



Operation and Maintenance Manual

Cat Gas Engine Lubricant, Fuel, and Coolant Recommendations

All Gas Engines

Special Publication

Important Safety Information

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

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

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

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

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



The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

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

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

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

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

NOTICE

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

Other parts may not meet certain original equipment specifications.

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

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

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PROOF

Foreword

Literature Information

This manual should be stored in the literature storage area.

The information contained in this document is the most current information available for coolants, fuels, and lubricants. Refer to the Operation and Maintenance Manual for any special lubrication requirements for your engine.

Whenever a question arises regarding the engine, this publication, or the Operation and Maintenance Manual, please consult any Cat dealer for the latest available information.

Safety

Refer to the Operation and Maintenance Manual for your engine for all safety information. Read and understand the basic safety precautions listed in the Safety Section. In addition to safety precautions, this section identifies the text and locations of safety signs used on the engine.

Read and understand the basic precautions listed in the Safety Section before operating or performing lubrication, maintenance and repair on this engine.

Maintenance

Refer to the Operation and Maintenance Manual for your engine to determine all maintenance requirements.

Maintenance Intervals

Use the Maintenance Interval Schedule in the Operation and Maintenance Manual for your engine to determine servicing intervals. The actual operating environment of the engine also governs the maintenance interval schedule. Therefore, under extremely severe, dusty, wet or freezing cold operating conditions, more frequent lubrication and maintenance than is specified in the Maintenance Interval Schedule may be necessary.

Extended Engine Oil Drains and Warranty

Failures that result from extended oil drain periods are not Caterpillar factory defects and therefore are not covered by Caterpillar's warranty. In addition, failures that result from not using the recommended oil type are not Caterpillar factory defects and therefore are not covered by Caterpillar's warranty.

Refer to the applicable Operation and Maintenance Manual for standard oil drain periods and to the Maintenance Section, "Lubricant Specifications" of this publication for engine oil type and viscosity grade recommendations.

To reduce the potential risk of failures associated with extended oil drain periods; it is recommended that oil drain intervals only be extended based on oil analysis, and subsequent engine inspections. Oil analysis alone does not provide an indication of the rate of formation of lacquer, varnish and/or carbon on pistons and other engine surfaces. The only accurate way to evaluate specific oil performance in a specific engine and application that utilizes extended oil drain periods is to observe the effects on the engine components. This involves tear-down inspections of engines that have run to their normal overhaul period with extended oil drain intervals. Following this recommendation will help ensure that excessive component wear does not take place in a given application.

NOTICE

Light loads, low hour accumulation, and excessive idling time can contribute to excessive water in the crankcase oil. Corrosive damage, piston deposits and increased oil consumption can also result. If oil analysis is not done or the results are ignored, the potential for corrosive damage and piston deposits increases. Refer to the appropriate Operation and Maintenance Manual for guidance.

Note: Failures that result from extended oil drain periods are not warrantable failures, regardless of use of this recommended procedure. Failures that result from extended engine oil drain periods are considered improper use under the warranty.

Aftermarket Products and Warranty

NOTICE

When auxiliary devices, accessories or consumables (filters, oil, additives, catalysts, fuel, etc.) made by other manufacturers are used on Caterpillar products, the Caterpillar warranty is not affected simply because of such use. Failures that result from the installation or usage of other manufacturers auxiliary devices, accessories or consumables, however, are not Caterpillar factory defects and therefore are NOT covered by Caterpillar's warranty.

Caterpillar is not in a position to evaluate the many auxiliary devices, accessories or consumables promoted by other manufacturers and their effect on Caterpillar products. Installation or use of such items is at the discretion of the customer who assumes ALL risks for the effects that result from this usage.

Furthermore, Caterpillar does not authorize the use of its trade name, trademark, or logo in a manner which implies our endorsement of these aftermarket products.

Maintenance Section

Lubricant Specifications

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General Lubricant Information

SMCS Code: 0645; 1000; 1300; 1348; 7581

Failure to follow the recommendations found in this Special Publication can cause engine failures, shortened engine service life, and reduced engine performance.

In order to avoid potential damage to your Cat engine, only purchase Cat fluids and filters through your Cat dealer or Cat authorized outlets. For a list of authorized Cat parts outlets in your area, consult your Cat dealer.

If you purchase what appear to be Cat fluids and/or filters through other outlets/sources, you are at high risk of purchasing counterfeit products.

Counterfeit products may visually appear the same as the original Cat product, but the product performance and internal quality will typically be very low.

Counterfeit products have a high likelihood of causing and/or causing the engine and machine compartment damage.

Use of fluids that do not meet at least the minimum performance recommendations and requirements may lead to lower compartment performance or compartment failure.

Problems that are caused by using fluids that do not meet the minimum recommended or required performance level for the compartment are not warrantable by Caterpillar® Inc. The fluid manufacturer and customer are responsible for any damage that is caused by use of these fluids. Refer to the Aftermarket Product and Warranty in the Foreword section of this Special Publication.

Different brand oils may use different additive packages to meet the various engine performance category and specification requirements. For the best results, do not mix oil brands.

The overall performance of engine and machine compartments is dependent on the choice of the lubricants and on the maintenance and cleanliness practices. These choices include filtration products, contamination control, fuel management, and general handling practices. Cat designed and produced filtration products offer optimal performance and system protection.

Cat Fluids

Cat fluids have been developed and tested by Cat in order to increase the performance and the life of Cat components. The quality of finished oil is dependent on the quality of the base stock, the quality of the additives, and the compatibility of the base stock and additives. Cat fluids are formulated of high quality refined oil base stocks and additives of optimal chemistry and quantity in order to provide high performance in engines and components. Cat fluids are used for factory fill of Cat engines and components. These fluids are offered by Cat dealers for service fills and as aftermarket products. Consult with your Cat dealer for more information on these Cat fluids.

Cat recommends the use of the following Cat fluids for Gas engines:

Maintenance Section
General Lubricant Information

Table 1

Caterpillar® Lubricants		Viscosity Grade
Cat Natural Gas Engine Oil Ultra 40 Next Generation High Performance NGEO	NGEO Ultra 40 ⁽¹⁾	SAE 40
Cat Natural Gas Engine Oil Advanced 40 Premium Performance NGEO	NGEO Advanced 40	SAE 40
Cat Natural Gas Engine Oil EL350 Premium Performance NGEO (Limited regional availability)	NGEO EL350 ⁽²⁾	SAE 40
Cat Natural Gas Engine Oil High Quality NGEO (Limited regional availability)	NGEO 40	SAE 40
Cat Natural Gas Engine Oil Special Application For Engines Operating in Landfill, Biogas, and Well-Head Applications	NGEO Special Application	SAE 40
Cat Natural Gas Engine Oil Synthetic High Performance Required for use in 2.5/2.6 MW, G3520 Standby and Load Management Engines	NGEO SYN HP	Synthetic, SAE 40
Hydraulic Oil	Cat HYDO Advanced	SAE 10W
		SAE 20W
		SAE 30
	Cat Bio HYDO Advanced (HEES)	ISO 46 Multigrade

(1) Cat Factory Fill oil

(2) Cat NGEO EL350 replaced Cat NGEO EL250

Table 2

Caterpillar Grease and Coolant Products	
Grease	Cat Utility Grease
	Cat Prime Application Grease
	Cat Extreme Application Grease
	Cat Extreme Application Grease - Desert
	Cat Extreme Application Grease - Arctic (Semi-Synthetic)
	Cat Ball Bearing Grease
	Cat White Assembly Grease
	Cat Hammer Paste
Coolants	Cat NGEC (Natural Gas Engine Coolant)
	Cat DEAC (Diesel Engine Antifreeze/ Coolant)
	Cat SCA (Supplemental Coolant Additive) for use with Cat DEAC

Always consult with the OMM of your engine to determine the recommended oil for your specific engine model.

Note: The optimal application of the lubricants is dependent on the oil quality and the maintenance practices such as contamination control, tank management, and general handling practices.

Engine Oil

Engine lubricants play multiple roles in engines. Appropriate lubricants offer the following:

- Provide lubrication to the moving components of the engine under a wide range of temperatures
- Keep the engine components clean and removes wear debris
- Remove heat from the lubricated components
- Neutralize acidic products due to combustion process
- Protect the engine from cavitation
- Protect the engine from corrosion and rust

Note: Cat fluids availability will vary by region.

- Control oil consumption
- Disperse/Solubilize contaminants (soot)

Engines that use gaseous fuel require oils that are formulated with additives that are specific to these engines. There are no industry standards that define the performance specifications of oils for these engines. Field evaluations must be used in order to determine oils that are acceptable. To aid in oil selection, guidelines are provided in this Special Publication.

The following costs are associated with maintenance of the engine lubrication system:

- Initial fill
- Consumption
- Analysis of the engine oil
- Replacement of the engine oil and engine oil filter
- Disposal of the used engine oil

Maintaining the engine lubrication system is usually between 10 and 20 percent of the total cost of the engine maintenance. This percentage can be affected by the type of fuel, the engine duty cycle, and the maintenance practices.

The temperature of the cooling system, extended operation at light loads, and the condition of the engine (wear) have an effect on the rate of consumption and on the engine oil service life.

Maintenance costs can be greatly increased by the wrong engine oil. Inadequate lubrication that destroys moving parts causes expensive unscheduled down time. The following problems can result from the use of incorrect engine oil:

- Buildup of varnish (glazing) in the cylinder liners
- Damage to bearings
- Deposits on the valves that can lead to guttering of the valves
- Oil coking in the turbocharger
- Piston rings and valves that stick

In order to achieve the lowest maintenance costs for the lubrication system, use the recommended and preferred Cat natural gas engine oils.

Hydraulic Oil

For information on hydraulic oil, see this Special Publication, "Hydraulic Oil" topic.

Lubricating Grease

For information on grease, see this Special Publication, "Lubricating Grease" topic.

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Engine Oil

SMCS Code: 1348

Cat Gas Engine Oils

Cat natural gas engine oils have been developed and tested in order to provide the full performance and service life that has been designed and built into Cat natural gas engines. Cat oils are used to fill engines at the factory as service fill. These oils are offered by Caterpillar dealers for continued use when the engine oil is changed. Consult your Caterpillar dealer for more information on these oils.

Due to the significant variations in the quality and in the performance of commercially available oils, Caterpillar recommends the Cat Gas Engine Oils that are listed in Table 1 in the General Lubricant Information section.

Cat natural gas engine oils are the preferred oils for use in ALL Cat natural gas fueled engines that are covered by this Special Publication. Commercial alternative natural gas engine oils are, as a group, second choice oils.

Cat natural gas engine oils are formulated of high-quality refined oil base stocks and additives of optimal chemistry and quality in order to provide superior performance in Cat natural gas engines.

Cat NGE0 products have been tested throughout the world in demanding environments and have been tested in engines that use all types of gaseous fuel. Cat NGE0 products are formulated and blended with special additives and high-quality basestocks in order to provide protection against oxidation and nitration and to provide very good thermal stability. The formulations of these oils have been proven to be superior to many brands of available oil.

Cat NGE0 products also provide the following benefits:

- Reduction of the formation of deposits and sludge
- Resistance to foaming
- Protection against cylinder liner wear
- Protection of valves and of valve seats
- Improved cleanliness of pistons
- Protection against scoring of the pistons and scuffing of the pistons and other rotating engine components

Table 3 lists some oil properties of Cat gas engine oil. Details are given in the product data sheets of the oils.

Temperature application range for Cat NGE0 is 5° C (41° F) - 50° C (122° F)

Oils of higher viscosity will maintain the highest possible oil film thickness.

Cat is introducing two new gas engine oils to add to the suite of the high performing Cat natural gas engine oils (NGEOs):

- **Cat NGE0 SYN HP** for certain Cat G3500 high power density engines used for load management in standby and continuous-duty applications
- **Cat NGE0 Special Application** for Cat gas engines operating in landfill, biogas, mine and wellhead applications

Cat Natural Gas Engine Oil SYN HP

Certain Cat natural gas engines are engineered with advanced combustion systems to deliver high power density. Cat NGE0 SYN HP is a synthetic, high-performance engine oil developed to achieve the exceptional performance and highest power output for these engines.

Cat NGE0 SYN HP is formulated with an optimized additive package combined with advanced synthetic base stock that features the following:

- Doubles the oil drain interval compared to typical gas engine oils in these applications
- Reduces downtime by improving combustion stability
- Maintains engine durability due to high chemical, thermal and shear stability
- Reduces oil consumption due to low oil volatility that reduces oil burn off and loss due to evaporation
- Sustains engine health by minimizing deposits and sludge on internal components

This oil is designed for full compatibility with certain G3500 high-power density engines used for load management in both standby and continuous duty applications. Oils of mineral base stocks that are adequately formulated per Caterpillar recommendations may be used but would not support the high-power output designed for these applications. Refer to Table 1 in this Special Publication, "Cat Gas Engine Lubricant, Fuel, and Coolant Recommendations" for information on Cat NGE0 SYN HP and refer to the engine Operation and Maintenance Manual for further G3500 engine information. Cat NGE0 SYN HP is available through your Cat dealers.

Cat NGE0 SYN HP unique synthetic base stock requires the use of an engine oil filter that is compatible with the synthetic base stock of this oil. These filters are available through your Cat dealer. Additionally, due to the unique synthetic base stock of Cat NGE0 SYN HP, elastomers, such as O-rings, seals, gaskets, and hoses in certain G3500 engines need to be replaced before using Cat NGE0 SYN HP to ensure total compatibility. See your Operation and Maintenance Manual, or contact your Cat dealer for additional information.

