core (equipped with blower fan).

The debris in a radiator core on machines equipped with a blower fan is thicker and packed more tightly than the debris in a radiator core on machines equipped with a suction fan. If necessary, use a light bulb behind the radiator core to see if it is completely clean. Use the air to check for thick areas of dirt.

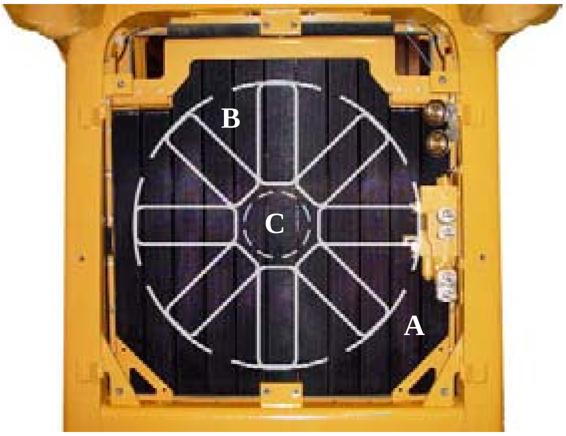


Fig. 70: Critical locations of the radiator core.

On machines equipped with a blower fan, the thicker debris will be in area A (Figure 70) on the outside edge of the radiator core surrounding the fan. Area B of the radiator core, which is the approximate location of the fan, will have some debris, but it will not be as thick as the debris in area A. The air velocity in area B is high. This will cause most of the debris to be in the second and third rows of tubes in the radiator core. Area C of the radiator core is the approximate location of the fan hub. The air velocity is very low in this area and most of the time it remains quite clean.

High pressure water is an excellent means to clean the debris out of a radiator core.

If there is oil in the fins of the radiator core, use a steam cleaner and soap to remove it. Use shop air to remove any loose debris before using the steam cleaner. Some materials like red-wood bark or shredded paper (normally found in sanitary landfill operations) and very stringy type materials can be difficult to remove. If necessary, remove the radiator core from the machine and use shop air and a steam cleaner. Make sure the core is thoroughly cleaned before it is installed in the machine.

Cleaning the Outside of a Folder Core Radiator

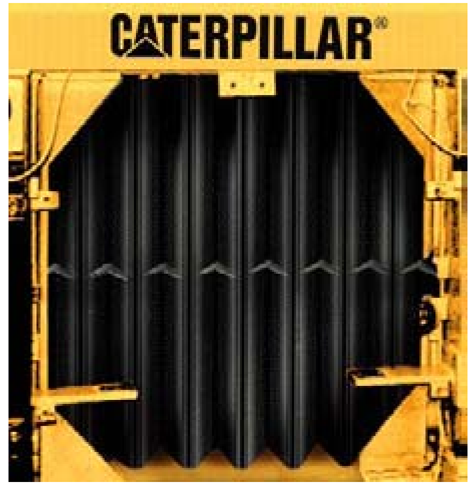


Fig. 71: Folded core radiator.

Although the folded core radiator looks different from a standard core radiator, the principle of cooling and cleaning are the same. The same precautions taken with a standard radiator should be used with the folded core radiator. For example, in a wooded application, engine enclosures should be used and kept in good repair. For machines used in dusty applications, the radiator should be blown out at regular intervals. The radiator is susceptible to plugging in certain applications and maintenance actions should be adjusted for these conditions. As with the standard core, reasonable maintenance should still be practiced.

Compressed air, high pressure water and steam are three preferred cleaning mediums that can be used to clean these radiator cores. For dust, leaves, and general debris, any of these methods may be used. However, the use of compressed air is preferred. Acceptable results will be obtained by opening the front grill and directing the cleaning medium at right angles to the front of each core face. Move the nozzle from the middle to the upper end of each core working from the rear of the vee, and then back again to the front of the vee. Go across the entire face of each core and then do the lower half.

After the core is cleaned, start the engine and accelerate to high idle several times, or until loosened debris is no longer blown from the core. Stop the engine and go over the face again. Exposure time may be kept shorter on this second pass. Restart the engine and accelerate it to high idle several times.

A method to increase the air velocity is to place a piece of plywood over the lower third of the radiator. Put the plywood in between the grill and the radiator toward the bottom of the core. Start and accelerate the engine several times or until trash ceases to be expelled. Stop the engine and then reposition the plywood toward the top of the core. The plywood may have to be wired in place. Repeat the engine acceleration process. The increased air velocities will aid in the removal of debris from between the fins. If steam or water is used, continue running the engine until the core is hot and does not have water vapor coming off the fins. The machine is then ready for use.

If oil, sap, or mud is encountered, a different cleaning procedure is required. Oil and sap can be cleaned from a core by using a commercial degreaser. The degreaser must be applied to both sides of the core face, especially in the area of visible plugging. Let it soak for a minimum of 5 minutes and then wash the core. Use very hot water under high pressure and a small amount of laundry detergent. Concentrate the cleaning efforts on areas which were exposed to the oil or sap, working from both sides of the core. Be sure to wash the areas on each end of each core in the area around the seal. Excess oil in this area can be detrimental to the seals. After washing, rinse the core with hot water. Start the engine. Accelerate the engine several times and rinse the core again. Repeat this rinse process until detergent bubbles are no longer emitted from the fins. Continue to operate the engine until there are no water vapors coming off the fins. Do not put the machine back to work until all water has evaporated.

Plugging by mud may be of two types: mud splatter and mud impregnation. Mud splatter may be easily removed by shutting the engine off and spraying water on both sides of the core to soften the mud. If heat from,the radiator causes the water to evaporate, spray the core again. Once the mud has softened, direct the water nozzle from the fan side towards the front of the radiator. Try to keep the nozzle perpendicular to the face of each core. Then go to the front of the radiator and spray water at each core. Keep the nozzle pointed to the rear of the engine. This nozzle position will allow the mud to flake or peel off. After the mud has flaked off, reposition the nozzle as in general cleaning and go across the core assemblies. When the water from the core appears clear, the core has been cleaned. Be sure to dry the radiator as previously described. Small patches of mud splatter and other debris may be removed with a file cleaner card, such as a Colton's file cleaner #10.

Mud impregnation is very difficult to clean on any type of radiator. For best results, remove the fan guards, fan, and shroud. Thoroughly flush both sides with high pressure water until the water flowing from between the fins is clear. To check for cleanliness of the radiator core, a light behind the core can be used to check for dirt. If dirt is visible, additional cleaning is necessary. If this method of cleaning impregnated mud does not give good results, remove the radiator. Cap the inlet and outlet holes in the top and bottom tank and place it in a large tank of water and laundry detergent. After soaking and agitating the core in water, rinse with hot water and blow dry. The time required for soaking is dictated by your particular problem.

