SEBU7003-05

CATERPILLAR®

Operation and Maintenance Manual

Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations

Use the bookmarks for navigation inside of the manual

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

s00435078

Foreword

SMCS - 1000; 7000

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.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05424553

Lubricant Information

SMCS - 1000; 1300; 7581

NOTICE

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

The information that is provided is the latest recommendations for Cat diesel engines that are covered by this Special Publication. This information supersedes all previous recommendations which have been published for Cat diesel engines that are covered by this Special Publication. Special fluids are required for some engines. These fluids will still be necessary in those engines. 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.

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 Cat engine, only purchase Cat fluids and Cat 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 Cat filters through other outlets/sources, you are at a very high risk of purchasing counterfeit ("look-alike") products.

Counterfeit or "look-alike" products may visually appear the same as the original Cat product. The product performance and internal quality will typically be very low.

Counterfeit or "look-alike" products have a very high likelihood of causing and/or allowing engine and/or machine compartment damage.

Many of the guidelines, recommendations, and requirements that are provided in this Special Publication are interrelated. Before using the provided information, The user is responsible to read this Special Publication and understand the information provided.

The user is responsible to follow all safety guidelines found in this Special Publication and in the engine Operation and Maintenance Manual when performing all recommended and/or required engine, engine systems, and/or machine maintenance.

For questions concerning the information presented in this Special Publication and/or in your product Operation and Maintenance Manual, and/or for additional guidelines and recommendations (including maintenance interval recommendations/requirements) consult your Cat dealer.

Commercial products that make generic claims of meeting "Cat" and/or "Cat" requirements without listing the specific Cat recommendations and/or requirements that are met may not provide acceptable performance. Reduced engine and/or machine fluid compartment life may result. Refer to this Special Publication and refer to the product Operation and Maintenance Manual for Cat fluids recommendations and/or requirements.

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

Problems/failures that are caused by using fluids that do not meet the minimum recommended and/or required performance level for the compartment are not warrantable by Caterpillar Inc.. The fluid manufacturer and customer are responsible.

When fluids made by other manufacturers are used on Cat products, the Cat warranty is not affected simply because of such use. Failures that result from the installation or usage of other manufacturer fluids, however, are not Cat factory defects and therefore are NOT covered by the Cat warranty. Cat is not in a position to evaluate the many fluids promoted by other manufacturers and the effect on Cat 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.

Different brand oils may use different additive packages to meet the various engine performance category/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. The choices include filtration products, contamination control, tank management, and general handling practices. Cat designed and produced filtration products offer optimal performance and system protection.

In order to obtain additional information on Cat designed and produced filtration products, refer to the "Reference Material" article, "Filters" and "Miscellaneous" topics in this Special Publication or consult your Cat dealer for assistance with filtration recommendations for your Cat machine.

Note: In order to help ensure the maximum expected compartment performance and life, use a fluid that meets Cat highest level of fluid performance as described in this Special Publication for the compartment. Using a fluid that is considered an acceptable, but lower performing option for typical applications, will provide lower performance.

NOTICE

Faulty engine coolant temperature regulators, or operating with light loads, short operation cycles, excessive idling, or operating in applications where normal operating temperature is seldom reached can contribute to excessive water in the crankcase oil. Corrosive damage, piston deposits, increased oil consumption, and other damage can result. If a complete oil analysis program is not followed or if the results are ignored, the potential for damage increases. Follow engine warmup recommendations provided in this Special Publication and/or given in your engine Operation and Maintenance Manual.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05331211

Engine Oil

SMCS - 1348; 7581

This article contains engine crankcase fluid recommendations for all Cat 3600 Series, C280 Series engines including marine engines, smaller Direct Injection (DI) engines, and Precombustion Chamber (PC) engines. Engine oil requirements of these engines are different than smaller engines due to the specific loads, cycles, and engine speed of these engine models.

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 remove wear debris
- Remove heat from the lubricated components
- Neutralize acidic products due to combustion process
- Protect the engine from cavitation and foaming
- Protect the engine from corrosion and rust
- Control Oil Consumption
- Disperse/Solubilize Contaminants (Soot)
- Support the regulated engine emissions limits

Current lubricant formulations are more advanced and complex than previous formulations. Current lubricants are developed to support advanced engine technologies that have lower emissions while supporting the performance and durability of these engines.

High performance oils are produced and validated using industry standard tests, proprietary tests, field tests, and often prior experience with similar formulation. Cat high quality and high performance lubricants are validated based on these factors.

In order to provide optimal engine performance and life and comply with regulated emission reduction, use the recommended engine oil as provided in this special publication. Due to the significant variations in the quality and performance of commercially available oils, Cat recommends the use of Cat oils as detailed in this article.

Cat Diesel Engine Oils

Cat fluids have been developed and tested by Cat in order to provide the full performance and service life

that has been designed and built into Cat engines. 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 machine components. Cat fluids are used for factory fill of Cat engines and components and are offered by Cat dealers for service fills and as aftermarket products. Consult your Cat dealer for more information on these Cat fluids.

Due to significant variations in the quality and in the performance of commercially available oils, Cat recommends the oils that are listed in Table 1 for 3600 and C280 Series engines that use distillate diesel fuel.