Cat NGE0 SYN HP is not backwards compatible with all engine models, refer to your engine Operation and Maintenance Manual to understand compatibility with oils to about 3%. Refer to Special Instruction, M0120065, "Changing from Existing Oil to Synthetic Based Oil" for more information.

Note: Cat G3500 gas engine models are subject to the same 7000-hour field validation requirements as described in this special publication.

Cat Natural Gas Engine Oil Special Application

Fuel from severe gas environments like biogas, landfill, coal seams, and wellheads have attributes that can negatively affect engine life. Cat NGE0 Special Application has been developed to combat these attributes and help deliver the durability Cat engines are known for. This oil is specifically designed to limit carbon formation on pistons, reduce wear on internal components, and neutralize severe acids.

Applications:

- Gas engines operating on fuel containing corrosive materials such as siloxanes and total organic halides (TOH) including fluoride and chloride, such as landfill or biomass applications.
- Gas engines operating on fuel that contains moderated levels of hydrogen sulfide (H²S) and other corrosives such as biogas and wellhead applications

Cat NGE0 Special Application is formulated with leading additive technology and advanced base stock. If you are using NGE0 Ultra 40 or NGE0 Advanced in a severe application, switching to NGE0 Special Application offers the following benefits:

- Doubles engine oil life compared to typical gas engine oils
- Significantly increase engine cleanliness by reduced deposits, varnish, and scaling on components
- High resistance to deposits that can cause pre-ignition

- Reduced war and scuffing of rings, liners, bearings, and other engine components
- Advance improvement of spark plug performance while protecting of valve seats and faces

Refer to Table 3 for information on Cat NGE0 Severe Application, refer to the engine Operation and Maintenance Manual for engine information. Cat NGE0 Severe Application is available through your Cat dealer.

Note: Cat gas engines operating on biogas, landfill, and wellhead gasses are subject to the same 7000-hour field validation requirements described in this special publication.

Table 3

Cat NGE0 SAE 40 Viscosity Grade Properties							
Characteristic	ASTM Test	Cat NGE0 Ultra 40	Cat NGE0 Advanced 40	Cat NGE0 EL350	Cat NGE0	Cat NGE0 SYN HP	Cat NGE0 Special Application
Flash Point °C (°F), minimum	"D0092"	247 (477)	252 (486)	247 (477)	252 (486)	190 (375)	250 (482)
Pour Point °C (°F)	"D0097"	-21 (-6)	-30 (-22)	-21 (-6)	-15 (5)	-30 (-22)	-12 (-10)
Viscosity (cSt) at 100°C (212 F)	"D0445"	13	13	13.5	13.2	13.6	13.2
Weight (Percent) of Sulfated Ash	"D0874"	0.54	0.5	0.54	0.52	0.73	0.5
Total Base Number	"D2896"	6	6	6.2	5.6	10.5	4.5

Note: Oil can be used at low temperature 5 degrees above the pour point temperature.

Engine Oil and Sour Gas Fuels

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

Sour gas can reduce the service life of an engine and of the engine oil. When the sulfur compounds are combined with water, acids are produced in the engine oil. These acids attack the metals in the engine crankcase and in other components. This causes corrosive wear. To reduce the effects of these sulfur compounds, Caterpillar recommends the use of devices that treat the fuel. For further information, see this Special Publication, "Hydrogen Sulfide Effects on Engine Maintenance Costs" in the Fuel Specifications section.

Note: Caterpillar does NOT recommend the use of engine oils with a high concentration of sulfated ash (greater than 0.6 percent) in order to reduce the harmful effects of sour gas. High levels of sulfated ash (greater than 0.6 percent) may produce excessive deposits on the valves and on the turbine wheel of the turbocharger. These deposits will reduce the service life of the engine. These deposits will also increase the cost of maintenance.

Engine Oil and Bio-Gas Fuels

Bio-gas fuels that are generated from landfill or digester gas power plants can include contaminants that react with the engine lube oil. This can create varied combustion deposits. Excessive deposits on the piston, the liner, and the cylinder head can occur if the oil is not properly matched for the application. Laquering of the liner may also occur.

Lube oils that are specifically designed for applications that use bio-gas are recommended. These oils should have a concentration of sulfated ash that is not greater than 0.6 percent. An exception is synthetic oil used for engines that can have pre-ignition under high-power output conditions. These oils can have up to 0.7% ash content. The use of a lube oil with concentration of sulfated ash that is higher than recommended levels will result in excessive deposits in the combustion chamber. Because of the inconsistent, variable composition of most bio-gas fuels, the lube oil may react differently to the composition of a particular fuel. Use the S·O·S oil analysis program to determine the proper oil change interval.

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

Consult your local Caterpillar dealer for a recommendation for lube oil for your bio-gas application.

S·O·S Services Oil Analysis

Caterpillar recommends the S·O·S oil analysis program in order to monitor the condition of the oil. The analysis can help determine the maintenance requirements for the engine. The S·O·S program is part of the preventive maintenance program. For further information about the S·O·S program, see this Special Publication, "S·O·S Services Oil Analysis" topic.

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Commercial Oils

SMCS Code: 1318; 1348

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

- Caterpillar recommends the use of oils that are formulated specifically for heavy-duty gas engines. Do not use oils that are specially formulated for gasoline engines or for diesel engines.
- Caterpillar does not recommend multigrade oils for use in gas engines.
- Caterpillar recommends the use of oils that have a sulfated ash content between 0.40 and 0.60 percent.

- Caterpillar recommends the use of specially formulated oils in engines of high power density ratings to pre-ignition (knock) events. These oils may have higher ash content than 0.6 percent, but up to 0.7 percent.
- The oil must demonstrate adequate protection for a minimum of 7000 hours in a field evaluation under controlled conditions.

7000 Hour Field Performance Evaluation

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

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

For more details on the 7000-hour Field Performance Evaluation, refer to this Operation and Maintenance Manual, "Field Evaluation of Commercial Oil" topic.

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Field Evaluation of Commercial Oil

SMCS Code: 1348

Due to the significant variations in the quality and in the performance of commercially available oils, Caterpillar recommends the oils found in Table 1 and Table 3 in "Engine Oil" earlier in this Special Publication .

Cat natural gas engine oils are the preferred oils for use in ALL Cat natural gas fueled engines that are covered by this Special Publication. Commercial alternative natural gas engine oils are, as a group, second choice oils.

Cat natural gas engine oils are formulated with the correct amounts of additives and high quality basestock in order to provide superior performance in Cat natural gas engines.

Caterpillar Inc. is frequently approached by engine owners and/or oil companies that wish to qualify an oil for use in gas engines. Caterpillar does not recommend the names of other commercial brands of lube oils. However, Caterpillar will evaluate the results of the Field Performance Evaluation for commercial brands of lube oils. The evaluation can verify that the oil meets the minimum lubrication requirements that are recommended by Caterpillar. Caterpillar has established the following guidelines for the Field Performance Evaluation of lube oil in gas engines. These guidelines are applicable to the engines that use the following fuels: dry natural gas, sour gas and bio-gas.

Operating Conditions for the Field Performance Evaluation

Duration – The minimum number of operating hours for a G3300, G3400, G3500, and G3600 is 7000 hours.

Load Factor – The load factor must be representative of the normal engine application at the site. High load factors are preferred.

Lube Oil – The oil must meet the requirements for the oil properties that are described in this Special Publication, “Engine Oil” topic. The oil must also meet the requirement for the formulation for gaseous fuel and the requirement for 0.40 to 0.60% sulfated ash that are described in the “Commercial Oils” topic.

Oil Analysis – Caterpillar recommends the S·O·S Services oil analysis program. Alternate oil analysis programs must measure oil condition and wear metals. Used oil samples must be obtained for analysis at 250 hour intervals. A baseline analysis of the new oil should also be obtained.

Oil Change Interval – The oil change interval is determined by condemning limits that are established by Caterpillar. The limits are based on analysis of the used oil and the trend lines that are established. For typical oil change intervals, see this Special Publication, “Oil Change Interval” topic.

Fuel Analysis – An analysis of the fuel must be provided by an independent laboratory at the beginning of the Field Performance Evaluation. The results from the gas analysis must meet the guidelines of the engine models. For the guidelines, see this Special Publication, “Fuel Specifications” section.

Criteria for the Evaluation

Oil Consumption – The oil consumption must not exceed two times the initial oil consumption during the Field Performance Evaluation. The initial oil consumption is established during the first 1000 hours of operation with the oil that is being evaluated.

Valve Recession – The valves and the valve seats wear over time. This causes the valves to recede into

the cylinder head. This condition is called “valve recession”. Measure the valve recession at the engine commissioning. This measurement is the baseline. The baseline is a reference for subsequent measurements. Measure the valve recession according to the engine Operation and Maintenance Manual, “Maintenance Interval Schedule”. The valve recession must not exceed the limits that are established for the engine by Caterpillar. Refer to the engine Operation and Maintenance Manual, “Valve Stem Projection - Measure/Record” topic for the limits for the valve recession.

Parts Requirements – If a new engine is used for the Field Performance Evaluation, all of the engine cylinders must be inspected with a borescope during the final inspection. The cylinder that shows the worst deposits or wear and the cylinder that shows average deposits or wear must be used for the visual inspection. If a used engine is used to evaluate the oil, two new sets of these components must be installed before the Field Performance Evaluation: pistons, piston rings, cylinder liners and cylinder heads. These new components will be examined during the final inspection.

Final Inspection – At the end of the Field Performance Evaluation, these components from two cylinders must be removed and inspected:

- Pistons
- Piston rings
- Cylinder liners
- Cylinder heads
- Connecting rod bearings

None of the following conditions are acceptable:

- Sticking of the piston rings
- Scuffing of the piston rings and/or cylinder liners
- Excessive wear of the piston rings
- Polishing of the cylinder liner bore must be confined to the area that is affected by the uppermost position of the top piston ring.
- The entire circumferences of the inlet valves and the exhaust valves must seal.
- Guttering of the valves is not acceptable.

Close up photographs that show the wear and deposits must be taken in order to document the appearance of these components: pistons, piston rings, cylinder liners, crankcase, top deck of the cylinder head, bottom deck of the cylinder head, inlet valves and exhaust valves (bottom, face, and stem). In addition, two exhaust valve guides must be removed from two cylinders and sectioned lengthwise. Photographs that show the entire component must also be provided.

Summary – This procedure for a field evaluation provides the oil company and the engine owner with a method of evaluating a lubricating oil for gas engines. If the oil meets these guidelines for the field evaluation, the oil has fulfilled the Caterpillar requirements.

Caterpillar will not endorse any oil for use in Cat gas engines as a result of field evaluation. The oil company can use the evaluation as proof of performance.

Responsibilities

Care must be taken in order to define the responsibilities of each person that is involved in the Field Performance Evaluation. The oil company and the engine owner must recognize the responsibilities if the performance of the oil reduces the service life of the engine. Caterpillar recommends specific definitions of the responsibilities for the oil company and the engine owner in a field evaluation. An agreement should be made before the field evaluation is initiated. Both the oil company and the engine owner must understand that the Field Performance Evaluation is not monitored by Caterpillar. The field evaluation is not sponsored by Caterpillar.

Field Performance Evaluation Agreement

The Field Performance Evaluation agreement is between the engine owner and the oil company. The agreement is a very important part of the field evaluation. The completion and signing of the agreement should occur before the initiation of the field evaluation. The agreement must fully define the field evaluation and the responsibilities of each party. This publication contains the information and guidelines that are necessary to write a detailed agreement. The initial field evaluation involves some risk. Use of the guidelines will minimize the risk. If the guidelines are followed, the probability of a successful field evaluation will be enhanced.

Responsibilities of the Oil Company

Performance – The performance of the oil is the responsibility of the oil company. The oil must maintain stable oil control and the oil must control deposits in the combustion chamber and in the crankcase. Engine service life must be maintained at

the predicted stage for the particular engine application.

Supply – The supply of the oil is the responsibility of the oil company. If special storage and/or shipping is required, the oil company should cover the cost of those items.

Oil and Fuel Analysis – During the evaluation, the oil company should pay for the cost of the oil and fuel analyses. The oil samples should be analyzed by a Cat S·O·S Services regional lab or by the local Caterpillar dealer in the S·O·S Services program. The data that is obtained from the oil analyses must be plotted in order to establish trends. The fuel should be analyzed by an independent laboratory. Results of the oil and fuel analyses must be sent to the engine owner. The owner should review the data. Also, the owner should keep records of the data.

Hardware – If the oil is evaluated in a used engine, two new sets of these components must be installed before the Field Performance Evaluation:

- pistons
- piston rings
- connecting rod bearings
- cylinder liners
- cylinder heads

The cost should be covered by the oil company. These new components will be examined as part of the final inspection.

Final Inspection – The cost of the final inspection should be paid by the oil company. If the final inspection reveals severe deposits and/or damage to the hardware, the oil company must make the repairs that are necessary for restoring the engine to an acceptable condition.

End of the Evaluation – After completion of the Field Performance Evaluation, the oil company should work with the engine owner in order to restore the engine to normal operation. If the Field Performance Evaluation is not completed, the same conditions should be applicable. The oil company should bear the cost of the restoration. This could include the cost for the removal of storage tanks, special piping, flow meters, and instrumentation.

Final Report – The oil company must prepare a final report that documents the following items:

- The data on oil consumption must be recorded on a minimum schedule of every two weeks. A chart of the data must be included in the final report.
- Results of the oil analysis must be plotted.
- Oil changes

- Replacement of the oil filters
- Results of fuel analysis
- A histogram for fuel consumption or a histogram for power output
- A histogram for average engine speed
- The typical duty cycle
- Valve recession
- Side clearance for the piston ring
- Valve guide to valve stem clearances
- Close up photographs of the following components from two cylinders must also be included: pistons, piston rings before removal and after removal, piston ring grooves after removal, cylinder liners, crankcase, top deck of the cylinder head, bottom deck of the cylinder head, inlet valves (top and bottom), exhaust valves (top and bottom), and valve guides.