Do not place folded core radiators in solvent baths that can remove paint. Folder core radiators are painted with a special process to get full fin penetration. If the original paint is removed, the fins will corrode at an accelerated rate.

Cleaning the Outside of a Multiple Row Module or Advanced Modular Cooling System (AMOCS) Radiator

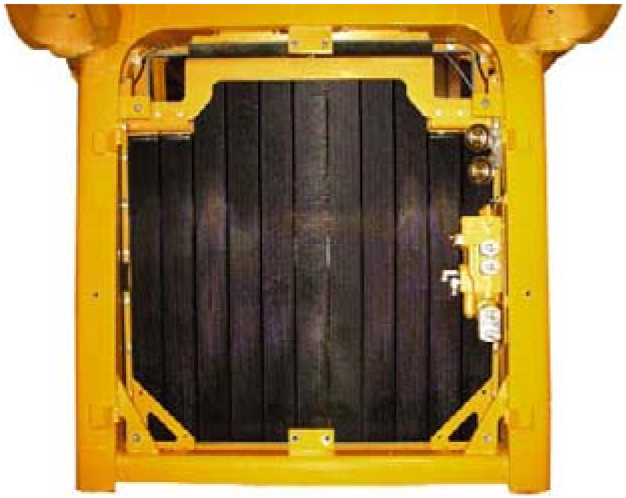


Fig. 72: AMOCS Radiator.

The Multiple Row Module and AMOCS radiator have evolved from the folded core radiator, which replaced the standard core radiator in most equipment. The Multiple Row Module and AMOCS radiators use individual core assemblies. However, use of these radiators greatly reduces many plugging problems previously experienced. Since they are similar to the other two types of radiators, please see "Cleaning the Outside of a Standard Radiator Core" and "Cleaning the Outside of a Folded Core Radiator" for cleaning assistance.

Cleaning Inside Parts of the Cooling System

There are several ways to determine if the cooling system needs more than a mild cleaning:

1. Flow restrictions - Remove the radiator cap and see if the cooling tubes are plugged. If so, simply using a mild cleaner will not be satisfactory.
2. Constant overheating - If the fan belt, thermostat, and water pump are functioning properly, but the engine continues to overheat, then the cooling system may be badly plugged.
3. Water pump failure - If the water pump fails and upon inspection, heavy water contamination damage is found in the bearing, seal, and shaft area, the cooling system probably needs a thorough cleaning with special chemicals.
4. Visible heavy rust and green slime - If green slime (chromium hydroxide) is evident in the bottom of the radiator cap and the coolant is so cloudy that an antifreeze tester cannot be read, the system will need a more thorough cleaning with special solvents.

When the inside parts of the cooling system become contaminated, normal heat transfer is not possible. Oil is a common form of contamination in cooling systems. If an oil cooler has a defect, oil can enter the cooling system when the engine runs because the oil pressure is higher than the water pressure. When the engine stops, water or antifreeze in the oil will settle into the oil sump because the circulation stops. Also, water or antifreeze will continue to leak into the oil system, since cooling system pressure drops very slowly. A pressure check of the oil cooler may reveal a defect. Alternatively, oil samples may determine the presence of antifreeze or water in the oil.

After the problem that caused contamination of the cooling system has been found, the cooling system can be cleaned as follows:

1. Drain all of the coolant from the cooling system.
2. Fill the cooling system with clean water.
3. Start the engine and run it until the thermostats open.
4. Add two cups of non foaming soap. Automatic dishwasher soap is best. Do not use plain laundry soap.
5. After the non foaming soap is added, run the engine for approximately twenty minutes. Check to see if the oil is breaking up or if the water has oil patches.
6. If oil patches.are still present, add two more cups of soap and.run the engine for ten minutes. Drain the mixture from the cooling system.
7. Fill the cooling system again with clean water. Check the surface of the water for oil. If oil is still present, repeat Steps 3 through 7. When the water is clear, drain and rinse the cooling system one more time. Add coolant and conditioner.

Scale or rust in a cooling system can affect heat transfer. The scale and rust can be cleaned out of the cooling system with a two step type heavy duty radiator cleaner. This cleaner consists of an oxalic acid, which cleans the scale and rust, and a neutralizer. Two step type heavy duty cleaners are available from industrial supply outlets or they can be mixed as follows:

Acid - Mix 900 g (2 lb) of sodium bisulfate ($NaHS0^4$) per 38 liters (10 gal) of water (25 grams per liter).

Neutralizer - Mix 225 g (1/2 lb) of sodium carbonate crystals Na^2CO^3 per 38 liters (10 gal) of water (6 grams per liter).

The cooling system may also be cleaned with Caterpillar Cooling System Cleaners. These are designed to clean the system of harmful scale and corrosion without taking the engine out of service. It can be used in all Caterpillar Engines' and other manufacturers' cooling systems in any application. This mild solvent must not be used in systems that have been neglected or have heavy scale buildup. These systems require a stronger commercial solvent available from local distributors.

Caterpillar's Cooling System Cleaners are available in the following size containers:

4C4609: 0.236 L (1 pint)
4C4610: 1,980 L (1 quart)
4C4611: 3.780 L (1 gallon)
4C4612: 18.90 L (5 gallon)
4C4613: 208 L (55 gallon drum)
6V4511L 1.9 liters (1 1/2 gallon'

Drain the cooling system completely. Refill with clean water and a 6% to 10% concentration of cleaner. Run the engine for 1/2 hours. Then, drain the coolant and flush the system with clean water. Refill the system with the proper amount of Cat ELC, or Cat DEAC and water. If Caterpillar Coolant is not used, the appropriate amount of Supplemental Coolant Additive must be added too.

Components that Affect the Cooling System

Battery Ground Connections

Improper ground connections at the engine can cause problems In the cooling system. Make sure all ground connections are clean and tight.

Fig. 73: Battery Ground.

Sea Water Inlet Screen

Marine vessels and dredges use raw water coolers. Raw water coolers must be equipped with inlet screens to prevent debris entry. A clogged inlet screen or no inlet screen at all can result in overheating.

Oil Cooler Cores

A pressure check of the oil cooler cores can be made to detect leaks. The cooler must be removed for such a check. Depending on their size and location, some leaks can be repaired.

Oil flows around the tube bundles in an oil cooler core and the water flows through the tubes. If the tubes that the water flows through become plugged, they can be cleaned as shown in Figure 74. If the oil passages in the cooler core become plugged, they cannot be cleaned.