Table 1

Cat Engine Lubricants for 3600 and C280 Series Engines		**Viscosity Grade**
Diesel Engine Oil-Ultra Low Sulfur (API CJ-4)	Cat DEO-ULS	SAE 15W-40
		SAE 10W-30
	Cat DEO-ULS Cold Weather	SAE 0W-40
Diesel Engine Oil (API CI-4)	Cat DEO	SAE 15W-40
		SAE 10W-30
Diesel Engine Oil (API CF) (1)	Cat DEO	SAE 40

(1) API CF category is obsolete. These oils are per the requirements of API CF category.

Table 2

Cat Grease and Coolant Products	
Grease	Cat Multipurpose Grease
	Cat Marine Multipurpose Grease
	Cat Advanced 3Moly Grease
	Cat Ultra 5Moly Grease (multiple NLGI Grades)
	Cat Desert Gold Grease
	Cat Arctic Platinum Grease
	Cat High Speed Ball Bearing Grease
	Cat Hammer Paste
	Cat White Assembly Grease
Coolants	Cat ELC (Extended Life Coolant)
	Cat ELC Extender (for use with Cat ELC)
	Cat ELI (Extended Life Inhibitor - non-glycol based coolant)
	Cat DEAC (Diesel Engine Antifreeze/Coolant)

Cat SCA (Supplemental Coolant Additive, for use with water or with Cat DEAC)

Note: Cat engine oils exceed the performance requirements of the respective API categories.

This information applies to Cat 3600 and C280 Series engines. For more lubricant recommendations see the following Special Publications:

- Special Publication, SEBU6250, "Caterpillar Machine Fluids Recommendations"
- Special Publication, SEBU6385, "Caterpillar On- Highway Diesel Engine Fluids Recommendations"
- Special Publication, SEBU6400,, "Caterpillar Gas Engine Fluids Recommendations"
- Special Publication, SEBU6251,,, "Cat Commercial Diesel Engine Fluids Recommendations"

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

Always consult your Cat dealer in order to ensure that you have the current revision level of the publication.

Cat diesel engine oils given in Table 3 are the recommended oils for 3600 Series and C280 Series engines covered by this Special Publication. Commercial alternative diesel engine oils are, as a group, second choice oils.

Table 3

Cat Engine Lubricants Recommendations for 3600 and C280Series Diesel Engines (1)		
	Tier 4 Certified (2)	Pre Tier 4 Certified
Preferred	Cat DEO-ULS (3)	Cat DEO, single grade oils
		Cat DEO-ULS
		Cat DEO, multigrade oils
Commercial Lubricants	Cat ECF-3/API CJ-4 and Field Proof of Performance	Field Proof of Performance, and Cat ECF-3/API CJ-4, Cat ECF-2, Cat ECF-1, or API CF quality oils

(1) Non-Road Tier 4 EPA Certified engines with aftertreatment devices require the use of Cat DEO-ULS (preferred) or commercial oils that meet Cat ECF-3, API CJ-4 requirements, and have passed the field proof of performance.

(2) C280 marine engine are Tier 4 Certified. These engines are equipped with aftertreatment devices.

(3) Engines using a single grade DEO, refer to your Cat dealer to verify the ash level in the oil.

Note: API engine oil categories are backwards compatible. Cat DEO-ULS (API CJ-4) oil can be used in all engines with some restrictions related to fuel sulfur level, refer to Table 4 for more details.

Note: Each of the Cat ECF specifications provides increased performance over lower Cat ECF specifications. For example, Cat ECF-3 provides higher performance than Cat ECF-2 and Cat ECF-3 provides much higher performance than Cat ECF-1-a. Refer to table 4 for details.

For C280 Tier 4 United States Environmental Protection Agency (U.S. EPA) certified engines that are equipped with aftertreatment devices refer to the specific section of this chapter.

Table 4

Cat Engine Crankcase Fluids (ECF) Definitions (1)	
Cat Minimum Performance Requirements for Commercial Oils	**Cat ECF Specifications Requirements**
Cat ECF-3	API CJ-4 Oil Category performance requirements
Cat ECF-2	API CI-4 / CI-4 PLUS Oil Category performance requirements and Passing standard Cat C13 engine test per API requirements and Oils of sulfated ash > 1.50 percent are not allowed
Cat ECF-1-a	API CH-4 Oil Category performance requirements and For oils that are between 1.30 percent and 1.50 percent sulfated ash, passing one additional Cat 1P SCOTE test ("ASTM D6681") is required and Oils of sulfated ash > 1.50 percent are not allowed

(1) Cat ECF specifications describe the minimum technical requirements for engine oils recommended for use in Cat engines. Cat diesel engine oils performance exceed ECF specifications.

Cat diesel engine oils DEO-ULS and Cat DEO exceed the limits of the respective API categories. These diesel engine oils also exceed the limits of Cat ECF specifications. Cat DEO-ULS and Cat DEO are rigorously tested with full-scale proprietary Cat engine tests to ensure optimal protection of Cat diesel engines. The tests include the following: sticking of the piston rings, piston deposits, oil control tests, wear tests and soot tests. Proprietary tests help ensure that Cat oils provide superior performance in Cat diesel engines.

There are significant variations in the quality and performance of commercially available oils. For this reason, Cat recommends the Cat oils listed in Table 3 and the recommendations in Table 4.

Cat DEO-ULS multigrade and Cat DEO multigrade and single grade oils are formulated with the correct amounts and chemistry of various additives including detergents, dispersants, antioxidants, alkalinity, antifoam, viscosity modifiers, and others in order to provide superior performance in Cat diesel engines where recommended for use.

Cat DEO-ULS (API CJ-4) multigrade is compatible for use in engines equipped with aftertreatment devices.