The final report should be confidential. The final report must be made available to the engine owner and to Caterpillar, Inc..

Responsibilities of the Engine Owner

Engine for the Evaluation – The owner must provide access to the engine for the duration of the Field Performance Evaluation. Special piping and instrumentation may be attached to the engine for the duration of the field evaluation.

Operation and Maintenance – Daily operation and maintenance of the engine is the responsibility of the owner. Operation and maintenance of the engine must follow the guidelines that are published by Caterpillar in the engine Operation and Maintenance Manual. The daily records of this activity should be made available to the oil company.

Oil Samples and Fuel Samples – Oil samples and fuel samples will be collected by the owner. The samples will be sent to the appropriate laboratory for analysis.

Caterpillar Responsibilities

Advisory – Caterpillar will not assume an active function in the field evaluation. However, Caterpillar will provide technical advice and guidance to the parties that are involved. Caterpillar understands that this function does not satisfy all of the situations that may arise in a field evaluation. Therefore, technical judgments may be required for the initiation of some evaluations.

To provide assistance with the Field Performance Evaluation, your Caterpillar dealer or district representative can consult the appropriate technical support personnel at Caterpillar Inc.

Final Inspection – Under some circumstances, Caterpillar is asked to assist with the inspection. This is evaluated on an individual basis. The decision depends on the availability of personnel and on the amount of technical interest.

Note: All associated travel, meals, and lodging are at the expense of the oil company.

Guidelines for the Use of A Proven Lubricant In Other Engines (Interchanging)

Interchanging – The information that is obtained from most field evaluations can be applicable to other gas engines at other sites. However, guidelines must be established in order to limit the application of a lubricant that has been evaluated. This is for the protection of the engine and the engine owner. The limit on the application of the lubricant is defined as interchanging.

The interchanging of the lubricant is limited by these factors:

- The oil viscosity grade: proper selection of the viscosity grade is critical to the performance of the engine, and should be guided by the ambient temperature of the application. The proper viscosity allows the formation of protective oil film to minimize wear. Interchange among viscosity grades may be limited. For example, if an oil of SAE 30 passes the field test per the guidance given in this special publication, then interchanging the same additive package in an SAE 40 finished oil should be discussed with Cat Engineering. Refer to your Cat dealer and your engine Operation and Maintenance Manual for more information.

- The base stock of the oil: Base stock of the oil (or base oil category) constitute 75 percent to 95 percent of the finished lubricant volume. The base oil plays multiple critical roles in the performance of the finished lubricant. Base oil groups are categorized into five groups by the American Petroleum Institute, Groups I through V. Interchange among these five base oil groups is NOT allowed. For example, if an oil of Group I base oil passes the field test per the guidance given in the special publication, then the same additive package in a Group II base stock cannot be considered passing. Interchange within one API base group should be reviewed with Caterpillar. Refer to your Cat dealer and your engine Operation and Maintenance Manual for more information.
- The engine: the loads and cycles, load factor as well as the application of the engine impact the oil life and performance. The oil thermal and oxidative breakdown, shearing, contamination, wear, and corrosion protection are impacted by the conditions of the engine operation, its configuration, and the application. Hence, if an oil has been validated for a certain engine configuration and application, refer to the details given below in this section before using it in an engine of different configuration and/or application. The interchange is impacted by the following factors:
 - The engine configuration: Refer to details given below on the engine configuration
 - The engine rating: refer to details given below on the engine rating
 - The fuel type: composition of the fuel can vary among different sites. Contaminants in the fuels also vary. Hence, if an oil has been validated on one fuel, consult your Cat dealer and your engine Operation and Maintenance Manual before using it in another location, and another fuel composition. Details of the various fuels used in gas engines are given later in this Special Publication.

Engine Configuration

Lube oil cannot be interchanged between engines that use different types of fuel.

Lube oil that is evaluated in G3500 Series Low Emissions Engines may also be used in G3300, G3400, and G3500 engines.

Lube oil for G3600 Series Engines must be evaluated in a G3600 Series Engine.

Lube oil that is evaluated in G3400 Series or G3300 Series Engines may ONLY be used in G3400 Series or G3300 Series Engines.

Lube oil for GCM34 Series Engine must be evaluated in a GCM34 Series Engine.

Engine Rating

The average power output that is produced by the engine during the field evaluation is used to establish the power rating of the field evaluation. The power output must be expressed as Brake Mean Effective Pressure (BMEP). The power output is derived from one of the following sources:

- Output of the generator set
- Torque meter
- Output of the gas compressor
- Displayed load for the engine

In order to calculate the BMEP, the average engine power output must be expressed in kilowatts. Use the equation in Table 4 to calculate the BMEP.

Table 4

Equation for Calculating the Brake Mean Effective Pressure (BMEP)	
$\frac{120\,000}{L} \times \frac{\text{kW}}{\text{rpm}} = \text{BMEP (kPa)}$	
kW is the average engine power output during the evaluation.	
L is the total displacement of the engine in liters.	
BMEP is expressed in kilopascals (kPa)	

Lube oil can be interchanged between engines at different sites that operate with a similar duty cycle. However, the interchanging is limited by a maximum of a ten percent increase in BMEP.

Duty cycles can vary greatly between different sites and between different engine configurations. Therefore, it is difficult to determine an accurate degree of severity for oil in all the various duty cycles. For best results, only use the proven oil in applications with a similar duty cycle. When different duty cycles are introduced, the risk is increased.

Note: For cases with different duty cycles, the oil company and the engine owner will assess the risk in order to determine if another Field Performance Evaluation is required. In most cases, an oil with proven performance in a particular duty cycle will be preferred over an oil that has not been proven for that duty cycle.

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Commercial Lubricants with Synthetic Base Stocks

SMCS Code: 1300; 1348; 7581

Some commercial lubricants are often advertised as synthetic. These commercial oils may contain a fully synthetic base stock or a base stock that has synthetic-like properties. Some of these commercial lubricants may also contain a blend of conventional base stocks, and synthetic base stocks. In any case, these synthetic oils are usually advertised as extended drain lubricants. Caterpillar does not recommend automatically extending the oil drain interval for any commercial oil, whether synthetic base stock or conventional base stock. This applies to all lubricated compartments on a Cat machine. In order to extend the oil drain interval in any lubricated compartment, refer to your machine or engine Operation and Maintenance Manual, and follow the guidance given in the Optimizing Oil Change Intervals of this Special Publication.

Note: Oils made of synthetic base stocks have to pass the 7000-hour field performance evaluation to be allowed for use in Cat gas engines.

i03116076

Re-refined Base Stock Oils

SMCS Code: 1300; 1348; 7581

Re-refined basestock oils are acceptable for use in Cat engines **IF these oils meet the performance requirements that are specified by Caterpillar**. Re-refined basestock oils can be used exclusively in finished oil or in a combination with new basestock oils. The US military specifications and the specifications of other heavy equipment manufacturers also allow the use of re-refined basestock oils that meet the same criteria.

The process that is used to make re-refined basestock oil should adequately remove all wear metals that are in the used oil and all additives that are in the used oil. Vacuum distillation and the hydrotreating of the used oil are acceptable processes that are used for producing a re-refined base oil.

Note: Just filtering is inadequate for the production of re-refined basestock oils from used oil.

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Aftermarket Oil Additives

SMCS Code: 1300; 1348; 7581

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

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

In order to achieve the best performance from a Cat engine, conform to the following guidelines:

- Select the proper Cat oil or commercial oil that has passed the Field Performance Evaluation. Refer to the "Lubricant Specifications" section of this Special Publication.
- Refer to the "Engine Oil Viscosity" table in this Special Publication in order to find the correct oil viscosity grade for your engine.
- At the specified interval, service the engine. Use appropriate new oil and install an appropriate new oil filter.
- Perform maintenance at the intervals that are specified in the engine Operation and Maintenance Manual, "Maintenance Interval Schedule".

i08274843

Hydraulic Oil

SMCS Code: 1348; 4250; 5050; 5095; 7581

Applications

- Hydraulic systems
- Hydrostatic transmissions

Caterpillar has developed a new class of hydraulic oils, the HYDO Advanced fluids. These advanced fluids are designed for optimal performance in advanced hydraulic systems that are designed with close tolerances for precise operation and that operate under demanding conditions of temperatures and pressures. These fluids ensure optimal performance in current and previous hydraulic systems. The four products are:

- HYDO Advanced 10 , SAE 10W. Temperature application range: -20° C (-4.0° F) to 40° C (104.0° F)
- HYDO Advanced 20 , SAE 20W. Temperature application range: -5° C (23.0° F) to 45° C (113.0° F)
- HYDO Advanced 30 , SAE 30. Temperature application range: 0° C (32.0° F) to 50° C (122.0° F)
- Bio HYDO Advanced , Multigrade. Temperature application range: -30° C (-22.0° F) to 45° C (113.0° F)

Cat HYDO Advanced Hydraulic Oils, SAE 10W, SAE 20W, and SAE 30

Cat HYDO Advanced hydraulic oils are designed to provide extended oil drain intervals and to provide extra protection to Cat hydraulic system components and hydrostatic transmissions.

Cat HYDO Advanced hydraulic oils are formulated of premium additives and premium base stocks that pass severe qualification testing requirements, in the field and in the laboratory, to provide superior protection for Cat hydraulic systems.

Cat HYDO Advanced hydraulic oils are preferred in most hydraulic systems and in most hydrostatic systems. Refer to this Special Publication, Lubricant Viscosities, Table Hydraulic Systems Lubricant Viscosities for Ambient Temperatures for the ambient operating temperatures for Cat HYDO Advanced hydraulic oils.

Cat HYDO Advanced oils allow 6000 hours or higher oil drain intervals for most applications. S.O.S Services oil analysis is recommended when the oil drain interval is increased to 6000 hours or higher. In comparison, non-Cat commercial hydraulic oils (second choice oils) allow 2000 hours oil drain interval. Follow the maintenance interval schedule for oil filter changes and for oil sampling that is stated in the Operation and Maintenance Manual for the particular machine. Consult your Cat dealer for details.

Cat HYDO Advanced hydraulic oils offer the following benefits:

- Enhanced anti-wear protection : protects wear surfaces and reduces component wear in various hydraulic pumps
- Protection against rusting and corrosive wear
- Dispersion of water prevents pump damage due to water ingestion and prevents system damage due to freezing of water
- 250% increase in oxidation stability per ASTM D943
- Rapid air release protects against cavitation
- Improved filtration properties help support component cleanliness

Cat HYDO Advanced oils, when switching to Cat HYDO Advanced oils, cross contamination with the previous hydraulic oil should be kept to less than 10%.

If a different viscosity is required due to ambient temperatures, the following Caterpillar oils can be used:

- Cat DEO-ULS and Cat DEO
- Cat DEO-ULS SYN and Cat DEO SYN
- Cat DEO Cold Weather
- Cat TDTO
- Cat TDTO Cold Weather
- Cat TDTO-TMS
- Cat MTO

Note: Caterpillar oil availability will vary by region.

Note: Oil drain intervals of the oils listed above are less than the intervals of Cat HYDO Advanced oils. The oil drain intervals of these oils are typically 2000 hours and up to a maximum of 4000 hours. An exception is Cat TDTO Cold-Weather oil which allows 6000 hours or higher oil drain interval. SOS Services Oil Analysis is required when the oils listed above are used in Cat hydraulic system components and hydrostatic transmissions.

Fire Resistant Hydraulic Fluids

For applications requiring the use of fire-resistant hydraulic fluids, Caterpillar recommends the use of water-free hydraulic fluids that are per "DIN 24317" and "ISO 12922" specifications. These fluids include HFDR, HFDU (ester based), HFDU (anhydrous glycol based), and others per the specs given above. Water-based hydraulic fluids are not recommended for use in Cat machine hydraulic systems. The acceptable water-free, fire-resistant hydraulic fluids are available as ISO 46 and 68 viscosity grade products. For more information and questions regarding compatibility and conversion, refer to the product information provided by manufacturers of fire-resistant hydraulic fluids.

Food Grade Hydraulic Fluids

For applications requiring the use of food grade hydraulic fluid such as for machines operating on cattle farms, food processing facilities or others, Caterpillar recommends the use of NSF H1 registered hydraulic fluid that offers high performance and protects the hydraulic system under severe operating conditions. Food grade fluids may have to comply with the Food and Drug Administration requirements. Refer to the regulations and requirements in your region. For information regarding compatibility, conversion and application details, refer to the product information provided by the manufacturer of your food-grade hydraulic fluid.

Caterpillar strongly recommends that the hydraulic oil user avoid any exposure, and makes every effort to avoid any contact of the hydraulic fluid with the feed supply, even in food-grade oils are used.

Cat Bio HYDO Advanced (Hydraulic Oil)

Cat Bio HYDO Advanced is biodegradable non-toxic hydraulic oil that is recommended for use in hydraulic systems when environmental compliance is required or desired. Cat Bio HYDO Advanced has a renewable content that exceeds 90% and complies with the European Eco-Label. Consult Federal, state, or local authorities for guidance on hydraulic oils environmental requirements in your area.

Cat Bio HYDO Advanced is formulated with premium additives and synthetic biodegradable base oil that pass severe qualification testing requirements to provide superior protection for Cat hydraulic systems and hydrostatic transmissions.