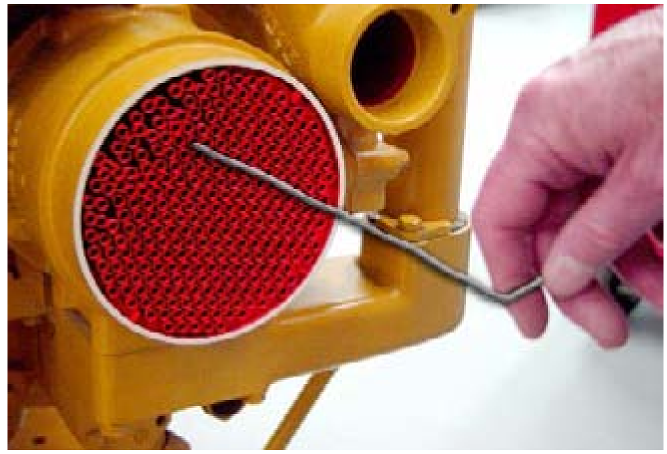


Fig. 74: Cleaning the tube bundles.

Cooler cores contaminated by a system failure should be replaced. Before installing the new core, inspect the oil filter. The oil filter will give an indication of the condition of the oil cooler core. Inspect the oil filter as follows:

1. Check the schematic of the lubrication system to determine if oil flows through the oil filter before it goes to the oil cooler core, or if oil flows through the oil cooler first and then goes to the oil filter. In most lubrication systems, oil flows through the cooler and then to the oil filter before it goes to the oil gallery.
2. Look for chips in the oil filter. If the oil flows from the oil cooler to the oil filter and the filter is full of chips, the oil cooler can also be full of chips. It is not possible to clean these chips out of the cooler core, so the core is not reusable. If the oil flows through the oil filter first, check the amount of chips in the oil filter and inspect the inlet of the oil cooler core to see if it contains any chips. If the oil filter is clean, the oil cooler will probably be clean.
3. Check the cause of a wear failure. If the failure was instant, only a few chips will be present. If the wear failure was gradual, the first few chips will be small, increasing in size as the failure progresses.

A failure that stops the flow of oil will not produce chips in the oil cooler even if there is a large amount of failure debris.

Refer to SEBF8077 Caterpillar Guideline For Reusable Parts and Salvage Operations "Engine Oil Coolers" and SEBF8085 Caterpillar Guideline, For Reusable Parts and Salvage Operations "Endsheet Inspection of Rubber Endsheet Oil Coolers".

Aftercooler Cores

See Technical Marking Information (TMI) for Marine Application Performance Specifications.

Usually, an aftercooler core used on a vehicle receives adequate air supply. However, adequate air supply is crucial if an aftercooler core is used on an engine that is in a room. If this is the case, make sure all blowby fumes are directed out of the room. If the fumes are piped into the air intake, they will decrease the efficiency of the aftercooler.

The water side of the core can be kept clean by the use of correct maintenance procedures. This is not true with raw water aftercoolers. Sea water and stream water can plug the water side of the core. A temperature check of the air, after it goes through the aftercooler, will determine whether or not the aftercooler core is plugged. Ideally, the inlet manifold air temperature will never be above 52°C (125°F), but the temperature on some arrangements can reach 93°C (200°F). If the aftercooler core is clean and the temperature of the sea water is 29°C (85°F), the air temperature on marine engines must not be more than 49° + 2.8°C (12° ± 5°F). The air temperature will decrease 1° (Fahrenheit or Centigrade) for each 1° (Fahrenheit or Centigrade) the water temperature is under 29°C (85°F). This means if the temperature of the sea water is 18°C (65°F) and the aftercooler core is clean, the air temperature must be 38° ± 2.8°C (100° ± 5°F). If the sea water is 18°C (65°F) or lower and the air temperature goes above 52°C (125°F) on marine engines, the aftercooler core needs to be investigated. If the jacket waterside temperature differential is low, suspect an aftercooler problem. If the jacket waterside temperature differential is high, check the pump as pump flow is most likely the problem.

Because of the construction of the aftercooler, it is impossible to clean the inside of the tube bundles with a rod. But it is possible, with special plumbing, to reverse the flow of raw water through the aftercooler to back flush it. This can be accomplished by running the engine for approximately one hour with a light load or no load. This will help clean the core. If this is not possible, remove all the pipes connected to the aftercooler and make adapters that can be used to flush the core with fresh water. If fresh water is used to clean the core, the water pressure must not be more than 170 to 205 kPa (25 to 30 psi). Do not stop the outlet flow of water out of the core and let the water pressure build up in the core. If the aftercooler core can be removed easily, it is best to clean it in a shop.

Radiator Cap

The radiator cap must prevent water and pressure loss in the cooling system. On large radiator caps, a worn gasket can be replaced. Smaller automotive type radiator caps cannot be serviced. A new cap must be installed.

Relief Valve

The cooling system relief valve cannot be serviced but it can be cleaned. If there is a loss of pressure in the cooling system, install a new relief valve and plate.

Fan Belts

Fan belts come in a set. If one of the fan belts is worn, all the fan belts must be replaced.

Pulleys

Some pulleys can be reconditioned under certain conditions. A pulley is reconditioned by remachining the grooves. For reconditioning procedures and specifications, see Guideline for Reusable Parts, Cast Iron And Steel Pulley Grooves, Form SEBF8046. Pulleys wear on the side faces of the groove. This wear is caused by abrasive material between belts and grooves. As the pulley wears, the belt will drop deeper into the groove. If the belt and pulley are in good condition, the belt will extend beyond the pulley edge as shown in Figure 75.

Fig. 75:. When fan belts and pulleys are in good condition belts extend beyond the edge of the pulley.

Do not use belt dressing or other compounds that prevent belt slippage. Most of these compounds will make the side walls of the belt soft and weak and cause the belt to wear.

Fan Assembly

Do not repair a damaged fan assembly. When a fan is constructed, a balance point is established so the fan will run with a minimum amount of vibration. A repair would affect this balance point and can weaken the structure of the fan.

Fan Shroud and Baffles

The fan shroud and baffles cannot be reconditioned. Make sure these parts are installed when a radiator core is replaced. The fan shroud and baffles have an effect on fan efficiency and prevent recirculation of air. At times, wear or interference between the fan blade tips and the baffles will be noticed. This is normal. When a radiator guard flexes, it can cause the shroud to contact the tips of the fan blades.