Use appropriate lubricating oils that are compatible with the engine certification and aftertreatment system and with the fuel sulfur levels. Refer to the oil recommendations for Tier 4 engines in this chapter and to Diesel Fuel Sulfur Impacts article of this Fuels Specifications section and to the Lubricants Specifications section of this Special Publication.

Cat diesel engine oils exceed many of the performance requirements of other manufacturers of diesel engines. Therefore these oils are excellent choices for many mixed fleets. Refer to your engine manufacturer literature for the recommended categories/specifications. Compare the categories/specifications to the specifications of Cat diesel engine oils. The current industry standards for Cat diesel engine oils are listed on the product labels. Also refer to the datasheets for the product.

Note: API oil categories CG-4 is obsolete. The API (American Petroleum Institute) does not license this category effective August 2009. Oils that claim API CG-4 are not recommended for Cat engines.

Note: API oil category CF is obsolete. The API (American Petroleum Institute) does not license this category effective end of 2010. API does not validate the quality of API CF oils and does not allow the display of API symbol (also called API doughnut) with CF as highest claim on the oil container. Single grade oils that used to conform to the requirements of API CF category and that do not have a modified formulation and that have passed the field validation test are acceptable for use in Cat engines as detailed in this Special Publication.

Recommendation for Tier 4 Engines

C280 marine engines for use in U.S. flagged vessels and for vessels operating in U.S. inland waterways must meet the Environmental Protection Agency (EPA) emission standards set forth in "40 CFR Part 1042 Control of Emissions from New and In-Use Marine Compression-Ignition Engines and Vessels". New C280 engines that are greater than 2000 bkW must meet EPA Tier 4 emission standards starting in 2014. These standards are referred to as EPA Marine Tier 4 in this Special Publication.

Emission control for the C280 marine engines for EPA Marine Tier 4 includes improved combustion systems and aftertreatment starting in 2014. The aftertreatment is a Selective Catalytic Reduction system (SCR). In the SCR system, Diesel Exhaust Fluid (DEF) is injected in controlled amounts into the engine exhaust stream in order to reduce NOx in the presence of the SCR catalyst. DEF is available in many brands, including those brands that carry the AdBlue or API certification. DEF is also generically referred to as urea. The SCR system is also effective in reducing certain hydrocarbon and particulate emissions.

Some C280 marine engines for use outside of the United States are also equipped with SCR aftertreatment systems. This includes C280 engines for vessels subject to the International Maritime Organization MARPOL Annex VI regulations.

Additives used in lubricating oils can negatively affect the performance of the SCR aftertreatment system. In order to maintain the expected aftertreatment device life, performance and service intervals, engine oils for use in C280 engines that are equipped with SCR aftertreatment systems must have the following chemical limits:

- 0.12 percent maximum phosphorous
- 2 percent maximum sulfated ash
- 0.4 percent maximum sulfur

Table 5 lists the oils that meet the required chemical limits and are recommended for C280 engines with SCR aftertreatment oils.

Table 5

Engine oils Recommendations for C280 marine engines equipped with SCR aftertreatment systems [1] [2]		
	Viscosity Grade	**Specification Requirements**
Cat DEO, mono grade	SAE 40	API CF [3]

Cat DEO-ULS, multigrade	SAE 15W-40	API CJ-4
Commercial lubricants	SAE 15W-40	Field Performance Evaluation and API CJ-4/Cat ECF-3/ACEA E9
	SAE 30, SAE 40	Field Performance Evaluation and API CF (3)

(1) Oils listed in this table must have the chemical limits listed in this section of this Special Publication.

(2) Caterpillar engine oils are the preferred oils. Commercial oils as a group are second choice oils.

(3) Oils that fulfill all the API CF requirements.

Note: Oils that do not meet the chemical limits given in this section of this Special Publication are not allowed for use in engines that are equipped with SCR aftertreatment systems. Follow the recommendations given in Table 5 above.

Commercial oils meeting Cat ECF-3, API CJ-4 and ACEA E9 specifications also meet the required chemical limits for engines that are equipped with SCR aftertreatment system. ACEA E9 oils are validated using some but not all ECF-3 and API CJ-4 standard engine performance tests. Consult your oil supplier when considering use of an oil that is not Cat ECF-3 or API CJ-4 qualified.

Note: Commercial oils that meet the chemical limits above should also have a field proof of performance in order to be used in C280 engines. Field Proof of Performance ensures that the oil performs adequately in C280 and 3600 engines. Refer to this Special Publication, "Field Evaluation of Commercial Oil"for details.

NOTICE

Do not add new engine oil, waste engine oil or any oil product to the fuel unless the engine is designed and certified to burn diesel engine oil (for example Caterpillar ORS designed for large engines). Caterpillar experience has shown that adding oil products to Tier 4 engine fuels (U.S. EPA Tier 4 certified), to Euro IV/Stage IV certified engine fuels, or to the fuels of engines equipped with exhaust aftertreatment devices, will generally cause the need for more frequent ash service intervals and/or cause loss of performance.

Adding oil products to the fuel may raise the sulfur level of the fuel and may cause fouling of the fuel system and loss of performance.

Selecting a Commercial Oil

Lubrication oil for 3600 and C280 Series diesel engines **must** have proof of performance in the Field Performance Evaluation. The TBN and the viscosity of the oil are also important factors.

NOTICE

The Field Performance Evaluation is required.