Cat Bio HYDO Advanced oils allow 6000 hours or higher oil drain intervals for most applications. S.O.S Services oil analysis is recommended when the oil drain interval is increased to 6000 hours or higher. In comparison, non-Cat commercial biodegradable hydraulic oils (second choice oils) allow a maximum of 2000 hours oil drain interval. Follow the maintenance interval schedule for oil filter changes and for oil sampling that is stated in the Operation and Maintenance Manual for your particular machine. Consult your Cat dealer for details.

Cat Bio HYDO Advanced performs similar to Cat HYDO Advanced 10 and offers the following benefits: superior protection against mechanical wear, foaming, and corrosion in hydraulic systems and in hydrostatic transmissions. This oil should be used to achieve maximum life and maximum performance from hydraulic system components and from hydrostatic transmissions. Cat Bio HYDO Advanced is preferred in most hydraulic systems and in most hydrostatic systems when ambient temperature is between -30°C (-22°F) and 45°C (113°F). Consult your Cat dealer for details.

To gain the most benefit from the improved performance designed into Cat Bio HYDO Advanced oils, when switching to Cat Bio HYDO Advanced oils, cross contamination with the previous hydraulic oil should be kept to less than 3%. Flushing of the hydraulic system is recommended to reduce the cross contamination. Cat Bio HYDO Advanced can be used in hydraulic systems of other Original Equipment Manufacturers (OEM). Refer to your manufacturer requirements for application details.

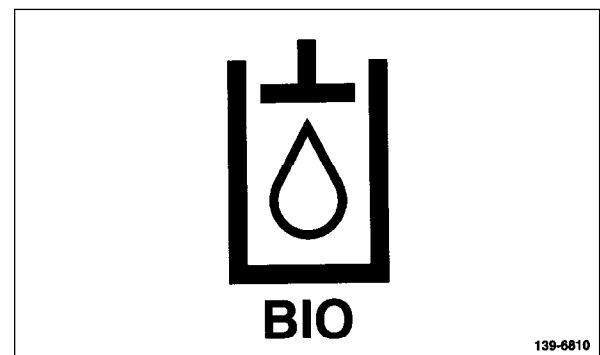


Illustration 1

g00103844

Machines with this symbol are filled with biodegradable hydraulic oil. This symbol is on the hydraulic tank.

Commercial Oils

Note: Non-Caterpillar commercial oils that are acceptable for use in most Cat hydraulic and hydrostatic transmission systems are as a group third choice oils. Within this grouping of third choice oils there are tiered levels of performance.

NOTICE

Cat does not warrant the quality or performance of non-Cat fluids.

The minimum viscosity for commercial alternative oils used in most Caterpillar machine hydraulic systems and in most Cat hydrostatic transmission systems is 6.6 cSt at 100° C (212° F) per ASTM D445.

If Caterpillar oils cannot be used, oils meeting the following commercial specifications can be used in most Cat hydraulic systems and in most Cat hydrostatic transmission systems:

- Engine oils that meet the Cat ECF-1-a, Cat ECF-2, or Cat ECF-3 specifications and have a minimum zinc additive of 0.09 percent (900 ppm)
- Biodegradable oils that meet the Cat BF-2 specification
- TO-4 specification oils that have a minimum zinc additive of 0.09 percent (900 ppm)

Note: Industrial hydraulic oils are not recommended for service fill-in Caterpillar hydraulic systems. Commercial Biodegradable Hydraulic Oil.

Note: Non-Cat commercial oils that are acceptable for use in most Cat hydraulic and hydrostatic transmission systems are as a group third choice oils.

Within this grouping of third choice oils there are tiered levels of performance. Commercial oils that meet the Cat BF-2 specification should be used.

Note: Oil meeting the Cat BF-2 specification should only be used in hydraulic systems where recommended.

NOTICE

Cat does not warrant the quality or performance of non-Cat fluids. If Cat oils cannot be used, commercial biodegradable hydraulic oils that meet the Cat BF-2 Performance Requirements should be used. Cat BF-2 replaces Cat BF-1 Performance Requirements. Cat BF-1 Performance Requirements are obsolete.

NOTICE

Do not use commercial oils that meet the BF-2 specification in compartments containing friction material except Hydraulic Excavators. Refer to the machine Operation and Maintenance Manual or consult your local Cat dealer for guidance before using commercial oils that meet the BF-2 specification in Hydraulic Excavators.

Biodegradable hydraulic oils are formulated with the following components: a saturated Hydraulic Environmental Ester Synthetic (HEES), synthetic base stock, and selected additives. Consult Federal, state, or local authorities for guidance on hydraulic oil environmental requirements in your area.

i06579723

Lubricating Grease

SMCS Code: 1000; 7581

NOTICE

These recommendations are subject to change without notice. Consult your local Cat dealer for the most up to date recommendations.

Note: Non-Cat commercial greases are as a group second choice greases. Within this grouping of second choice greases there are tiered levels of performance.

NOTICE

Cat does not warrant the quality or performance of non-Cat fluids and greases.

Caterpillar provides a family of grease products that vary in performance from moderate to high performance. These greases services the entire line of Cat products in the wide variety of climates throughout the world. From this variety of Cat grease products, you can find a Cat grease that will meet or exceed the performance requirements for almost every machine that is produced by any Original Equipment Manufacturer (OEM), and for almost every machine application or equipment application.

Before selecting a grease product, the performance requirements must be determined. Consult the grease recommendations in your Operation and Maintenance Manual. Also, consult your Cat dealer for a list of greases that have the performance specifications and the available container sizes.

This grease chapter refers to NLGI of the grease products offered by Caterpillar. The National Lubricating Grease Institute (NLGI) classifies the greases per the consistency or hardness according to "ASTM D4950" and "SAE J310". The higher the NLGI value the more firm the grease. NLGI is an important classification for greases and it should be used along with other properties such as stability, corrosion resistance, and viscosity.

Note: Always choose grease that meets or exceeds the recommendations that are specified by the equipment manufacturer for the application.

Some work sites require the use of a single grease to fulfill the needs of all the equipment. Always choose a grease that meets or exceeds the requirements of the most demanding application. Remember that commercial products which barely meet the minimum performance requirements can be expected to produce the minimum life for the parts. It is not recommended to purchase grease products based on the lowest cost as the only consideration. Instead, use the grease that yields the lowest **total** operating cost. This cost should be based on an analysis that includes the improved product life, costs of parts, labor, downtime, and the cost of the amount of grease that is required.

Note: Certain Cat grease products are formulated with Molybdenum disulfide (MoS_2 or “Moly”). The Moly used in Cat greases is of a technical fine grade. This size meets the special requirements of some rolling element bearings, joints, and other moving components of tight clearances.

Note: When the grease in a joint is changed from one type of grease to another or a grease from a different supplier is to be used, the general recommendation is to purge all the old grease from the joint. Some greases are not chemically compatible. Consult your supplier to determine if the greases are compatible.

If in doubt, Purge!

Note: All Cat greases are “chemically” compatible with each other. Mixing of Cat greases will not result in an adverse chemical reaction. However, mixing of Cat greases might result in reduced performance.

Moderate Applications

The Caterpillar family of greases includes several which are formulated for moderate applications of medium loads and speeds. These greases are formulated to provide optimal performance for these applications.

Cat Utility Grease

Cat Utility Grease is formulated for use in applications that have a low severity to a medium severity and moderate temperatures. Cat Utility Grease is a National Lubricating Grease Institute (NLGI) grade 2 grease. This grease is made with petroleum base oil and a lithium complex thickener.

Note: If the application calls for a utility grease and Cat Utility Grease is not available, consult the grease data sheets. Use a substitute that meets or exceeds the performance characteristics of Cat Utility Grease.

Cat White Assembly Grease

Cat White Assembly Grease is formulated for use in applications that have low to medium severity and moderate temperatures. This grease has been made extra tacky to hold gaskets, O-rings, and needle bearings to aid in the assembly of engines, transmissions, and other components. Cat White Assembly Grease is an NLGI grade 2 grease. This grease is made with a petroleum base oil and a lithium complex thickener.

Cat Prime Application Grease

Cat Prime Application Grease is formulated for use in applications with low severity to high severity at moderate temperatures. Cat Prime Application Grease is recommended for heavily loaded pin joints and high impact applications in machines such as track-type tractors, backhoe loaders and skid steer loaders.

Cat Prime Application Grease is an NLGI grade 2 grease. This grease is made with petroleum base oil and a lithium complex thickener. This grease has 3% Molybdenum Disulfide (MoS_2 or “Moly”).

Note: If the application calls for a multipurpose grease with molybdenum and Cat Prime Application Grease is not available, consult the data sheets for the greases. Use a substitute that meets or exceeds the performance characteristics of Cat Prime Application Grease.

Severe Applications

The Caterpillar family of greases includes several which are made with a Calcium Sulfonate Complex thickener. This type of grease is ideal for severe applications. These greases provide more load carrying (galling resistance), lower wear, longer working life, exceptional water washout, and resistance to corrosion.

Hammer Grease

Note: Refer to the Operation and Maintenance Manual for a particular hammer for recommendations that relate to greases for Cat Hammers.

Cat Extreme Application Grease

Cat Extreme Application Greases are specially formulated to protect all the most heavily loaded joints in any Cat machine against galling, wear, and corrosion. This protection is sustained while operating in moderate temperatures and with wet or dry working conditions.

Cat Extreme Application Greases are available in NLGI grades, 1, and 2. Cat Extreme Application Greases are made with special blends of petroleum base oils and Calcium Sulfonate Complex thickener. These greases also have 5% Molybdenum Disulfide (MoS_2 or "Moly") and performance enhancing additives.

A significant challenge exists in order to get grease to pump into the joints at low temperatures. Once the grease gets to the joint, the grease must have high resistance to galling, wear, fretting, water washout, and corrosion in order to protect highly loaded joints adequately. Cat Extreme Application Greases are formulated with special blends of naphthenic petroleum base oils that have low pour points and will pump at lower temperatures. The ability to pump Cat Extreme Application Greases at lower temperatures means added insurance that all of the grease joints in the machine will be adequately lubricated even if the ambient temperature drops unexpectedly.

Even under severely loaded conditions, the grease should have a long working life. In order to make greases that meet these greater demands, a Calcium Sulfonate Complex thickener with a properly blended naphthenic oil and/or a synthetic base oil is preferred. Caterpillar uses these ingredients in Cat Extreme Application Greases.

Cat Extreme Application Greases also have 5% Moly, instead of the 0% to 3% that is found in most other greases. This additional Moly greatly improves the ability of the grease to protect parts from damage in applications with severe impact (slamming).

Cat Extreme Application Greases are also made to be extra tacky. In some applications, the film of grease must adhere to vertical surfaces. An example of this application is swing gears for excavators. Many conventional greases do not have enough of the tacky characteristic to keep the grease in place resulting in incomplete lubrication and premature wear or failure of components.

Note: If the application calls for Cat Extreme Application Grease and Cat Extreme Application Grease is not available, consult the data sheets for the grease. From these data sheets, use a substitute that meets the performance characteristics of Cat Extreme Application Grease.

Cat Extreme Application Grease-Desert

Cat Extreme Application Grease-Desert is formulated to protect the most severely loaded joints in Cat machines against galling, wear, and corrosion. This protection is sustained while working in moderate to hot temperatures with wet or dry conditions.

Cat Extreme Application Grease-Desert is an NLGI grade 2 grease. This grease is made with petroleum that has a high viscosity and a Calcium Sulfonate Complex thickener. This grease also has 5% Molybdenum Disulfide (MoS_2 or "Moly") and tackifier.

As the temperature changes, Cat Extreme Application Grease-Desert experiences minimal change in viscosity and will maintain a thick lubricant film even at hot temperatures.

Cat Extreme Application Grease-Desert is made with a Calcium Sulfonate Complex thickener. Cat Extreme Application Grease-Desert provides the necessary protection against galling, wear, fretting, water washout, and corrosion. Cat Extreme Application Grease-Desert also has a long life. This grease will resist breakdown even when the application is under heavy loads and with frequent oscillations. This protection is sustained while work is being done at moderate to hot temperatures under wet or dry conditions.

Cat Extreme Application Grease-Desert has 5% molybdenum instead of the 0% to 3% that is found in most other greases. This additional molybdenum greatly improves the ability of the grease to protect parts from damage in applications with severe impact (slamming).

Cat Extreme Application Grease-Desert is made to be extra tacky. In some applications, the film of grease must adhere to vertical surfaces. An example of this application is swing gears for excavators. Many conventional greases do not have enough of the tackifier to allow the grease to stay in place resulting in incomplete lubrication and premature wear or failure of components. In addition, many of these conventional greases do not have the performance, particularly at high ambient temperatures, to protect the gear teeth in these applications.

Cat Extreme Application Grease-Desert prevents galling and wear in hot temperatures under severe loads and conditions. In moderate temperatures, Cat Extreme Application Grease-Desert can be used in severe applications if an improvement over Cat Extreme Application Grease is desired. Cat Extreme Application Grease-Desert can be used in applications that require the lubricant to last for long periods of time because this grease has an high performance and long life.

Note: If the application calls for Cat Extreme Application Grease-Desert and Cat Extreme Application Grease-Desert is not available, consult the data sheets for the grease. From these data sheets, use a substitute that meets the performance characteristics of Cat Extreme Application Grease-Desert.