Radiator Mounts

The flexible radiator mounts protect the radiator from damage normally caused by machine and/or engine vibration. When a radiator is removed for any repair, check the mounts, especially the condition of the rubber. If the rubber is deteriorated, install new mounts. Be sure the mounting bolts are tightened to the correct torque. See the appropriate Service Manual module.

Fan Guards

Vibration can damage fan guards. Make sure the bolts that hold the fan guards are tight at all times. If a guard wire is broken at an original weld joint, it can be tack welded into place. If a guard wire is broken, a new wire must be installed.

Water Temperature Regulators

There are no parts in the water temperature regulator that can be repaired. See the topic, "Test Water Temperature Regulators" on page 46.

Hoses and clamps

On machines where it is possible, turn the valves in the heater lines to the "OFF" position during summer months so that there is no system pressure in the heater hoses. If one heater hose comes loose, all of the coolant can be lost if coolant flow is available to these hoses. Knowing the location of heater hoses is important because they must be checked often.

When you install hose clamps, do not tighten them too much. Tighten the clamp until it compresses the rubber coating on the hose. If the clamp tears the rubber coating, revealing the cords in the hose, it has been over tightened. Hoses are usually replaced when they have a leak or during a scheduled service interval. Remember, all hoses in the cooling system are made of similar material and operate in the same environment. So, if any one hose starts to leak, replace all of the hoses. If a scheduled service interval is used, change hoses every three years or 4000 hours.

It is difficult to check the condition of a hose because all hose coverings are painted and it is normal for paint to flake, check, and crack. As pressure in a cooling system increases, the hoses expand, causing the paint to check. The exterior appearance of the hose is not a good indication of wear. The "feel" of the hose is a good indication of wear. When the temperature of the cooling system is cold and the pressure in the system is released, the hose will need to be replaced if it feels soft. Softness of the hose may be due to a number of factors. If a radiator or cooling system has had oil in it, the inner liner of the hose will soften. The hose will also feel soft if it is very old and the inner liner has loosened from the fabric. A loose inner liner can fold down into a water passage on the suction side of the water pump and restrict the flow of coolant. An inner liner folded into a water passage is not only rare, but because there is no external leakage, it is also difficult to find. Finding a loose liner is especially difficult if you are troubleshooting an overheating problem.

Temperature Gauges

There are two types of temperature gauges, electrical and mechanical. If there is a problem with an electric gauge, the temperature sending unit and the gauge must be checked separately. With the mechanical gauge, the bulb and tube are fastened to the gauge and must be checked as a unit. If you install a new mechanical gauge, make sure the tube is long enough for correct installation.

There are different types of mechanical gauges and their red ranges are different. The red range is 108°C (227°F) for most gauges and 99°C (210°F) for highway trucks. The red range for most transmission temperature gauges is 132°C (270°F). The part number is different on each gauge because of the difference in the length of the tube to the bulb.

Later model machines have EMS panels. On these machines, the high coolant temperature light will come on at a temperature of 107°C (225°F).

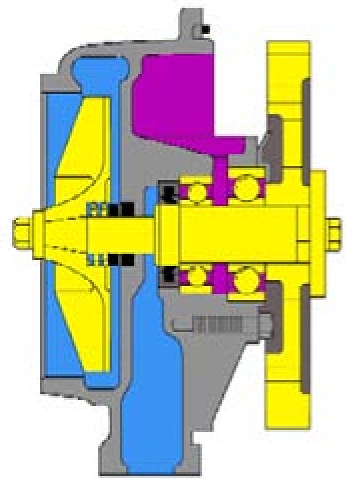


Fig. 76: Water pump.

Water Pump

The need for water pump repair is generally the result of seal leakage. All water pumps have a drain cavity in the pump housing. The cavity will direct water leakage to the ground. If this cavity is closed, the water will be pushed past the oil seal on the shaft, allowing the water to get into the engine oil system. This will cause damage to the engine.

Fig. 77: Use a special tool to install the seal assembly.

Seal assemblers are available for all water pumps. Some seal assemblers come with a small tool that is used to install the seal and ring correctly. Clean water, used as a lubricant, will make the installation of the seal easier. Never use oil as a lubricant. Oil can make the seal swell or soften or cause it to turn on the shaft.

The bearings in the water pump can be replaced when the pump is reconditioned. The impeller, shaft, and cover can be used again, unless there was a bearing failure and the pump has operated for some period of time. Most of the time the impeller wears into the cover when there is a bearing failure.

NOTE: When reconditioning a water pump, make sure the shaft is clean before any seals are installed. Rust or scale can tear the seal. Do not use a hammer to install the impeller. A hammer will crack the seal face. Use a press or a retaining bolt to pull the seal in position on the shaft.

NOTE: When installing a new water pump, put a small amount of oil on the bearings. Do not start or turn over an engine unless the cooling system is filled with coolant. If the water pump is operated in a dry condition, seal failure will result from overheating.

NOTE: If a cooling system has been flushed, check the condition of the water pump closely for approximately one week. Many times, a seal failure will result soon after the cooling system has been flushed. This is because the loose rust and scale, which is purged by the cleaning process, goes through the pump seal area.

Cylinder Heads

Normally, cylinder head repair is needed because of leaks or cracks. A defect in a core plug (freeze plug) in the top deck of the cylinder head can cause a leak. If there is a leak in this area, water spots will be visible in the plug recess. The old plug must be removed, the hole for the plug cleaned and a new plug installed. Make sure to put a sealant on the new plug before installation.

Fig. 78: Freeze plug in cylinder head.

Cracks in a cylinder head are generally found between valve ports. Cracks can also be found at precombustion chamber or nozzle openings to a valve port. Cracks in a cylinder head can be repaired by a remanufacturing welding process. Remanufactured cylinder heads are available from the Caterpillar Parts Distribution System.

Before installing a new precombustion chamber in a cylinder head, check the precombustion chamber gasket surface in the head for pits or rust. If there are pits or rust, a new precombustion chamber will not seal correctly.

If you remove a precombustion chamber from a cylinder head, install a new O-ring seal on the precombustion chamber before it is used again in the head. O-ring seals can harden and break. If there is a leak in the area around the seal, overheating will result, especially if scale prevents heat transfer from the body of the precombustion chamber. Also, it is important that a new gasket is installed. This gasket helps make sure the hole for the glow plug is in the correct position. See the appropriate Service Manual module for the orientation of this hole.