Field Performance - The lubrication oil must demonstrate acceptable performance under controlled operating conditions for a minimum of 7000 hours in a 3600 or C280 Series diesel engine. For the evaluation of a particular oil, the oil company should arrange a field test with the owner of the engine. For a complete explanation of field evaluation for 3600 and C280 Series diesel engine oil, see this Supplement, "Field Evaluation of Commercial Oil" topic.

The Caterpillar Micro-Oxidation Test is recommended as a pre-screening method to qualify oils for Field Performance Evaluation.

Note: Passing the Cat Micro-Oxidation Test does NOT guarantee passing the Field Performance Evaluation requirements, but oils that do not pass the Cat Micro-Oxidation Test will likely fail the Field Performance Evaluation.

Caterpillar Micro-Oxidation Test - The oil must demonstrate a minimum induction time of 90 minutes in the test. The test measures the oxidation stability of engine oil at 230 °C (446 °F). The results of the test have been correlated to levels of piston deposits. The piston deposits have been measured in Caterpillar tests for evaluating oil. Engine oils that have an induction time less than 90 minutes have produced excessive piston deposits. The excessive deposits have occurred in laboratory testing and in actual field operation. The micro-oxidation test is only one part of the criteria for the selection of a lubrication oil.

The micro-oxidation test can be conducted at Caterpillar or at a reputable test facility. For testing at Caterpillar, consult your local Cat dealer or Cat customer support lines.

Note: A high induction time for the test does not ensure that the oil performance is adequate for 3600 and C280 Series diesel engines a Field Performance Evaluation is still required.

NOTICE

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

Lubricant Recommendations for Engines that Use Heavy Fuel Oil (HFO)

NOTICE

Heavy Fuel Oils should not be used in 3600 and C280 Series engines that have aftertreatment devices and that are Tier 4 EPA certified.

For 3600 Series diesel engines that use heavy fuel oil, select a lubrication oil that is blended for use with heavy fuel oil. These oils are blended for use in centrifuges. The oils must release water and contaminants in the centrifuges without losing additives.

The oils must have the proof of performance that is explained in the "Selecting a Commercial Oil" topic.

Note: Currently, Cat does not sell a brand of lubrication oil for use in engines that operate with heavy fuel oil. Consult your oil company and/or your Cat dealer for assistance.

Total Base Number (TBN) and Fuel Sulfur Levels for Cat 3600 Series and C280 Series Diesel Engines That Use Distillate Fuel or Biodiesel

This article provides information for Direct Injection (DI) Diesel Engines, Precombustion Chamber (PC) Engines and Direct Injection (DI) 3116 and 3126 Marine Diesel Engines.

The use of Cat S·O·S Services oil analysis is recommended for determining oil life.

TBN is also commonly referred to as Base Number (BN).

The minimum required Total Base Number (TBN) for oil depends on the fuel sulfur level. For commercial diesel engines that use distillate fuel, the following guidelines apply:

Table 6

TBN recommendations for 3600 and C280 Series Cat engines that use distillate fuel or biodiesel fuel		
Fuel Sulfur Level percent (ppm)	Cat Engine Oils (1)	TBN of Commercial Engine Oils
0.05 percent (500ppm)	Cat DEO-ULS Cat DEO	Min 7
>0.05-0.2 percent (>500- 2000 ppm) (2)	Cat DEO Cat DEO-ULS	Min 10
Above 0.2 percent (above 2000ppm) (3) (4)	Cat DEO (5)	Min 10

(1) Cat DEO-ULS applies to Cat DEO-ULS SAE 15W-40, SAE10W-30, Cat DEO-ULS SYN SAE 5W-40, and Cat DEO Cold Weather SAE 0W-40. Cat DEO applies to Cat DEO SAE 15W-40 and SAE 10W-30.

(2) Use of an oil analysis program to determine oil drain intervals is strongly recommended if fuel sulfur is between 0.05% (500 ppm) and 0.5% (5000 ppm).

(3) Use of an oil analysis program to determine oil drain intervals is required if fuel sulfur is above 0.5% (5000 ppm).

(4) For fuels of sulfur levels that exceed 1.0 percent (10,000 ppm), refer to TBN and engine oil guidelines given in this section.

(5) Cat DEO-ULS may be used if an oil analysis program is followed. High fuel sulfur levels may reduce the oil drain intervals.

For regions in the world where fuels of high sulfur that exceed 1.0 percent (10,000 ppm (mg/kg)) are available and allowed for use by law, use the following guidelines:

- Choose multigrade oil with the highest TBN that meets one of these specifications: Cat ECF-1-a, Cat ECF-2, or Cat ECF-3.
- Reduce the oil change interval. Base the oil change interval on the oil analysis. Ensure that the oil analysis includes the condition of the oil and a wear metal analysis. Cat S·O·S Services oil analysis is required.

TBN testing is an optional part of the SOS Services oil analysis program. TBN testing may be done in addition to the standard SOS Services tests for oil deterioration. In most applications, the SOS Services tests for oxidation, sulfation, viscosity, and wear will identify oil deterioration.

TBN of the oil is typically measured using "ASTM D2896" and/or "ASTM D4739" test methods. Both methods can be used to measure the TBN of used oils. However, "ASTM D4739" is the preferred method for used oils.