Cat Extreme Application Grease-Arctic (Semi-Synthetic)

Cat Extreme Application Grease-Arctic is formulated to protect the most heavily loaded joints in Caterpillar machines against galling, wear, and corrosion. This grease resists breakdown even under heavy loads and/or in applications with frequent oscillations. This grease provides protection that will be sustained for long periods of time and in wet or dry conditions. This protection is sustained, while work is being done in moderate temperatures and in low temperatures that may reach -50°C (-58°F). In moderate temperatures, Cat Extreme Application Grease-Arctic can be used in the application if the compartment is sealed tightly to contain the grease

Cat Extreme Application Grease-Arctic is available in NLGI grade 0.5. This grease is made with a semi-synthetic base oil that has a low viscosity for optimal cold-weather performance. The performance is enhanced with 5% Molybdenum Disulfide (MoS_2 or "Moly") and tackifier.

Because the base oil is semi-synthetic, Cat Extreme Application Grease has a minimal change in viscosity as the temperatures drop. Because the synthetic base oil has a low viscosity, the Cat Extreme Application Grease-Arctic has a minimal change in viscosity and continues to flow easily as the temperature drops. Cat Extreme Application Grease-Arctic pumps easily at low temperatures. In fact, Cat Extreme Application Grease-Arctic NLGI grade 0.5 can be pumped through standard automatic lubrication systems that are machine mounted and at temperatures down to -50°C (-58°F). This means that the grease can be pumped through long unheated lines and into the required joints.

Cat Extreme Application Grease-Arctic has 5% of molybdenum instead of 0% or 3% that is found in most of the other greases. This additional molybdenum greatly improves the ability of the grease in order to protect parts from damage in applications with severe impact (slamming).

Cat Extreme Application Grease-Arctic is made to be extra tacky. In some applications, the film of grease must adhere to the vertical surfaces. An example of this application is swing gears for excavators. Many conventional greases do not have enough tackifier to adhere well to the vertical surfaces. This ability is necessary in order to protect the gear teeth in these applications adequately.

Cat Extreme Application Grease-Arctic may be used in applications that require the lubricant to last for long periods of time. This grease has an high performance and also has a long life.

If the application calls for Cat Extreme Application Grease-Arctic and no Cat Extreme Application Grease-Arctic is available, consult the data sheets for the grease. Use a substitute that most closely meets the performance characteristics.

Cat Ball Bearing Grease

This grease is recommended for applications that utilize roller bearings and ball bearings at low loads to moderate loads at high speed. Typical applications for this grease are electric motors, alternators, and constant velocity (CV) joints for automotive products. Cat Ball Bearing Grease is an NLGI grade 2 grease. This grease is made with petroleum base oil and polyurea thickener.

Grease Application Charts

Types of Grease

Severe Applications are heavy loads, frequent oscillations, and heavy shock loads.

Extreme pressure (EP) refers to 4-Ball Weld point in the technical data sheet ("ASTM D 2596").

N/R = Not Recommended

Maintenance Section
Lubricating Grease

Pumpability is based on "USS Mobility and Lincoln Ventmeter Tests". Performance may vary depending on lubrication equipment and the length of the lines.

Service Life refers to the percent of change after 100,000 strokes in technical data sheet ("ASTM D 217").

Corrosion protection was measured per "ASTM D1743 Rust preventative Properties" and "ASTM D4048 Copper Corrosion Test".

Water washout resistance refers to roll stability with water and the percent of change ("ASTM D 1264").

For additional performance data on these greases refer to this Special Publication, "Reference Material" article.

Table 5

Type of Cat Grease						
Cat Grease Name	NLGI Grade	Low Temp. Pumpability	Service Life	Corrosion Protection	Water Washout Resistance	Extreme Pressure (EP)
Cat Extreme Application Grease-Desert	2	above 2° C (35° F)	Excellent	Excellent	Excellent	Excellent
Cat Extreme Application Grease	2	above -7° C (20° F)	Excellent	Excellent	Excellent	Excellent
Cat Extreme Application Grease	1	above -18° C (0° F)	Excellent	Excellent	Excellent	Excellent
Cat Extreme Application Grease-Arctic	0	above -43° C (-45° F)	Excellent	Excellent	Excellent	Excellent
Cat Prime Application Grease	2	above -18° C (0° F)	Good	Fair	Fair	Very Good
Cat Utility Grease	2	above -23° C (-10° F)	Good	Fair	Fair	Fair
Cat Ball Bearing Grease	2	above -18° C (0° F)	Very Good	Good	Good	N/R
Hammer Paste	2	N/R	Good	Fair	Fair	Excellent

Table 6

Types of Cat Grease						
Cat Grease Name	NLGI Grade	Severe Applications	Severe Applications	Severe Applications	Severe Applications with Extremely Heavy Loads	Severe Applications
Operating Conditions	-	Extremely low to low temperatures	Low to Moderate Temperatures	Moderate to high temperatures	Moderate to high temperatures	High to extremely high temperatures
Optimum Temperature Range	-	-50° C (-58° F) to -18° C (0° F)	-23° C (-9° F) to 29° C (85° F)	18° C (64° F) to 60° C (140° F)	18° C (64° F) to 41° C (105° F)	38° C (100° F) to 232° C (450° F)

(continued)

(Table 6, contd)

Types of Cat Grease						
Cat Grease Name	NLGI Grade	Severe Applications	Severe Applications	Severe Applications	Severe Applications with Extremely Heavy Loads	Severe Applications
Cat Extreme Application Grease-Desert	2	N/R	Excellent	Excellent	Excellent	Very good
Cat Extreme Application Grease	2	N/R	Excellent	Excellent	Very good	Good
Cat Extreme Application Grease	1	Good	Excellent	Good	Good	
Cat Extreme Application Grease-Artic	0	Excellent	Very good	N/R	N/R	N/R
Cat Prime Application Grease	2	N/R	Fair	Good	Good	N/R
Cat Utility Grease	2	N/R	N/R	N/R	N/R	N/R
Cat Ball Bearing Grease	2	N/R	N/R	N/R	N/R	N/R
Hammer Paste	2	N/R	N/R	Excellent	Excellent	Excellent

i08314658

S·O·S Services Oil Analysis

SMCS Code: 1000; 1348; 3080; 4070; 4250; 4300; 5095; 7000; 7542; 7581

NOTICE

These recommendations are subject to change without notice. Consult your local Cat dealer for the most up to date recommendations.

Note: DO NOT USE ONLY THIS SPECIAL PUBLICATION AS A BASIS FOR DETERMINING OIL DRAIN INTERVALS.

Evaluation of oils to determine their condition as they are used in the engines or machine compartments is a powerful tool to indicate the engine or component performance and to support durability and reliability that has been designed into these engines and machine components.

Caterpillar has developed a maintenance management tool that evaluates oil degradation and detects the early signs of wear on internal components. The Cat tool for oil analysis is called S·O·S Oil Analysis and the tool is part of the S·O·S Services program. S·O·S Oil Analysis divides oil analysis into four categories:

- **Component wear:** elemental analysis of the oil evaluates wear metals and contamination in the oil. Wear metals analysis allows the evaluation of wear of lubricated components or engines.
- **Oil condition:** determines if the oil has degraded due to chemical or thermal stresses. This analysis includes oxidation, nitration, sulfation, viscosity, soot and if needed total acid number and/or total base number.
- **Oil contamination:** testing of harmful contaminants that may have entered the oil including dirt, water, fuel and coolants. Oil contamination can cause wear and damage of engine and lubricated components.
- **Oil identification:** this analysis ensures that the appropriate quality of oil is used and that the right oil is used in the right compartment. The wrong oil in a compartment can severely damage major components.

These four types of analysis are used to monitor the condition of your equipment, and to help you identify potential problems. A properly administered S·O·S Services Oil Analysis program will reduce repair costs and the program will lessen the impact of downtime.

The S·O·S Oil Analysis program uses a wide range of tests to determine the condition of the oil and the condition of the lubricated compartment. Guidelines that are based on experience and a correlation to failures have been established for these tests. A trained person at your Cat dealership should make the final analysis.

Oil analysis is one of the diagnostic tools to determine engine health. Oils that are within the limits given by the guidelines may not indicate all engine health issues. Under certain conditions, including, but not limited to severe operating conditions, oils that are within the limits given by the guidelines may require changing early.

Note: Cooling system problems will also reduce the life of engines, transmissions, and hydraulic systems. S·O·S Coolant Analysis together with S·O·S Oil Analysis provide a complete and accurate method for monitoring the health of all machine systems. Refer to the S·O·S Coolant Analysis information in this publication. A properly administered S·O·S Services program will reduce repair costs and lessen the impact of downtime.

Refer to the “Contamination Control” article in this Special Publication for recommended fluid cleanliness targets.

Note: Most oil analysis programs do not detect larger particles in the oil sample. Some failure modes only produce larger particles. Oil analysis alone will not always detect an impending failure. Oil filters should be sectioned and inspected for the presence of visible particles.

The engine oil consumption must be measured and recorded. A significant increase in oil consumption can indicate a problem with cylinder pack deposits or components. Additionally, oil additions dilute wear metals and other contaminants. Oil analysis results may become inaccurate.

Consult your Cat dealer for complete information and assistance about the S·O·S Oil Analysis program.

Obtaining S·O·S Oil Samples

Before you obtain an S·O·S oil sample, operate the machine until the oil is warm and the oil is well circulated. Then obtain the S·O·S oil sample.

In order to obtain a good oil sample, do not take the oil sample from the drain stream. The drain stream method can allow a stream of dirty oil from the bottom of the compartment to contaminate the sample. Likewise, never dip an oil sample from an oil container or pour a sample from a used filter.

NOTICE

Always use a designated pump for oil sampling, and use a separate designated pump for coolant sampling. Using the same pump for both types of samples may contaminate the samples that are being drawn. This contaminate may cause a false analysis and an incorrect interpretation that could lead to concerns by both dealers and customers.

There are two ways to obtain S·O·S oil samples. The following methods are listed in the order that is preferred:

- Use an in-line sampling valve for pressurized oil systems.
- Use a sampling gun that is inserted into the sump.

Use of the in-line sampling valve is the preferred method. This method provides samples that are less likely to be contaminated. Whenever you obtain the samples, obtain the samples from the same point. The samples will be more representative of the oil that is in the system.

Normally, the oil sample is taken at low idle. If the flow rate is too low, increase engine speed to obtain the oil sample.

In-line sampling valves cannot be used on nonpressurized oil systems such as differentials and final drives. Use of the sampling gun is the preferred method for nonpressurized oil systems.

Refer to the Operation and Maintenance Manual, “Maintenance Interval Schedule” for the proper interval.

i08314696

Oil Sampling Interval

SMCS Code: 1000; 3000; 4000; 4050; 4250; 4300; 5050; 7000; 7542

Take the oil samples as close as possible to the standard intervals. To receive the full value from S·O·S Oil Analysis, establish a consistent trend of data. To establish a pertinent history of data, perform consistent oil samplings that are evenly spaced.

General recommendations for oil sampling intervals for gas engines are recommended to be:

- Engine: 250 hours
- Hydraulics: 500 hours

Note: Refer to the Operation and Maintenance Manual that came with your engine for the recommended oil sampling intervals. Severe applications may require a more frequent oil sampling interval.

In severe service applications, more frequent oil sampling is recommended. Severe service for lubricated compartments occurs at high loads, in high temperatures, and in dusty conditions. If any of these conditions exist, work with your engine OMM, or Cat dealer to determine an appropriate sampling interval. These additional oil samples will increase the chance of detecting a potential failure and reducing unexpected down time.

Consult your Cat dealer for complete information and assistance in establishing an S·O·S Services program for your equipment.

Optimizing Oil Change Intervals

The recommended oil drain intervals for your machine are published in the Cat Operation and Maintenance Manual (OMM). These oil drains are for typical applications where the listed practices are followed:

- Use recommended oils, as described in this document or the OMM
- Use of recommended fuels, as described in this document or the OMM
- Use of Cat oil filters
- Use of Caterpillar recommended maintenance

In the vast majority of applications, the recommended oil drain intervals are designed to provide excellent protection for your machine. In a few specialized applications, there may be a need for shorter oil drains. The need for a shorter oil drain will be identified through oil sampling and oil analysis.

Improvements in product design and improvements in lubricant performance have created the opportunity for extended oil drains in all lubricated compartments. Some of these extended oil drains are reflected in current OMM recommendations. The common requirements for these extended oil drains are:

- Use of Cat branded lubricants
- Use of Cat filters
- Use of Cat S·O·S Services oil analysis

These three requirements lower the risk of an extended oil drain and enable the longest oil drains. Your Cat dealer can provide you with the best lubricants for extended oil drains.

With these improvements to product design and lubricant performance, extended oil drains are a proven way to lower maintenance costs and improve profitability. A properly managed extended oil drain program allows the full life designed into the machine and supports recommended component overhauls. Extended oil drains do allow you to obtain all the life designed into Cat lubricants and reduce waste.

The recommended process for extending engine oil drains is to follow the use of recommended lubricants, filter, and oil analysis. Additionally, start with increasing the oil drain in reasonable increments in the range of 250 to 500 hours while following the oil analysis results. Work with your Cat dealer to select the proper high-performance Cat lubricant for your extended oil drain program. Your Cat dealer has additional resources to guide you in the extended oil drain process.

Corrosive Gaseous Fuels

Corrosive gases may contain high levels of sulfur compounds such as hydrogen sulfide (H₂S), halide compounds such as fluorine, and ammonia compounds. Your Cat dealer has specific guidelines for these corrosive compounds. Consult your Cat dealer regarding the best methods for measuring and controlling these compounds in your gaseous fuel supply.

When these corrosive compounds are presenting gaseous fuels, perform additional tests on used gas engine oils. These additional tests on used gas engine oils. These additional tests may also be used if an oil-related issue cannot be resolved through the standard set of S·O·S Services tests.