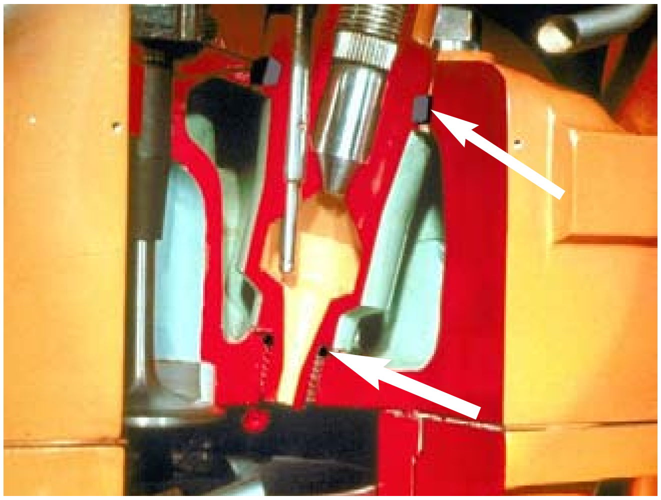


Fig. 79: O-ring seals and gasket on precombustion chamber.

Cylinder Block

If an engine has been completely disassembled, check the condition of the cylinder block carefully.

Be sure to measure the depth of the counterbores for the cylinder liners. The thickness of the flange on the cylinder liner must be more than the depth of the. counterbore. See the appropriate Service Manual for the correct liner projection. If the liner projection is not correct, there will be insufficient compression on the cylinder head gasket. If the counterbore has been damaged by a loose cylinder head, a fretting pattern will be visible on the ledge of the counterbore. The block can be reconditioned with a counterboring tool and the use of inserts under the flange of the cylinder liner. These inserts are available from the Caterpillar Parts Distribution System.

If the deck surface of a cylinder block is damaged, consult the factory for information as to how much stock can be removed from the block. If the block is ground, the clearance will decrease between the valves and the top of the pistons at top dead center of crankshaft rotation for that cylinder.

Cylinder Liners

Check the condition of the cylinder liners. Look for fretting on the flange and any pits and scale on the water side of the liner. If there are pits in the liner, turn the liner 90° from its original position during reinstallation in the, cylinder block. Put liquid soap on the lower seals of the liner before installation. Do not use ethylene glycol on these seals because some of it may drain down to the oil pan and give a positive antifreeze reaction in an S• 0•S Services oil analysis test. Put mineral oil or crankcase oil on the upper seal in the liner. Install the seal immediately. The mineral oil or crankcase oil will cause the seal to swell. Normal wear dimensions for the different types of cylinder liners can be found in the Service Manual.

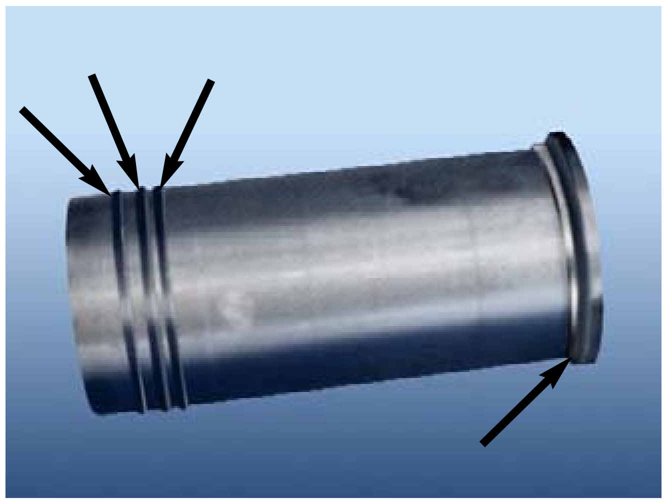


Fig. 80: Filler band and O-ring seals on cylinder liner.

Test Equipment

Troubleshooting and analyzing cooling system conditions can be easier with the right test equipment.

See pages 62-69 for cooling system troubleshooting and analyzing tools available from the Caterpillar Parts Distribution System.

Cooling System Maintenance Products

Cat ELC (Extended Life Coolant)

Fig. 81: 101-2844 Cat ELC (1 gal).

Developed, tested, and approved by Caterpillar, Cat ELC lasts up to six times as long as conventional coolant. Cat ELC requires no supplemental coolant additives (SCA's); instead, Cat ELC Extender is added once, at 6000 service hours or one half of the service life. Cat ELC is the coolant used as standard factory fill worldwide for all Caterpillar machines. Cat ELC can be used in all Cat and most OEM diesel and gasoline engines.

See page 18 for available quantities and part numbers.

Supplemental Coolant Additive

Fig. 82: Cat SCA (Supplemental Coolant Additive).

Cat SCA helps prevent rust, mineral and deposit formation in the cooling system. Cat SCA helps protect all metals, including aluminum. Cat SCA does not affect gaskets or hoses and is compatible with glycol-base antifreeze.

See page 24 for available quantities and part numbers.

Supplemental Coolant Additive Elements

Fig. 83: 9N3718 Caterpillar Conditioner Element.

Spin-on supplemental coolant additive elements contain a pre-measured amount of chemical coolant additives that dissolve during engine operation. The elements can be used year-round to help prevent cavitation, corrosion, and erosion. Elements are available for most Cat diesel engines. To avoid over-concentration, never use supplemental coolant additive elements and liquid supplemental coolant additive simultaneously. Never use supplemental coolant additive elements with Cat ELC.

See page 24 for available quantities and part numbers.

Antifreeze

Fig. 84: 8C-3684 Cat DEAC (Diesel Engine Antifreeze/Coolant) (1 gal).

Cat DEAC is specially formulated for use in diesel cooling systems. Cat DEAC helps protect against cylinder liner and block pitting and helps prevent corrosion. Cat DEAC does not require supplemental coolant additive at initial fill. See page 18 for available quantities and part numbers.

Cooling System Cleaners

Fig. 85: 6V4511 Cooling System Cleaner - Standard (1/2 gal).

Caterpillar Cooling System Cleaner - Standard is designed to clean the system of harmful scale and corrosion without taking the engine out of service. Caterpillar Cooling System Cleaner - Standard can be used in all Caterpillar engines' and other manufacturers' cooling systems in any application.

Caterpillar Cooling System Cleaners, both "standard" and "Quick Flush," must not be used in systems that have been neglected or have heavy scale buildup. These systems require a stronger commercial solvent available from local distributors.

Caterpillar's Cooling System Cleaner 1.9 liters (1/2 gallon) - Standard is available (Part No. 6V-4511) in containers or, if an immediate cleaning is desired, the following Caterpillar Cooling System Cleaners can be used:

4C4609: 0.236 L (1 pint)
4C4610: 1,980 L (1 quart)
4C4611: 3.780 L (1 gallon)
4C4612: 18.90 L (5 gallon)
4C4613: 208 L (55 gallon drum)

Refer to label for cleaning instructions.