- Consider changing the oil if the "ASTM D2896" test result reaches 4 TBN. Look for other signs of oil deterioration, or abnormal wear to verify the need to change oil.
- Consider changing the oil if the "ASTM D4739" test result reaches 3 TBN. Look for other signs of oil deterioration, or abnormal wear to verify the need to change oil.
- Be aware that both of these test methods have variability of approximately ±1 TBN. Care should be taken when analyzing the results of the TBN test. Consult a trained S·O·S Services analyst when making oil drain decisions based on oil sample results.

Note: The use of Cat S·O·S Services oil analysis helps environmental sustainability as the best way to optimize oil life. The service will help engines reach the expected life. Consult your Cat dealer regarding the testing required to establish a safe, optimized oil drain interval.

In order to help protect your engine, and optimize oil drain intervals for engine applications and duty cycles, use Cat S·O·S Services oil analysis as follows:

- Recommended as a matter of course
- Recommended in order to determine oil drain intervals when operating on fuel with sulfur levels between 0.05% (500 ppm) and 0.5% (5000 ppm)
- Required in order to determine oil drain intervals when operating on fuel with sulfur levels that are above 0.5% (5000 ppm)

Note: Engine operating conditions play a key role in determining the effect that fuel sulfur will have on engine deposits and on engine wear. Consult your Cat dealer for guidance when fuel sulfur levels are above 0.1% (1000 ppm).

Excessive piston deposits can be produced by oil with a high TBN and/or high ash. These deposits can lead to a loss of control of the oil consumption and to the polishing of the cylinder bore.

There are many factors that contribute to rapid TBN depletion, a not all inclusive list follows:

- High sulfur fuel (The more fuel sulfur, the more rapid the TBN depletion.)
- Faulty engine coolant regulators
- Light loads
- Short operation cycles
- Excessive idling
- Operating in applications where normal operating temperature is seldom reached
- High humidity (allowing excessive condensation)

Bullets 2 through 7 above can contribute to excessive water in the crankcase oil. The water combines with available sulfur to form sulfuric acid. Neutralizing acids that are formed contribute to rapid TBN depletion.

NOTICE

Depending on application severity and localized environmental conditions, and also depending on maintenance practices, operating Direct Injection (DI) diesel engines and operating PC (Precombustion Chamber) diesel engines on fuel with sulfur levels over 0.1 percent (1000 ppm) may require significantly shortened oil change intervals in order to help maintain adequate wear protection. Refer to this Special Publication, "Fuel Specifications" section, "Diesel Fuel Sulfur" topic for additional information.

Note: Do NOT use only this Special Publication as a basis for determining oil drain intervals.

This Special Publication does not address recommended oil drain intervals, but rather provides guidance that should be used with your specific engine/machine Operation and Maintenance Manuals in determining acceptable oil drain intervals. Consult your engine/machine Operation and Maintenance Manuals, and consult your Cat dealer for additional guidance, including but not limited to guidance on establishing optimized and/or acceptable oil drain intervals.

Total Base Number (TBN) and Fuel Sulfur Levels for Engines That Use Heavy Fuel Oil (HFO)

Note: Only specially configured 3600 diesel engines can use HFO.

The use of Cat S·O·S Services oil analysis is recommended for determining oil life.

TBN is also commonly referred to as Base Number (BN).

Generally, lubrication oils for engines that use heavy fuel oil are available with a TBN in a range of 20 to 50 ("ASTM D2896"). Oil companies list these oils that have a high TBN as oils for "trunk piston" or "medium speed marine" diesel engines. Most of the Caterpillar experience is with the oils that have a TBN of 30 or 40. The TBN for a new oil depends on the fuel sulfur level.

The TBN for a new oil depends on the fuel sulfur level. For 3600 Series engines that use heavy fuel oil, the minimum new oil TBN must be 20 as determined by the "ASTM D2896" procedure.

Engine oils of high TBN can neutralize the sulfur in the fuel and allow for long drain interval. However, oils with a high TBN and/or high ash can produce excessive deposits on the pistons and valves. These deposits can lead to the following results:

- A loss of stable oil control
- Polishing of the cylinder bore
- Guttering of the valves

High quality engine oils that are formulated for operation using HFO are balanced to allow the desired oil drain intervals while protecting engines from excessive deposits. The oil must also have the proof of performance that is explained in the Selecting a Commercial Oil article.

Use the following guidelines for fuel sulfur levels that exceed 2.0 percent:

- Choose an oil with the highest TBN that meets the Caterpillar performance requirements.
- Base the oil change interval on the oil analysis. Ensure that the oil analysis includes the condition of the oil, TBN, and a wear metal analysis. Reduce the oil change interval, if necessary.

TBN testing is an optional part of the S·O·S Services oil analysis program. TBN testing may be done in addition to the standard S·O·S Services tests for oil deterioration. In most applications, the S·O·S Services tests for oxidation, sulfation, viscosity, and wear will identify oil deterioration.

TBN of the oil is typically measured using "ASTM D2896" and/or "ASTM D4739" test methods. Both methods can be used to measure the TBN of used oils. However, "ASTM D4739" is the preferred method for used oils.

- Consider changing the oil if the "ASTM D2896" test result reaches 8 TBN. Look for other signs of oil deterioration, or abnormal wear to verify the need to change oil.
- Consider changing the oil if the "ASTM D4739" test result reaches 6 TBN. Look for other signs of oil deterioration, or abnormal wear to verify the need to change oil.
- Be aware that both of these test methods have variability of approximately ±1 TBN. Care should be taken when analyzing the results of the TBN test. Consult a trained S·O·S Services analyst when making oil drain decisions based on oil sample results.