Some gaseous fuels may contain significant amounts of corrosive compounds. These compounds can form highly corrosive acids in the engine oil. The S·O·S Services tests for Oxidation, Nitration, and Viscosity will indicate that these acids have degraded the oil. In many applications, these tests are sufficient to alert the customer regarding problems with oil deterioration. Two additional oil tests can be requested when corrosive gasses are used: Total Base Number (TBN or BN), and Total Acid Number (TAN). TBN and TAN measure the acid formation in the oil. When available, the results of these tests can be combined with the normal S·O·S data to provide full evaluation and can be helpful in trending the oil condition.

Note: S·O·S Services oil analysis for all biogas sites and any site that may have corrosive compounds in the gaseous fuel should include: Oxidation, Nitration, Viscosity, Wear Metal, TAN, and TBN test results.

Silicon Containing Gases

Cat gas engines that operate on landfill gases may experience high levels of silicon in the lubricating oil. One possible source of this silicon is from a family of gases called siloxanes. Siloxanes are organic compounds composed of silicon, oxygen, and methyl groups. After combustion, this type of silicon enters the oil through the blow-by gases and the oil from the cylinder liners.

The silicon compounds from siloxane gases are much less abrasive than silicon compounds found in dirt. Gas engines can operate with silicon levels up to 125 ppm when the source of the silicon is siloxane gases. A trained analyst should be utilized to determine the safe level of silicon and the source of the silicon. Elevated silicon levels caused by dirt entry will severely damage internal engine components. Refer to the Special Publication, LEBW4977, "Gaseous Fuels - Application and Installation Guide" for more information on siloxane gases and other contaminants.

PROOF

Fuel Specifications

i03127807

General Fuel Information

SMCS Code: 1250; 1280

NOTICE

Every attempt is made to provide accurate, up to date information. By use of this document you agree that Caterpillar Inc. is not responsible for errors or omissions.

Follow all applicable industry standards. Follow all applicable governmental and environmental safety guidelines, practices, regulations, and mandates.

The information that is provided is the latest recommendations for the Cat gas engines that are covered by this Special Publication. This information supersedes all previous recommendations which have been published for the Cat gas engines that are covered by this Special Publication. Special fluids are required for some engines and it will be necessary to continue to use these special products. Refer to the applicable Operation and Maintenance Manual.

This publication is a supplement to the Operation and Maintenance Manual. This publication does not replace the engine specific Operation and Maintenance Manuals.

NOTICE

These recommendations are subject to change without notice. Consult your local Cat dealer for the most up to date recommendations.

NOTICE

Caterpillar does not warrant the quality or performance of non-Caterpillar fluids and filters.

NOTICE

Refer to the engine Operation and Maintenance Manual for any fuel information that may be specific to that application.

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

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

Cat gas engines will operate successfully on a broad range of gaseous fuels. Adjustments must be made to the fuel system when the engine is commissioned or when the fuel is changed. Consult your Caterpillar dealer about the proper adjustments.

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

- Composition
- Contaminants
- Heat value
- Methane number
- Specific gravity

Field gas can have varying characteristics of combustion. Field gas can contain numerous harmful impurities. The impurities can alter the BTU value. The impurities can also alter the methane number. The impurities include everything from water up to complex hydrocarbons that can lead to detonation and severe engine damage. In order to minimize these effects, Caterpillar recommends the following guidelines:

- Evaluate the fuel with the most current revision level of Caterpillar Methane Number Program, LEKQ6378.
- Methane values below 30 are not recommended for use in a Cat engine. Fuels with a methane number that is below 30 must first be processed in order to remove harmful impurities in the fuel and raising the methane number into the acceptable range.
- If necessary, use an engine that is configured for a fuel that has a high energy. Consult the appropriate manual for the engine in order to determine the recommended engine timing.
- Reduce the oil change interval according to the results of the oil analysis.

Before the engine arrangement is ordered, use the methane number in order to determine the following characteristics for the new engine:

- Compression ratio
- Fuel system components
- Ignition timing
- Rated load

For a detailed explanation of methane numbers, refer to the most current revision level of Special Publication, LEBW4977, "Gaseous Fuels - Application and Installation Guide".

The High Heat Value (HHV) is a measurement of the total heat that is generated by combustion of a fuel. When any hydrocarbon is used as a fuel in an internal combustion engine, water is one of the products of combustion. The water is converted into steam before leaving the engine. The conversion requires heat. The steam removes the heat and the energy is not used by the engine. The HHV minus the heat that is used to vaporize the water equals the Low Heat Value (LHV) of the fuel. The LHV is sometimes known as the fuel energy content. Generally, fuel with a lower LHV releases heat less rapidly.

i03615747

Fuel Effects on Maintenance Costs

SMCS Code: 1280

There are many sources of the fuel that is used in gas engines. These different sources may have an effect on the engine maintenance intervals. These sources include pipeline natural gas, wellhead gas, bio-gas, and propane.

With pipeline natural gas, maintenance intervals might be extended. Due to the harmful effects of impurities that contaminate gases such as bio-gas, shorter maintenance intervals would be expected. These maintenance intervals can be improved by processing the gas in order to remove damaging impurities.

For more information on types of fuels, refer to the appropriate topics in this Special Publication, "Fuel Specifications" section. For specific information on the maintenance intervals, refer to the Operation and Maintenance Manual for the engine.

i03615781

Propane

SMCS Code: 1280

NOTICE

Propane and blends of propane may cause detonation in high compression engines. Propane fuel should never be used with G3600 engines.

Propane is transported to a site as a liquid. The liquid is converted into a gas at the site.

For the guidelines in this Special Publication, propane must meet these HD-5 specifications ("Gas Processors Association, GPA Standard 2140-97, Liquefied Petroleum Gas Specifications and Test Methods"):

- 95 percent propane
- Remaining 5 percent is not heavier than butane.

The engine must be properly equipped for the use of propane. The use of pistons with a low compression ratio and a derating is required.

HD-5 propane has a Low Heat Value (LHV) between 2427 to 2532 kJ/0.305 m³ (2300 to 2400 Btu/ft³). Due to the higher heat of combustion that is produced by propane, engines that use this fuel will have higher exhaust port temperatures than engines that use dry natural gas.

The higher exhaust temperatures tend to reduce the service life of the cylinder head, of the exhaust manifold, and of the turbocharger.

i03616061

Dry Natural Gas (Pipeline)

SMCS Code: 1280-G6

Dry natural gas is a mixture of methane and traces of heavier hydrocarbons. Dry natural gas has been processed in order to remove liquids. This gas has a low tendency to detonate.

For dry natural gas, the acceptable limit of hydrogen sulfide is 0.43 mg/MJ (0.45 µg/Btu).

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

i03615900

Wellhead Gas

SMCS Code: 1280-G6

Wellhead gas (field gas) is a mixture of hydrocarbons and inert gases that is drawn directly from the wellhead in the gas field. Wellhead gas has minimal processing before entering the fuel manifold. This fuel is commonly used in engines that power gas compressors.

The composition of gas from the wellheads in different gas fields varies, and the composition of the gas from different wellheads within the same gas field can vary. Different compositions have different characteristics of combustion. As a result, the gas from one source may be acceptable for use but the gas from a different source may not be acceptable. Heavier hydrocarbons such as pentane and butane can cause detonation and other problems. For these reasons, a fuel analysis is required to determine if the fuel is acceptable for a particular Cat engine.

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

Some gas fields contain significant amounts of hydrogen sulfide. In these cases, follow the precautions that are recommended in this Special Publication, "Sour Gas" topic.

The site may have equipment such as scrubbers, liquid separators, and heat exchangers that remove water and liquid hydrocarbons from the gas. However, vapor can still be drawn into the engine. The maintenance costs are variable for engines that use wellhead gas. Sometimes, overhauls are needed at intervals that are sooner than the expected time. However, the practices and factors at many sites enable overhaul intervals that are longer than the expected times: efficient preventive maintenance, proper engine oil, and operation below the rated load.

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

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

Note: Use the Cat Methane Program, LEKQ6378 to determine if the fuel is suitable for the particular engine application.

i03127810

Sour Gas

SMCS Code: 1280

Many gaseous fuels contain sulfur compounds. These compounds are primarily composed of hydrogen sulfide (H_2S). Gaseous fuels with more than 0.43 mg H_2S /MJ (.45 μg H_2S /Btu) or above 10 ppm are considered to be sour gas. The following gases are within this category:

- Some wellhead gases
- Landfill gas
- Digester gas

Required maintenance is increased by the introduction of hydrogen sulfide into the fuel. For sour gas, Caterpillar recommends engine arrangements for landfill gas.

The use of gases that have hydrogen sulfide can damage the engine. Products of combustion (water vapor and sulfur oxides) form sulfurous acid and sulfuric acid.

Analyze the gas before use. If the gas has more than 0.43 mg of H_2S /MJ (.450 μg of H_2S /Btu), treat the gas in order to reduce the content of hydrogen sulfide. For more information, see this Special Publication, "Hydrogen Sulfide Effects on Engine Maintenance Costs".

i08274817

Bio-Gas

SMCS Code: 1280-G5

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

- Landfills
- Facilities that produce digester gas

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

Landfill Gas

Note: Caterpillar recommends the use of Cat NGENO Special Application engine oil for engines operating on landfill gases.

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

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

- Chlorine
- Fluorine
- Siloxanes
- Sulfur
- Water vapor

Fuel analysis is required in order to provide guidelines for treatment of the fuel.

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

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

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

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

In addition, calcium from engine oils contributes to deposits. Hence, deposits in the combustion chamber are generally a combination of these materials: silicon, calcium and some traces of other elements.

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

Deposits also form on the pistons and on the bottom deck of the cylinder heads. These deposits can increase the compression ratio, which can lead to detonation and/or preignition. Detonation and/or preignition can loosen the deposits. The deposits that are loosened can be trapped between the valve and the valve seat. The valve will be held open. Guttering of the valve will result.

The formation of deposits depends on the following factors:

- Composition of the fuel
- Operating conditions
- Type of lubrication oil

Most landfill applications will generate some deposits in the combustion chamber and in the turbocharger. Siloxanes are a major contributor to these deposits. The fuel requires treatment in order to remove the siloxanes. For information on equipment for processing landfill gas, refer to the most current revision level of Special Publication, LEBW4977, "Gaseous Fuels - Application and Installation Guide".

Note: Caterpillar has developed gas sampling equipment for siloxane and halogen measurements. It may be used to accurately collect and meter gas for the mineral oil sampling method. The kit contains three containers of mineral oil and a system to pass a fixed amount of gas through the mineral oil. The exposed mineral oil is then sent to a laboratory for testing. This kit will also gather gas in a bag for halogen and hydrogen sulfide content tests.

Silicon sampling kits are available through the following companies:

SiTest Landfill 1 Program
Bio-Engineering Services
36 Virginia Street
Southport, PR8 6RU England
Telephone 44 (0) 1704-539094
Fax 44 (0) 1704-501660

or

Jet Care Silicon Analysis Sampling Kit
Jet-Care International Inc.
3 Saddle Road
Cedar Knoll, NJ 07927-1902
Telephone (201)292-9597
Fax (201)292-3030

or

Spectro/Jet-Care
Hatchwood Place, Farnham Road
Odiham
Hampshire, RG29 1AB, UK
Telephone 44 (0) 1256-704000
Fax 44 (0) 1256-704006

Refer to your Cat dealer for more information.

Note: Caterpillar is not responsible for the performance or quality of aftermarket products.

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

The formation of water in the crankcase and in the valve mechanisms can result in an acid solution which allows corrosion to occur. A high jacket water coolant temperature helps to prevent the condensation of water in the crankcase. Engines that are used for landfill gas have a high temperature jacket water cooling system as standard equipment.

In order to protect the service life of the engine, it is necessary to follow the guidelines for operation and maintenance that are recommended by Caterpillar. Engines operating on Landfill gas need to have a positive crankcase ventilation system to help decrease acid formations. Landfill gas also requires regular, careful maintenance of the spark plugs. Misfire causes the engine to run rough and the cylinder temperatures are reduced. Cooler cylinders allow deposits to build up faster in the combustion chamber, in the exhaust manifold, and in the turbocharger. Exhaust port temperatures can indicate the performance of the spark plugs. An exhaust port temperature that decreases more than 66 °C (150 °F) below the average operating temperature may indicate the misfire of a spark plug. Inspect the spark plug in accordance with the engine Operation and Maintenance Manual, "Ignition System Spark Plug - Inspect/Adjust/Replace" article.

Note: For more information on bio-gas, refer to the most current revision level of Special Publication, LEBW4977, "Gaseous Fuels - Application and Installation Guide".

Digester Gas

A variety of materials can produce digester gas:

- Sewage

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

- Ag Biogas

Ag Biogas is a methane based fuel created from an anaerobic digestion process of animal waste or a combination of animal waste and agricultural products. It does not include landfill, gasifier (syngas) or wastewater treatment plant type gas producing applications. Ag biogas usually has some variable amounts of sulfur, which can reduce maintenance intervals. Regular maintenance of the product will depend on quality of the fuel. Oil sampling and data trending will determine optimum oil change interval. Spark plugs may have reduced life as well based on the quality of the fuel.

i08274812

Hydrogen Sulfide Effects on Engine Maintenance Costs

SMCS Code: 1280

Sour gas refers to fuels that contain more than 0.43 mg of H₂S/MJ (0.450 µg of H₂S/Btu). The following gases are within this category:

- Some wellhead gases
- Landfill gas
- Digester gas

Sweet gas pertains to fuels that have less than 0.43 mg of H₂S/MJ (.450 µg of H₂S/Btu). Typically, propane and processed dry natural gas are in this category.