NOTICE

Use of commercially available cooling system cleaners may cause damage to the aluminum components in the cooling system. Use only cleaners that are approved for use with aluminum.

Coolant Sampling Tools

Fluid Sampling Bottle Kit (169-8373)

Fig.86: Sampling Bottle with Cap and Probe.

The 169-8373 Fluid Sampling Bottle Kit provides a 118 ml (4 oz) sampling bottle attached to the 177-9343 Cap and Probe Group. There are 300 bottle kits to a box.

The 177-9343 Fluid Sampling Cap and Probe Group can be ordered without a bottle attached. There are 500 cap and probe groups in a box. Both the kit and the group have a metal tipped probe with a plastic housing and 317 mm (12.5 in) of tubing attached. The probe is for use with systems that have self-sealing probe adapters installed. This probe allows taking samples from the cooling system without first cooling down and opening the system. The probe and cap are a single use, disposable system.

There are two sizes of sampling bottles with caps available. The 169-7372 Fluid Sampling Bottle Assembly holds 118 ml (4 oz.). The 169-7373 Fluid Sampling Bottle Assembly holds 74 ml (2.5 oz.). Both bottle assemblies are packaged 200 to a box.

Vacuum Pump (1U-5718)

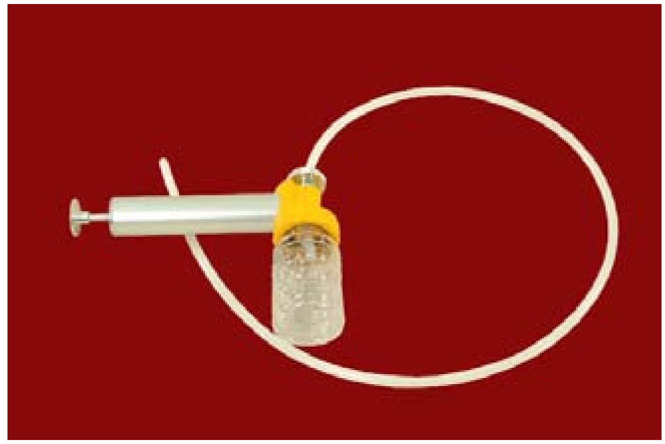


Fig. 87: Vacuum Pump with Bottle Attached.

The 1U-5718 Vacuum Pumps is used for taking samples for analysis when live sampling under pressure with a probe is not available. The 30.5 m (100 ft) roll of 4C4056 Plastic Tubing is used with the vacuum pump after cutting to the required length for sampling. The plastic bottle assemblies from the previous article are used with this vacuum pump to contain and ship the samples.

Probe Adapter Groups (5P-2720, 5P-2725, and 5P-3591)

Fig. 88: Self-sealing Probe Adapter Groups.

These self-sealing probe adapters allow one to use sampling probes, temperature probes, and pressure probes in the cooling system without first cooling down and opening the system. The adapters automatically seal when the probes are removed. Use the probe adapters to make a cooling test faster and easier. The probe adapters can be used in any cooling system with pressures up to 690 kPa (100 psi) and temperatures up to 120°C (250°F). The 5P-2720 Probe Adapter Gp has 1/8 inch pipe threads. The 5P-2725 Probe Seal Adapter has 1/4 inch pipe threads. The 5P-3591 Probe Adapter Gp has 9/16-18 threads.

Coolant Condition Test Tools

Cat ELC Dilution Test Kit (223-9116)

Fig. 89: Cat ELC Test Kit.

This simple pass/fail 223-9116 Cat ELC Dilution Test Kit indicates, by color, if the inhibitor level of the coolant is correct. All new Caterpillar machines are shipped with Cat ELC in the cooling system. This kit contains enough material for ten tests. Complete instructions for performing the test and interpreting the results are enclosed within the kit. This kit has been cancelled.

NOTE: When the inventory of these kits is exhausted, they will not be restocked.

Coolant Condition and Ethylene Glycol Test Kit (8T-5296)

Fig. 90: Cat SCA and Ethylene Glycol Test Kit.

This test kit accurately measures the concentration of Cat SCA and ethylene glycol in your coolant. The kit helps monitor Cat SCA and ethylene glycol concentrations to ensure proper protection of the cooling system. The test can be performed in only minutes. The kits contain material for approximately 30 tests.

NOTE: The Cat SCA and ethylene glycol test kit checks for the concentration of nitrites in the coolant. Some other brands of supplemental coolant additives are based on phosphate inhibitors and the test kit will yield readings that are inaccurate. If another supplemental coolant additive is used, refer to the manufacturer for an appropriate test kit.

Coolant Condition Test Kit (4C-9301)

Fig. 91: Nitrite Concentration Test Kit.

This kit gives quick results for systems that use nitrite. The kit can be used with Caterpillar liquid cooling system conditioners. The kit contains material for 100 tests.

Coolant/Battery Tester (245-5829)

Fig. 92: Portable Refractometer Freezing Point Tester.

The 245-5829 Refractometer measures the freezing points of both ethylene glycol coolant and propylene glycol coolant. The refractometer also measures the specific gravity of battery acid in order to determine the condition of a battery's charge.

The technician simply applies two or three drops of the coolant or the acid in the refractometer. The refractometer displays in degrees Celsius. The refractometer also displays in degrees Fahrenheit. The prism and lens design with a focus adjustment provides ease of operation for the technician. The design includes automatic temperature compensation features in order to deliver accurate results.

A carrying case and a calibration screwdriver are included with the refractometer.

Temperature Testing Tools

Infrared Thermometer (164-3310)

Fig. 93: High Temperature Scale Infrared Thermometer.

The 164-3310 Infrared Thermometer is rugged and easy to operate. This thermometer is ideal for determining the temperature of objects that are out of reach, too hot to touch, or continuously moving. The measure range is -30° to 900°C (-24° to 1600°F). This thermometer is powered by 2 AA cell batteries. 110 VAC and 220 VAC models are also available.

Infrared Thermometer (213-4310)

Fig. 94: Caterpillar Non-Contact Infrared Thermometer.

The 213-4310 Infrared Thermometer with a built-in laser pointer is convenient, reliable, and easy to use. Just point, shoot, and read the temperature instantly on the backlit display. The temperature measurement range is -20° to 260°C (-4° to 500°F) ±1°F/C.