Note: The use of Cat S·O·S Services oil analysis helps environmental sustainability as the best way to optimize oil life. The service will help engines reach the expected life. Consult your Cat dealer regarding the testing required to establish a safe, optimized oil drain interval.

There are many factors that contribute to rapid TBN depletion, a not all inclusive list follows:

- High sulfur fuel (The more fuel sulfur, the more rapid the TBN depletion)
- Faulty engine coolant regulators
- Light loads
- Short operation cycles
- Excessive idling
- Operating in applications where normal operating temperature is seldom reached
- High humidity (allowing excessive condensation)

Bullets 2 through 7 above can contribute to excessive water in the crankcase oil. The water combines with available sulfur to form sulfuric acid. Neutralizing acids that are formed contribute to rapid TBN depletion.

Note: Do NOT use only this Special Publication as a basis for determining oil drain intervals.

This Special Publication does not address recommended oil drain intervals, but rather provides guidance that should be used with your specific engine/machine Operation and Maintenance Manual in determining acceptable oil drain intervals. Consult your engine/machine Operation and Maintenance Manual, and consult your Cat dealer for additional guidance, including but not limited to guidance on establishing /optimized and/or acceptable oil drain intervals.

Severe Applications

An engine which operates outside of normal conditions is operating in a severe service application.

An engine that operates in a severe service application may need more frequent maintenance intervals in order to maximize the following conditions:

- Reliability
- Service life

Severe Applications Require the Use of Higher Performing Diesel Engine Oils. Examples of severe duty applications include, but not limited to the following:

- operating at greater than 75% load factor
- operating in high humidity
- operating with fuel sulfur levels that are above 0.2% (2000 ppm)

In order to help ensure the maximum expected compartment performance and life, higher performing fluids as described in this Special Publication may be required. Fluids that meet only the minimum performance levels may be allowed for typical applications, but maintenance intervals must be reduced. For the maximum expected engine compartment performance and life and where LSD or ULSD fuels are available, oils meeting the Cat ECF-3 specification must be used.

The number of individual applications cause the impossibility of identifying all of the factors which may contribute to severe service operation. Consult your Cat dealer for the unique maintenance that may be necessary for your engine.

An application is a severe service application if any of the following conditions apply:

Severe Environmental Factors

- Frequent operation in dirty air
- Frequent operation at an altitude which is above 1525 m (5000 ft)
- Frequent operation in ambient temperatures which are above 32° C (90° F)
- Frequent operation in ambient temperatures which are below 0° C (32° F)

Severe Operating Conditions

- Frequent operation with inlet air which has a corrosive content
- Operation with inlet air which has a combustible content

- Operation which is outside of the intended application
- Operation with a plugged fuel filter
- Extended operation at low idle (more than 20% of hours)
- Frequent cold starts at temperatures below 0° C (32° F)
- Frequent dry starts (starting after more than 72 hours of shutdown)
- Frequent hot shutdowns (shutting down the engine without the minimum of 2 minutes to 5 minutes of cool down time)
- Operation above the engine rated speed
- Operation below the peak torque speed
- Operating with fuel which does not meet the standards for distillate diesel fuel as stated in Special Publication, SEBU7003, "Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations", "Distillate Diesel Fuel"
- Operating with a blend of distillate fuel which contains more than 20 percent biodiesel

Improper Maintenance Procedures (Maintenance Procedures Which May Contribute to a Severe Service Application)

- Inadequate maintenance of fuel storage tanks from causes such as excessive water, sediment, and microorganism growth.
- Extending maintenance intervals beyond the recommended intervals
- Using fluids which are not recommended in Special Publication, SEBU7003, "Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations"
- Extending maintenance intervals for changing the engine oil and engine coolant without S·O·S validation
- Extending maintenance intervals for changing air filters, oil filters, and fuel filters
- Failure to use a water separator
- Using filters which are not recommended by Special Publication, PEWJ0074, "2008 Cat Filter and Fluid Application Guide"
- Storing the engine for more than 3 months but less than 1 yr (For information about engine storage, refer to Special Publication, SEHS9031, "Storage Procedure for Caterpillar Products")

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05362700

Field Evaluation of Commercial Oil

SMCS - 1348; 7581

Caterpillar Inc. is frequently approached by engine owners and/or oil companies that wish to qualify an oil for use in 3600 or C280 Series diesel engines. For 3600 and C280 Series diesel engines that are configured to use distillate fuel: When the following fuels are used (distillate fuel, crude oil fuel or biodiesel fuel that meets the Cat published recommendations), Caterpillar recommends the use of Cat DEO (Diesel Engine Oil) single grade and multigrade and DEO-ULS multigrade.

Caterpillar does not recommend the names of other commercial brands of lube oils. Caterpillar has established the following guidelines for the Field Performance Evaluation of lube oil in 3600 and C280 Series diesel engines.

Note: These Field Performance Evaluation guidelines provide a way for oil companies to "**self certify**" oil for use in Cat 3600 and C280 Series diesel engines.

Note: These guidelines are applicable to engines that use distillate fuel, heavy fuel oil, crude fuel oils, or biodiesel.

Note: Approximately 50 percent of engine problems are related to the cooling system. Follow the recommended maintenance practices.

Operating Conditions for the Field Performance Evaluation

Duration - The minimum number of operating hours for a single engine installation is 7000 hours. The minimum for one engine at an installation with multiple engines is also 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 candidate oil must be selected by the oil company.