Without precautions, maintenance costs are greatly increased by the introduction of hydrogen sulfide into the engine's fuel. For sour gas, Caterpillar recommends engine arrangements for landfill gas.

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

- Fuel valves
- Valve mechanisms
- Piston pin bushings
- Piston rings
- Cylinder liners
- Exhaust manifolds
- Aftercoolers
- Turbochargers

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

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

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

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

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

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

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

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

- Use an engine configuration that has a fuel system that is designed for sour gas and a positive crankcase ventilation system.
- Maintain the temperature of the coolant outlet to a minimum of 110 °C (230 °F). Lower jacket water coolant temperatures permit water vapor and hydrogen sulfide to condense on the cylinder liners. Higher temperatures will reduce this condensation. Do not allow the rise in temperature across the engine to exceed 8.3 °C (15 °F). A rise in temperature of 5.6 °C (10 °F) is preferable.

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

For additional information on gaseous fuels and on treatment of the fuel, refer to the following publication:

- Special Publication, LEBW4977, "Gaseous Fuels - Application and Installation Guide"

i08274802

Fuel Filtration

SMCS Code: 1260; 1280

NOTICE

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

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

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

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

Note: Use a fuel filter that is designed to capture a minimum of 99 percent of the particles that are 1 micron in diameter.

Consult your Cat dealer about the requirements for filtering your fuel.

Cooling System Specifications

i06579726

General Coolant Information

SMCS Code: 1350; 1395

NOTICE

Refer to the engine Operation and Maintenance Manual for any coolant information that may be specific to that application.

Functions of Cooling System

The cooling systems of modern gas engines are precisely balanced. The performance of the cooling system affects many of the engine components. Optimum performance can only be obtained by proper installation and maintenance of the cooling system.

The engine cooling system is designed to meet specific guidelines. The proper coolant/antifreeze will provide the following functions:

- Adequate heat transfer
- Compatibility with the cooling system components such as hoses, seals, and piping
- Protection from water pump cavitation
- Protection from other cavitation erosion
- Protection from freezing and from boiling
- Protection from the buildup of corrosion, of sludge, and of scale

If a cooling system fails to perform any of the above functions, the following conditions can occur:

- Overheating
- Overcooling
- Leaks from hoses, from seals, and from piping
- Cavitation erosion
- Damage from freezing or from boiling
- Plugging of passages for the coolant/antifreeze in components such as radiators, aftercoolers, oil coolers, and other heat exchangers

Many engine failures are related to the above conditions: cracking of the cylinder head and/or of the engine block, piston seizure, leakage of the water pump, failure of the water pump and pitting of the cylinder liners and cylinder block.

These problems can be avoided through proper maintenance of the cooling system. Periodically evaluate the maintenance practices in order to make sure that the cooling system is properly maintained.

Properties of Coolant/Antifreeze

Coolant/antifreeze is normally composed of three elements: water, glycol and additives. Each element must meet specific guidelines.

Water

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

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.

Deionized water or distilled water is recommended for use in engine cooling systems.

If distilled water or deionized water is not available, use water with the properties that are listed in Table 7.

Table 7

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

NOTICE

Use of water that does not meet the recommendations for the cooling system will damage the cooling system.

Do not use these types of water in the cooling system: sea water, softened water that has been conditioned with salt, hard water and tap water.

Only use water that meets the recommendations for the cooling system.

If you are not sure about the properties of your water, consult one of the following sources for a water analysis:

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

Glycol

Glycol in the coolant helps to provide protection against boiling and freezing.

Note: Glycol used in finished coolants or in concentrates is inhibited using appropriate additives.

Most conventional heavy-duty coolant/antifreezes use ethylene glycol. In many applications, propylene glycol may also be used. In a 50/50 mixture with water, ethylene and propylene glycol provide similar protection against freezing and boiling.

Use a mixture that will provide protection against the lowest ambient temperature. For a comparison of the protection against freezing, refer to Table 8 .

Table 8

Antifreeze Protection		
% Mixture Glycol and Water	Lowest Protective Temperature	
	Ethylene Glycol	Propylene Glycol
50 / 50	-37 °C (-34 °F)	-32 °C (-26 °F)
60 / 40	-51 °C (-60 °F)	

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

The minimum recommended mixture is 50 percent glycol and 50 percent water. For optimum performance, Caterpillar recommends a 50/50 mixture of a water/glycol solution.

Protection against freezing is reduced if the mixture is greater than 60 percent of ethylene glycol.

Protection against freezing is reduced if the mixture has more than 50 percent of propylene glycol.

NOTICE

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

In order to check the concentration of glycol, use the 245 - 5829 Coolant/Battery Tester Gp (REFRACTOMETER) or use the 360 - 0774 Refractometer. The testers give readings that are immediate and accurate. The testers can be used with ethylene or propylene glycol.

Additives

Note: Glycol used in finished coolants or in concentrates is inhibited using appropriate additives.

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

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

Many additives are depleted during engine operation. These additives must be replaced periodically. This can be done by adding Cat Supplemental Coolant Additive (SCA).

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

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

For further information, see this Special Publication, "Supplemental Coolant Additive (SCA)" article.

Requirements for Venting of the Cooling System

In order to achieve optimum service life for the water cooled components in the gas engine, the cooling system must be able to purge air. Air can be introduced into the cooling system by different means:

- Air can be trapped in the cooling system when the system is filled or when the system is refilled.
- Air that is entrained in the mixture of coolant/antifreeze can be released by cavitation.
- Combustion gas can leak into the cooling system.

For maximum service life of the water cooled components, all of the air must be purged from the water jacket of each component. The presence of air can allow some of the coolant/antifreeze to convert into steam. This changes the properties of the coolant/antifreeze. Removal of the air reduces the possibility of forming steam and improves the service life of the coolant/antifreeze.

The preferred method for venting of the engine cooling system is the installation of vent lines. Follow these guidelines:

- The vent line must be routed from the highest point of the cooling system on the engine to a point that is higher than any of the engine water cooled components.
- Each component that is in a position which can trap air must be vented. For example, the turbocharger and the exhaust bypass valve are usually located at the highest points of the cooling system. One line cannot remove the air from both components. If only one of the components is vented, the other component can still trap air. Both of the components must be vented.
- For each cooling circuit, route the vent line into the bottom of the expansion tank.
- The vent line must have a continuous upward slope. In order to avoid blockage in the vent line, ensure that the vent line is routed in a manner that will avoid trapped fluid. Do not allow any dips in the routing of the vent line.
- Always remove the pressure cap in order to fill the cooling system. Leave the pressure cap loose during the first few minutes of engine operation in order to allow air to be fully purged.

In some applications, it may not be possible to install the recommended vent lines. In these cases, automatic vent lines must be installed. Install an automatic valve that is 0.6 to 0.9 m (2.00 to 3.00 ft) above the highest point of the cooling system on the engine.

Note: An automatic valve requires periodic service. Ensure that the valve is not plugged. If coolant/antifreeze leaks from a valve, correct the condition immediately. A valve that malfunctions can allow air to enter the cooling system after the engine is shut down. A vent line is always preferred over an automatic valve.

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Coolant Recommendations

SMCS Code: 1350; 1352; 1395

General Recommendations

NOTICE

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

During shipping and storage, the engine must be protected from damage that can be caused by freezing of the cooling system. If the engine is shipped to a site with freezing temperatures and/or if the engine is stored in a location with freezing temperatures, the cooling system must contain antifreeze that will withstand the lowest ambient temperature. Frequently check the concentration of glycol in the coolant/antifreeze. Ensure that the concentration is adequate in order to prevent freezing. Otherwise, the cooling system must be completely drained, including pumps and coolers..

For engines in any location, periodically check the concentration of the additives in the coolant/antifreeze. Ensure that the concentration is adequate in order to help prevent corrosion and other harmful conditions.

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.

NOTICE

Fill the cooling system no faster than 19 L (5 US gal) per minute to avoid air locks.

Maintenance Section
Coolant Recommendations

After a cooling system has been refilled, monitor the level of the coolant/antifreeze in the expansion tank. Maintain the level above the minimum mark until all of the air has been purged from the system. Then maintain the proper level for normal operation.

During normal operation, frequently check the level of the coolant/antifreeze in the expansion tank. If the level is low, add the proper mixture of coolant/antifreeze.

For engines in any location, check the concentration of the conditioner in the coolant/antifreeze according to the engine Operation and Maintenance Manual, "Maintenance Interval Schedule". Obtain an S·O·S coolant analysis (Level 1) or use the appropriate test kit. Ensure that the concentration is adequate in order to help prevent corrosion and other harmful conditions.

To further monitor the cooling system, obtain regular S·O·S coolant analyses (Level 2) according to the engine Operation and Maintenance Manual, "Maintenance Interval Schedule".

Recommended Coolant/Antifreeze

NOTICE

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

ELC was not formulated for use in Cat Gas Engines.

Do not use heat transfer fluids in Cat Gas Engines.

Use only the coolant/antifreeze that is recommended.

The coolants that are recommended or acceptable for use in Cat Natural Gas Engines are listed in Table 10.

Table 9

Recommendations For Finished Coolants For Use In Cat Natural Gas Engines				
Coolant Type	Recommendation	Product	Service Hours ⁽¹⁾ (2)	Required Maintenance ⁽³⁾
Cat NGEC, Cat DEAC, Cat SCA, Commercial Conventional Coolants	Preferred	Cat NGEC	3000 hours or 3 years	SCA at maintenance interval
	Acceptable	Cat DEAC Cat SCA (water based) ⁽⁴⁾	3000 hours or 3 years	SCA at maintenance interval
	Min requirements for fully formulated heavy duty commercial coolants	ASTM D6210 and Nitrite (NO ₂) with the concentration: Min of 1200 ppm and max of 2400 ppm. Silicon concentration: min of 100 ppm and max of 275 ppm	3000 hours or 2 years	SCA at maintenance interval

(continued)

(Table 9, contd)

Recommendations For Finished Coolants For Use In Cat Natural Gas Engines				
Coolant Type	Recommendation	Product	Service Hours ⁽¹⁾ (2)	Required Maintenance ⁽³⁾
	Min requirements for commercial coolants requiring SCA precharge	ASTM D4985 ⁽⁴⁾ and Nitrite (NO ₂) with the concentration: Min of 1200 ppm and max of 2400 ppm. Silicon concentration: min of 100 ppm and max of 275 ppm	3000 hours or 1 year	SCA at maintenance interval
	Min requirements for commercial SCA and water ⁽⁵⁾	Commercial supplemental coolant additive and water having Nitrite (NO ₂) with the concentration: Min of 1200 ppm and max of 2400 ppm. Silicon concentration: min of 100 ppm and max of 275 ppm	3000 hours or 1 year	SCA at maintenance interval

- (1) New Coolants at 50 volume percent diluted. Coolants that are prediluted at the coolant manufacturer must be diluted with water that meets Reagent 4 "ASTM D1193" requirements.
- (2) Maintain the in-service coolant at the given limits.
- (3) For appropriate maintenance procedures, refer to the details given in this procedure. For applications that allow the use of SCA and water, a minimum of 6 percent to a maximum of 8 percent concentration of Cat SCA are recommended.
- (4) Water-based coolants are not allowed for use in machines that has NOx reduction aftertreatment devices, in engines that has AATAC and in Marine engines that have SWAC.
- (5) There are currently no industry standards to define the quality of water-based conventional coolants. In order to control the quality of SCA and water coolants, the commercial SCA additive package should pass ASTM D6210 and/or ASTM D4985 when this package is used in a glycol based coolant. Do not use a commercial SCA additive package that only meets the ASTM D3306 or equivalent specification when used in a glycol based coolant.

Preferred – Cat Natural Gas Engine Coolant (NGEC)

Cat coolants have been developed and tested in order to provide the full performance and service life that has been designed and built into Cat cooling systems. Cat NGEC coolant is currently used to fill Cat gas engines at the factory. This coolant is offered by Caterpillar dealers for continued use when the coolant is changed. Consult your Caterpillar dealer for more information on Cat coolants.

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

Commercial coolants are, as a group, second choice.

Commercial heavy duty coolant/antifreeze can contain either ethylene glycol or propylene glycol. The coolant/antifreeze must contain 200 ppm (parts per million) silicates to 500 ppm silicates in concentrate or 100 ppm to 275 ppm silicates in a 50/50 mix. 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 ASTM "D3306" or equivalent specification. This type of coolant/antifreeze is made for light duty automotive applications.

Use only the coolant/antifreeze that is recommended.

Acceptable – In applications that do not require protection from boiling or from freezing, a mixture of Cat SCA and water that meets the properties that are listed in the "Caterpillar Minimum Acceptable Water Requirements" Table in the "General Coolant Information" topic is acceptable.

Note: The preferred coolant/antifreeze and the acceptable mixture of SCA and water require different concentrations of SCA. Refer to the "Supplemental Coolant Additive (SCA)" topic.

Table 10 is a list of the coolant/antifreeze that is recommended for Cat Gas Engines. The service life of the coolant/antifreeze that is used in Cat Gas Engines is also listed. **In order to achieve this service life, the coolants must be properly maintained. The maintenance program includes S-O-S coolant analysis.**

Maintenance Section
Supplemental Coolant Additive (SCA)

Table 10

Recommended Coolant/Antifreeze and Service Life of the Coolant/Antifreeze	
Coolant/Antifreeze	Service Life ⁽¹⁾
Cat NGECC	Three Years
Cat DEACC	
Commercial Heavy-Duty Coolant/Antifreeze that meets "ASTM D6210"	Two Years
Commercial Heavy-Duty Coolant/Antifreeze that meets "ASTM D4985"	One Year
Cat SCA and Water	Two Years
Commercial SCA and Water	One Year

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

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Supplemental Coolant Additive (SCA)

SMCS Code: 1350; 1352; 1395

Recommended Supplemental Coolant Additive (SCA)

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

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

Preferred – Cat Supplemental Coolant Additive (SCA)

Acceptable – A commercial SCA that provides 1400 mg/L (82 gr per US gal) or 1400 ppm of nitrites in the final mixture of coolant/antifreeze

Note: A 50/50 concentration of Cat NGECC or of Cat DEACC does not require a treatment with an SCA at the initial fill. Commercial heavy-duty coolant/antifreeze that meets "ASTM D6210" or "ASTM D4985" specifications may require a treatment with an SCA at the initial fill. Read the label or the instructions that are provided by the OEM of the product.