Additional uses beyond testing engine cooling systems could include determining undercarriage component temperature, checking brake and bearing temperatures, verifying heating and air conditioning systems, and determining defrost grid temperatures.

Multimeter with Infrared Thermometer (237-5130)

Fig. 95: Caterpillar Digital Multimeter with Built-in Infrared Thermometer.

The 237-5130 Digital Multimeter Group has a built-in laser pointer and a type-K thermocouple included. The temperature range of the infrared thermometer is -20° to 270°C (-4° to 518°F). The temperature range of the thermocouple is -20° to 750°C (-4° to 1382°F). The multimeter group with included leads, also measures true root mean square (RMS) AC voltage, DC voltage, current, resistance, capacitance, frequency, duty cycles, and temperature for display on the backlit display.

Digital Thermometer Group (4C-6500)

Fig.96: Five Channel Digital Thermometer Group.

The 4C-6500 Digital Thermometer Group is a portable tool with five channels for measuring temperatures. This tool will calculate the differential temperature between any 2 of the 5 channels. The range of temperature is from -50°C to 850°C (-58°F to 1582°F). The group includes 3 probes, ranging from 25.4 mm (1") to 63.5 mm (2.5 in.) in length. The probes are designed for use with included Probe Seal adapters and the 4 included 20 foot cable assemblies. One high temperature and one exhaust probe is also included in the foam insert in the carrying case. Additional probes are available for use with the digital thermometer.

Thermocouple Temperature Adapter (6V-9130)

Fig. 97: Temperature Adapter for Digital Multimeters.

The 6V-9130 Thermocouple Temperature Adapter is available for use with most digital multimeters. The ranges are from -46° to 900°C (-50° to 1,652°F). Probes available include a hand probe, wire, immersion, and exhaust probe.

Recorder Group (8T-2844)

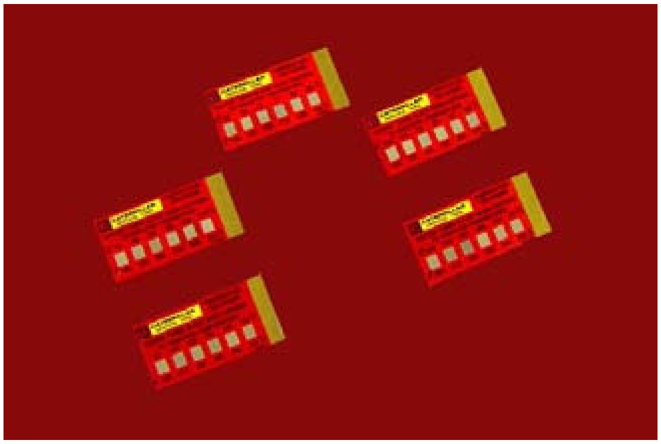


Fig. 98: Adhesive cards for Varied Temperature Ranges.

The 8T-2844 Recorder Group group contains temperature recorders in order to check five different ranges of temperatures. Each card is used for a specific temperature range. The cards have adhesive backs. Attach a card to any clean dry surface. Remove the card and keep the card as a permanent record.

Thermometers (5N-4562, 9U-5325, 6H3050, and 2F-7112)

Fig. 99: Selection of Thermometers Available.

These thermometers check coolant temperature and accuracy of the coolant temperature gauge. The 2F-7112 Thermometer can be installed in a hole with 1/4 inch pipe threads. The 5N-4562 Thermometer can be installed in a hole with 1/2-14 NPTFs threads or 3/4-14 NPTF threads.

Air Flow Test Tools

Multitach II Tool Group (9U-7400)

Fig. 100: Multitach to Check Fan and Engine Speed.

The 9U-7400 Multitach II Tool Group contains a LED Photo Pickup and several tachometer adapters for use with the included tachometer generator. A battery charger is included for the required AA batteries. A 9U-7402 Multitach II Tool Group that contains only the LED Photo Pickup is also available.

Blowby/Air Flow Indicator (8T-2700)

Fig. 101: Indicator for Checking for Plugged Radiator.

The 8T-2700 Blowby/Air Flow Indicator Group contains a hand-held digital indicator, a remote mounted pickup, 915 mm (36 inch) of cable, a blowby hose, and the necessary connectors. This indicator can measure the volume of the blowby gases that are coming out of the crankcase breather. Also, the indicator can measure the air velocity through the radiator. The indicator will check if the air flow through the radiator is within specifications. Use the indicator to check the different areas of the core and determine if any of the areas in the core are plugged.

Pressure Test Tools

Pressurizing Pump (9S-8140)

Fig. 102: Pump for Pressurizing Cooling Systems.

The 9S-8140 Pressurizing Pump is designed to put pressure into the cooling system in order to test for leaks. The pressurizing pump can also be used to test the pressure relief valve and pressure gauges.

Pressure Probe (164-2192)

Fig. 103: Pressure Gauge Probe Adapter.

Use the 164-2192 Probe with a pressure gauge in order to check the coolant pressure at the water pump inlet or at the water pump outlet. The probe can be installed in a 1/8 inch pipe threaded hole or the probe can be installed in any of the probe adapters that were mentioned on page 65.

Pressure Gauge (6V-7830)

Fig. 104: Tetragauge Group.

The 6V-7830 Tetragauge Group is a general purpose pressure gauge. The gauge can be used to measure pressure from -100 kPa (-15 psi) to 40000 kPa (5800 psi).

Digital Pressure Indicator (198-4240)

Fig. 105: Digital Pressure Indicator for Remote Reading.

The 198-4240 Digital Pressure Indicator is a microprocessor based device that reads vacuum, pressure, differential pressure, and temperature. The indicator uses sensors and cables to remotely measure systems that are under pressure.

Engine Pressure Group (1U-5470)

Fig. 106: Digital Pressure Indicator for Remote Reading.

The 1U-5470 Engine Pressure Group is used to check the performance of turbocharged diesel and natural gas engines. With the optional 1U-5554 Panel and 8T-0840 Pressure Gauge, operating adjustments to naturally aspirated gas engines can be made.

Leak Detection Tool

Ultraviolet Lamp Group (1U-5566 [10 VAC] and 1U-6444 [220 VAC])

Fig. 107: Tooling for Leak Detection.

Use the 1U-5566 Ultraviolet Lamp Gp (110 Volt) and 1U-6444 Ultraviolet Lamp Gp (220 Volt) ultraviolet lights to detect leaks. The following additives help detect leaks in the cooling system: 1U-5576 Additive (1 oz) and 1U-5577 Additive (0.473 L [1 pint]).