The Cat Micro-Oxidation Test is recommended as a pre-screening method to qualify oils for Field Performance Evaluation.

Note: Passing the Cat Micro-Oxidation Test does NOT guarantee passing the Field Performance Evaluation, but oils that do not pass the Cat Micro-Oxidation Test will likely fail the Field Performance Evaluation.

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.

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. Generally, the service life of lube oil for engines that use distillate fuel is between 600 and 1400 hours. Usually for engines that use heavy fuel oil, the service life of the lube oil ranges between 300 and 700 hours. If SOS oil analysis and other factors allow, maximum oil service life for diesel fueled engines is 3000 hours. Maximum oil service life for heavy fuel oil fueled engines is 2000 hours. Refer to the S·O·S article in this Special Publication.

Fuel Analysis - An analysis of the fuel must be provided by an independent laboratory at the beginning of the Field Performance Evaluation. Subsequent analyses of the fuel must be provided at intervals of 2000 hours or provided when new shipments of fuel are received. The fuel must meet the guidelines that are listed in this Special Publication, "Fuel Specifications" topic.

Criteria for the Evaluation

Oil Consumption - The oil consumption must not exceed two times the initial oil consumption during the 7000 hour period. The initial oil consumption is established during the first 3000 to 5000 hours of operation with the oil that is being evaluated.

Final Inspection - At the end of the Field Performance Evaluation, these components from two cylinders must be removed and inspected: pistons, piston rings and cylinder liners. None of the following conditions are acceptable: sticking of the piston rings, scuffing of the piston rings or cylinder liners and 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.

If a new engine is used for the Field Performance Evaluation, all of the cylinders in the engine must be inspected with a borescope. 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 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 and cylinder liners. Those new components will be examined for the final inspection.

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, valve guides, inlet valves and exhaust valves. Photographs that show the entire component must also be available on request.

Summary - This Field Performance Evaluation procedure provides the oil company and the engine owner with a method of evaluating a lubricating oil for the 3600 and C280 Series diesel engines. If the oil meets these guidelines for the 7000 hours of the Field Performance Evaluation, the oil has fulfilled the Cat requirements. Caterpillar will not endorse any oil for use in Cat 3600 and C280 Series diesel engines as a result of a Field Performance Evaluation. The oil company can use the Field Performance Evaluation as proof of performance.

Responsibilities

Care must be taken in order to define the responsibilities of each party 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 Performance

Evaluation agreement. The agreement should be made before the Field Performance 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 Performance Evaluation is not sponsored by Caterpillar.

Field Evaluation Agreement

The Field Performance Evaluation agreement is between the engine owner and the oil company. The agreement is a important part of the Field Performance Evaluation. The completion and signing of the agreement should occur before the initiation of the Field Performance Evaluation. The agreement must fully define the Field Performance Evaluation and the responsibilities of each party. This publication contains the information and guidelines that are necessary to write a detailed agreement. Initial Field Performance Evaluation involves some risk. Use of these guidelines will minimize the risk. If the guidelines are followed, the probability of a successful Field Performance 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 the local Cat 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 periodically 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 be allowed to 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 and cylinder liners. 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. The costs of additional downtime can also be part of the cost of inspection. 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. The cost includes 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:

- Initial oil consumption and final oil consumption
- The data on oil consumption must be recorded on a minimum schedule of every week. A chart of the data must be included in the final report.

- Results of oil analyses
- Oil changes
- Replacement of oil filters
- Results of fuel analyses
- Fuel consumption or power output
- Average engine speed (rpm)
- The typical duty cycle
- Close up photographs of the following components from two cylinders must also be included: pistons, piston rings before removal and after removal, piston rings after removal, cylinder liners, crankcase, top deck of the cylinder head, bottom deck of the cylinder head, inlet valves and exhaust valves.

The final report should be confidential. The final report should be made available to the engine owner.

Responsibilities of the Engine Owner

Engine for the Evaluation - The owner must provide access to the engine for a minimum of 7000 hours. Special piping and instrumentation may be attached to the engine for the duration of the Field Performance 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 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.

Cat Responsibilities

Advisory - Cat will not assume an active function in the Field Performance Evaluation. However, Cat will provide technical advice and guidance to the parties that are involved. Cat understands that this function does not satisfy all of the situations that may arise in Field Performance Evaluation. Therefore, technical judgments may be required for the initiation of some evaluations.

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

Final Inspection - Under some circumstances, Caterpillar may be asked to assist with the inspection. The evaluation is 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 oil company expense.

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

NOTICE

ALL risks associated with "interchanging" rests with the oil company and the engine owner.

Interchanging - The information that is obtained from Field Performance Evaluations may be applicable to other 3600 and C280 Series diesel engines at other sites. However, guidelines must be established in order to limit the application of a lubricant that has been evaluated. The guidelines are for the protection of the engine and the engine owner. The limit on the application of the lubricant is defined as an interchanging.

The interchanging of the lubricant is limited by these factors:

- The oil viscosity grade
- The base stock of the oil
- The engine configuration
- The engine application
- The engine rating
- The engine load factor
- The fuel type (distillate, crude, heavy fuel oil, or biodiesel)

Engine Configuration

- Lube oil CANNOT be interchanged between engines that use different types of fuel. A separate Field Performance Evaluation is required for distillate diesel fuel, heavy fuel oil, crude oil, and biodiesel.
- Lube oil CANNOT be interchanged between engines with cuff type cylinder liners and engines without cuff type cylinder liners. A separate Field Performance Evaluation is required.