Commercial SCAs, as a group, are second choice additives.

To ensure that the correct amount of SCA is in the cooling system, the concentration of SCA must be tested on a scheduled basis. Obtain an S·O·S coolant analysis (Level 1) or use a test kit to check the concentration of the SCA according to the engine Operation and Maintenance Manual, "Maintenance Interval Schedule".

WARNING

Cooling system coolant additive contains alkali. To help prevent personal injury, avoid contact with the skin and eyes. Do not drink cooling system coolant additive.

Coolant/Antifreeze and SCA

Note: Mixtures of glycol and water require a lower concentration of SCA than mixtures of only water and SCA. Mixtures of glycol and water require 3 to 6 percent of SCA.

NOTICE

Do not exceed the recommended six percent supplemental coolant additive concentration.

Test the concentration of the SCA with an S·O·S coolant analysis (Level 1) or with the 4C-9301 Coolant Conditioner Test Kit.

Instructions are provided with the 4C-9301 Coolant Conditioner Test Kit.

Note: Cat SCA has a nitrite base. Many commercial types of SCA have a base of phosphate that cannot be checked with a Caterpillar test kit. If a commercial SCA is used, follow the recommendations for testing that are provided by the OEM of the product.

If a commercial SCA is used, the final mixture of coolant/antifreeze must have 1400 mg/L (82 gr per US gal) or 1400 ppm of nitrites.

Maintain a concentration level of nitrites in the cooling system that is between 1200 mg/L (70 gr per US gal) and 2400 mg/L (140 gr per US gal).

Water and SCA

A cooling system that uses a mixture of water and SCA requires more SCA than a cooling system that uses a mixture of glycol and water. The mixture of water and SCA requires 6 to 8 percent of SCA.

NOTICE

Do not exceed the recommended eight percent supplemental coolant additive concentration.

Test the concentration of SCA with an S·O·S coolant analysis (Level 1) or with the 4C-9301 Coolant Conditioner Test Kit. Follow the instructions that come with the kit, including the addition of SCA if needed.

Excessive Concentrations of SCA

An excessive concentration of SCA can result in the formation of deposits.

If the concentration of SCA is greater than the recommended level, drain some of the coolant/antifreeze. Refill the cooling system with water and operate the engine in order to dilute the mixture. Then, test the concentration again. Repeat this process until the concentration is acceptable.

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Cooling System Maintenance

SMCS Code: 1350; 1352; 1395

Cooling system maintenance has a direct effect on engine operation and on the service life of the engine. Maintain the coolant to the standards that are recommended in the engine Operation and Maintenance Manual. Refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule". Follow these guidelines:

- Use the recommended coolant/antifreeze.
- Maintain the proper concentration of Supplemental Coolant Additive. Use the correct method of testing.
- Maintain the protection against freezing.
- Clean the cooling system and refill the system according to the engine Operation and Maintenance Manual.
- Consult your Caterpillar dealer about S·O·S Coolant Analysis.

Note: Cat cleaners can be used in order to clean the cooling system. Follow the instructions on the label. Consult your Caterpillar dealer for availability.

Fluid Products for the Cooling System

Table 11

Quantities and Part Numbers of Cat Natural Gas Engine Coolant (NGEC)			
Type	3.8 L (1 US gal)	19 L (5 US gal)	208 L (55 US gal)
50% Glycol 50% Water	339-3776	339-3777	339-3778

Table 12

Quantities and Part Numbers of Cat Diesel Engine Anti-freeze/Coolant (DEAC)		
Type	3.8 L (1 US gal)	208 L (55 US gal)
Undiluted Concentrate	339-3768	339-3769

Table 13

Quantities and Part Numbers of Cat Supplemental Coolant Additive (SCA)			
0.47 L (1 pint)	0.95 L (1 qt)	18.9 L (5 US gal)	208 L (55 US gal)
8T-1589	3P-2044	8C-3680	5P-2907

Table 14

Quantities and Part Numbers of Cat Cooling System Cleaner - Quick Flush			
0.95 L (1 qt)	3.8 L (1 US gal)	18.9 L (5 US gal)	208 L (55 US gal)
4C-4610	4C-4611	4C-4612	4C-4613

Test Tools for the Cooling System

Table 15

Test Tools for the Cooling System and Function of the Tools	
Part	Function
245-5829 Coolant/Battery Tester Gp 360-0774 Refractometer	Check the freezing point of the coolant/antifreeze.
4C-9301 Coolant Conditioner Test Kit	Check the concentration of the SCA in the coolant.
4C-9297 Test Strip (Coolant Conditioner)	Test strips for checking the concentration of the SCA in mixtures of glycol and water
164-3310 Infrared Thermometer	Measure surface temperatures without contacting the surface.
164-3320 Infrared Thermometer Gp (110 Volt AC Adapter)	
166-9030 Infrared Thermometer Gp (220 Volt AC Adapter)	

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S·O·S Services Coolant Analysis

SMCS Code: 1350; 1352; 1395; 7542; 7542-008

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

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

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

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

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

- The application of the equipment

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

NOTICE

Always use a designated pump for oil sampling, and use a separate designated pump for coolant sampling. Using the same pump for both types of samples may contaminate the samples that are being drawn. This contaminate may cause a false analysis and an incorrect interpretation that could lead to concerns by both dealers and customers.

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

S·O·S Coolant Analysis (Level 1)

A coolant analysis (Level 1) is a test of the properties of the coolant that includes the following items:

- Glycol concentration for protection from boiling and freezing
- Ability to protect from erosion and corrosion

- pH
- Conductivity
- Water hardness
- Visual analysis
- Analysis of the odor

The results are reported, and appropriate recommendations are made.

S·O·S Coolant Analysis (Level 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 following services are provided:

- Full Level 1 analysis
- Identification of the source of metal corrosion and of contaminants
- Identification of buildup of the impurities that cause corrosion
- Identification of buildup of the impurities that cause scaling
- Determination of possible electrolysis within the engine cooling system

The results are reported, and appropriate recommendations are made.

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

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Contamination Control

SMCS Code: 1054; 108K; 1261; 1263; 1280; 1308; 1348; 3080; 5068; 5095; 7342; 7581

Contamination Control

Contamination is defined as the presence of unwanted foreign substances in fluid and gas fuel systems or fluid wetted parts. Contamination alters the properties of fluids, causes damage of engine systems, and prevents systems and components from attaining the desired reliability and durability. Contamination is the primary cause of fluid system failures.

Contaminants include a wide variety of unwanted substances including but not limited to the following:

- Foreign and abrasive substances such as wear particles, fibers, dirt, and dust
- Chemical substances such as products of combustion that are suspended in the fluids
- Cross contamination of water, coolant, and oil
- Biological micro-organisms such as algae or fungi
- Physical/chemical contaminants such as products of oxidation and heat

Some contaminants are generated within the fluid system due to the normal operation of the system. Contaminants may also be drawn into the system from the outside environment such as through a poorly maintained air filter, contaminated fill fluids or improper maintenance and repair practices.

Particle contaminants are visible to the naked eye if the particles are visible to the naked eye if the particles are approximately 40 µm (microns) and larger while smaller particles are not visible. Particle contaminants can cause damage even if the particles are not visible to the naked eye.

Contaminants of all types can be controlled by following contamination control practices and using appropriate filtration. Refer to your Operation and Maintenance Manual (OMM) and to your local Cat dealer for recommendations.

Controlling contamination is especially important for current engine models. Current engine and hydraulic systems are designed with close tolerances and operate at high pressures for enhanced performance. These design improvements emphasize the importance of higher performing gas fuels and fluids, enhanced fluid filtration, and greatly improved fluid cleanliness levels.

Measuring Cleanliness

Fluid cleanliness can be measured by taking fluid samples from the engine and hydraulic system. Your Cat dealer can analyze the samples. Particle contaminants are typically measured by particle counters and the results expressed per "ISO 4406" (International Organization for Standardization) classification. Chemical contaminants can be measured by specific analysis techniques such as oxidation, water, or soot tests. Refer to your Cat S·O·S lab or to your Cat dealer for more information.

Note: Several factors affect the results of particle counts. The factors include the cleanliness of the equipment used to obtain the sample, sampling techniques, the cleanliness, and type of sample container, particle counter accuracy (calibration, maintenance, and process), and the environment where the sample is procured. Samples should be taken at representative locations in the fluid circulation system or the fluid distribution system when possible. The sample should be protected adequately from contamination during transport to the lab for analysis.

In addition, particle counters may count water droplets and air bubbles as particulate contamination.

Cleanliness Standards for Fluids used in Gas Engine Systems

Cat recommends that gas engine systems be maintained at the factory defined fluid cleanliness targets.

Minimum cleanliness targets for gas fuels and fluids used in gas fuels and fluids used in gas engine systems are given below. These targets are for gas fuels and fluids used for engine and hydraulic system fill and for engine roll-off. The latter is defined as the cleanliness targets for engines before they return to work after maintenance and invasive repairs.

Note: Use a gas fuel filter that is designed to capture a minimum of 99 percent of the particles that are 1 micron in diameter.

Cleanliness targets:

- Gas fuels: Should contain ,<1% of particles 1 micron or less
- Engine oil as dispensed into the engine: filtered through a 12 micron absolute efficiency filter. Refer to details given below.
- Hydraulic oil as dispensed into the hydraulic system: ISO -/18/15

Note: Particle counting of new multi-viscosity engine oils may not be effective to assess their cleanliness level. Optical particle counters cannot distinguish between particulate contaminants and additives. Instead, filter the new engine oils as described below. Additionally, do not use optical particle count for the evaluation of used engine oils because soot levels render oil too dark for optical particle counters. Soot levels in used engine oils should be evaluated by using S·O·S Services Oil Analysis.

When filtering engine oil before dispensing into the engine tank or when engine oil kidney looping filtration is done, follow these recommendations:

- Use engine oil filters of 12 microns absolute efficiency. A Cat Ultra High Efficiency Lube filter is recommended. Consult your Cat dealer for the most current part number.
- Ensure that the temperature of engine oil is 20° C (68° F) or higher.

Consult your Cat dealer for information and solutions to your oil and fuel analysis needs.

General Contamination Control Recommendations or Practices

Maintaining a low contamination level can reduce down time, and can control the maintenance cost of the engine. The productive life as well as the reliability of components and fluid systems is often increased as a result of proper contamination control practices.

The following are general guidelines for controlling contaminants.

- Refer to the recommendations for gas fuels in the publication for recommended fuel specification, cleanliness, levels and filtration guidelines.
- Refer to the engine Operation and Maintenance Manual for the required maintenance for all engine fluids.
- When you add oil to the engine, use 12 micron absolute filter to ensure adequate cleanliness.
- Use only coolants that are recommended by Cat for your machine. Follow the recommended maintenance procedure for the cooling system in the Operation and Maintenance Manual for your machine.
- Maintain the engine air filters and air intake system to avoid unwanted contaminant ingress.
- Follow contamination control practices for the shop area, component/engine disassembly areas, parts, shop tools, test setups, test areas, storage areas, and waste collection areas. Keep components clean during inspection, assembly, testing, and filling machines with clean fluids. Good practices will enhance component life and reduce downtime associated with contaminants. Your Cat dealer can provide details on proper contamination processes and practices.
- Follow contamination control practices for the workplace and for the worksite. Maintaining clean oil fill fluids saves time and effort and ensures that fill fluids are at the proper cleanliness levels.
- Use properly designed and maintained bulk storage fluids tanks.
- Protect the fluids storage tanks from dirt and water entry by using 4 µm or less absolute efficiency breathers with the ability to remove water.
- Keep the areas around the tanks' filler necks clean from debris and water.

- Drain the storage tanks of water and sediments frequently. The draining schedule depends on use of proper inlet and outlet filters, the use of 4 μm breathers with the ability to remove water, and following recommended contamination control practices.
- Install and maintain a properly designed and grounded filtration system. Filtration should be at the entry and at the dispensing point. Continuous bulk filtration may be required to ensure that dispensed oils meet the cleanliness target.
- Cover, protect, and ensure cleanliness of all connection hoses, fittings, and dispensing nozzles.

PROOF

Reference Information Section

Reference Materials

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Reference Material

SMCS Code: 1000

Additional literature regarding your product may be purchased from your local Cat dealer or by visiting www.cat.com. Use the product name, sales model, and serial number in order to obtain the correct information for your product.

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Product and Dealer Information

Note: For product identification plate locations, see the section "Product Identification Information" in the Operation and Maintenance Manual.

Delivery Date: _____

Product Information

Model: _____

Product Identification Number: _____

Engine Serial Number: _____

Transmission Serial Number: _____

Generator Serial Number: _____

Attachment Serial Numbers: _____

Attachment Information: _____

Customer Equipment Number: _____

Dealer Equipment Number: _____

Dealer Information

Name: _____ Branch: _____

Address: _____

Dealer Contact

Phone Number

Hours

Sales: _____

Parts: _____

Service: _____