Attachments

All machines and engines have some attachments for the cooling system. A few of the attachments described here are used exclusively on earthmoving machinery. Others can be used on all engines. Attachments for specific models are shown in the appropriate Parts Book.

Hood and Engine Enclosures

In certain applications, such as logging, land clearing, or sanitary landfilling, loose material in the engine compartment can be a problem. Loose material can plug the radiator core, which make frequent cleaning of the radiator necessary. If the radiator is not cleaned, overheating will result. One way to reduce the problem is to use hood and side panels that are perforated. These perforated panels can extend the cleaning intervals and/or service life of the radiator by permitting air to flow to or from the radiator while preventing entry of loose material into the engine compartment.

Fig. 108: Perforated Hood and Engine Side Enclosures.

Abrasion Resistant Grid for Radiators and Ejector-type Fans

In applications where there is blowing sand or abrasive material kicked up by the machine, sandblasting can be a problem. Sandblasting is the erosion of radiator tubes and fins by fine particles. This normally only occurs with blower fans. After a period of time, sandblasting can cause coolant leaks.

The abrasion resistant grid deflects and slows the particles so they pass through the radiator without wearing the tubes or fins. This will give the radiator a longer service life.

An ejector-type blower fan will also lessen sandblasting problems. The ejector fan has the back edge of its blades bent around into a hook shape. This makes a channel along the back of each blade which takes most of the debris out of the air flow and discharges it radially.

In applications where sandblasting is not a problem, use of the abrasion resistant grid is not recommended. However, larger loose particles may yet lodge between the grid and radiator and make frequent cleaning of the radiator necessary.

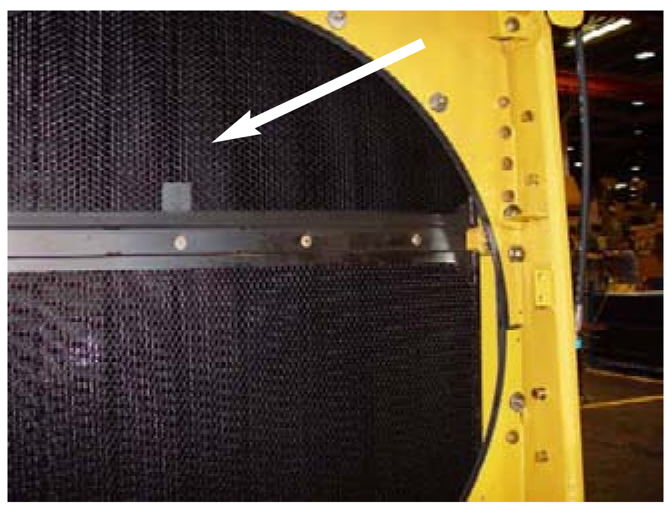


Fig. 109: Abrasion Resistant Grid.

Crankcase Guards

Although crankcase guards are not a cooling system attachment, they can have a positive or negative effect on the cooling system. The crankcase guard will decrease the amount of loose material that enters the engine compartment. On machines with blower fans, this can decrease radiator core plugging or sandblasting. In logging, land clearing, or sanitary landfilling applications, the additions of screens over the openings in and around the crankcase guard will further decrease the entry of loose material into the engine compartment.

Normally, some of the heat in the engine transmission and torque converter is transferred directly to the air that flows around these components. Mud, dirt, or other material that becomes packed in and around the crankcase guard will act as an insulating material and prevent heat transfer to the air. This will cause the engine, transmission and torque converter oil temperatures to rise and, in some conditions, cause coolant overheating.

Fig. 110: Crankcase Guards.

Reversible Fan

A reversible fan makes it possible to change from a suction to a blower fan or vice-versa very easily. Some reversible fans automatically reverse every few minutes to blow or suck out debris that may get lodged in the radiator.

Fig. 111: Reversible Fan.

Hinged Radiator Guard

A hinged radiator guard permits easy access to the front of the radiator. This makes it easy to inspect and thoroughly clean the radiator without removing the heavy guards.

Fig. 112: Hinged Radiator Guard.

Coolant Flow Indicators

Coolant flow indicators are found on some machines. When there is a loss of coolant, the coolant flow indicator, which will be a horn and a light, will signal the operator to let him know there is a problem. Loss of coolant flow can be caused by low coolant level, water pump failure, sudden loss of coolant, broken fan belts or severe water pump cavitation.

Fig. 113: Coolant Flow Indicator.

Jacket Water Heater

Jacket water heaters have an electric heating element to keep the coolant warm in the engine. These heaters are required to start a cold engine in temperatures below -18°C (0°F). Jacket water heaters are also used on electric set engines that have automatic stop-start.

Summary

Cooling system maintenance is your responsibility. Extra time invested in caring for your cooling system can prolong engine life and lower operating costs.

The consequences of improper coolant selection and cooling system maintenance are evident. Coolant related failures and loss of efficiency directly affect your operation.

Selecting and maintaining the proper coolant helps your engine in the long run. Understanding coolant and its effects on your engine is crucial to an efficient operation.

Reference Material Available From Caterpillar

The following publications are available through your local Caterpillar dealer. Some publications may have a nominal charge.

NOTE: The information contained in the listed publications is subject to change without notice. Contact your local Caterpillar Dealer for the most up to date recommendations.

NOTE: Refer to this publication, the listed publications, the respective product data sheet, and to the appropriate Operation and Maintenance Manual for product application recommendations.

"Cold Weather Recommendations", SEBU5898

"Cooling System Fundamentals," LEKQ1475

"Oil And Your Engine," SEBD0640

"Diesel Fuels And Your Engine," SEBD0717

"Caterpillar Machine Fluids Recommendations," SEBU6250

"Know Your Track-type Tractor Cooling System," REHS1063

"Caterpillar Commercial Diesel Engine Fluids Recommendations," SEBU6251

"Caterpillar On-highway Diesel Truck Engine Fluids Recommendations," SEBU6385

"Data Sheet - Cat DEAC (Diesel Engine Antifreeze/Coolant)," PEHP9554

"Cat ELC (Extended Life Coolant) 222-9116 Dilution Test Kit," PELJ0176

"Label - ELC Radiator Label," PEEP5027

"Data Sheet - Cat ELC (Extended Life Coolant)," PEHJ0067

Standards Methods for the Examination of Water and Wastewater, 20th ed.

American Public Health Association,
800 I Street NW,
Washington, D.C. 20001-3710
Phone - 201-777-2742

Annual Book of Standards for Section II, Volume 11.01

ASTM
100 Bar Harbor Drive
Conshohocken, PA 19428
Phone - 610-832-9585

SEBD0518-09