Engine Rating

The average power output that is produced by the engine during the Field Performance Evaluation is used to establish the power rating of the Field Performance 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
- Fuel consumption

To calculate the BMEP, the average engine power output must be expressed in kilowatts. Use the equation in Table 1 to calculate the BMEP.

Table 1

Equation for Calculating the Brake Mean Effective Pressure (BMEP)	
$\frac{120\,000 \times kW}{L \times rpm}$	= 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 10 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.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i04058329

Synthetic Basestock Oils

SMCS - 1300; 1348; 7581

Synthetic base oils are acceptable for use in Cat engines. **These oils must meet the performance requirements that are specified by Cat for the engine compartment.**

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

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

Some synthetic base oils have performance characteristics that enhance the service life of the oil. However, Cat does not recommend the automatic extension of oil drain intervals for any type of oil, whether synthetic or non-synthetic.

Oil drain intervals for Cat engines can only be adjusted higher (longer interval) after an oil analysis program that contains the following data:

- Oil condition, oil contamination, and wear metal analysis (Cat S·O·S Services oil analysis)
- Trend analysis
- Fuel consumption
- Oil consumption

Refer to the "Extended Engine Oil Drains and Warranty" article in the Foreword of this Special Publication.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i04058332

Re-refined Basestock Oils

SMCS - 1300; 1348; 7581

Rerefined basestock oils are acceptable for use in Cat engines **IF these oils meet the performance requirements that are specified by Cat.**

Rerefined 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 rerefined basestock oils that meet the same criteria.

The process that is used to make rerefined basestock oil should adequately remove all wear metals 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 rerefined base oil.

Note: Filtering is inadequate for the production of high quality rerefined basestock oils from used oil.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i02496744

Governor Oil

SMCS - 1348; 7581

For optimum performance, Caterpillar recommends **136-9642** Governor Oil (SAE 5W-40 synthetic oil). This recommendation applies to all self-contained oil supply actuators used on 3600 Series diesel engines.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i04248995

Aftermarket Oil Additives

SMCS - 1300; 1348; 7581

Cat does not recommend the use of aftermarket additives in oil. Aftermarket additives are not necessary in order to achieve the maximum service life of the engine or rated performance of the engine. 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 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 and produce sludge in the crankcase. Cat discourages the use of aftermarket additives in finished oils.

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 "Selecting a Commercial Oil" article in the "Lubricant Specifications" section of this Special Publication.
- Refer to the appropriate "Lubricant Viscosities for Ambient Temperatures" table in this Special Publication in order to find the correct oil viscosity grade for your engine.
- At the specified interval, service the engine compartment. Use appropriate new oil and install an appropriate new oil filter.
- Perform maintenance at the intervals that are specified in the Operation and Maintenance Manual, "Maintenance Interval Schedule".

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i04237411

Specialty Lubricants

SMCS - 7000; 7581

Table 1

Special-Purpose Cat Lubricants	
Item	**Size**
6V-4876 Lubricant (1)	500 g (17.6 oz)
5P-3931 Thread Compound (2)	150 g (5.3 oz)
334-0519, Rod bolt torque grease	576 g (20 oz)

(1) Recommended for use on typical components such as head bolt threads and washers.

(2) Recommended for mating connectors such as exhaust manifold studs and exhaust manifold nuts.

Table 2

UV Visible Dyes for Leak Detection			
Part Number	**Description**	**Size**	**Dosage**
To detect oil leaks in engines, transmissions, hydraulic systems			
1U-5572	Oil Glo 22 Additive	28.4 gram(1 ounce) bottle	28.4 gram (1ounce) per 7.58 L (2 Us gal) of oil
1U-5573	Oil Glo 22 Additive	0.47 L(1 pint) bottle	28.4 gram (1 ounce) per 7.58 L(2 US gal) of oil
To detect fuel leaks or suspected fuel dilution			
1U-5574	Gas Glo 32 Additive	28.4 gram(1 ounce) bottle	28.4 gram (1 ounce) per 37.9 L (10 US gal) of gasoline or diesel fuel
1U-5575	Gas Glo 32 Additive	0.47 L(1 pint) bottle	28.4 gram (1 ounce) per 37.9 L (10 US gal) of gasoline or diesel fuel
To detect cooling system leaks			
1U-5576	Water Glo 23 Additive	28.4 gram(1 ounce) bottle	28.4 gram (1ounce) per 151.5 L (40 US gal) of water
1U-5577	Water Glo 23 Additive	0.47 L(1 pint) bottle	28.4 gram (1ounce) per 151.5 L (40 US gal) of water

The dyes must be used with a special Glo Gun to detect the leaks. Consult your local Cat dealer for availability.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05331130

Cold Weather Lubricants

SMCS - 1300; 1348; 7581

NOTICE

Recommended engine warm-up procedure must be followed. Refer to the engine Operation and Maintenance Manual. Also refer to the relevant "Lubricant Viscosities for Ambient Temperatures" table in this Special Publication.

For easier cold weather starting, ensure that all of the components of the engine electrical system are properly maintained. All electrical wiring and connections should be free of the following: fraying, damaged insulation and corrosion. Batteries should be kept fully charged and warm. The batteries and the battery cables must be sized properly for the application.

Various starting aids are available in order to assist with cold engine starts in low temperature conditions. Follow the recommendations that are provided by the manufacturer of the starting aid. Refer to the foreword section of this Special Publication, "Aftermarket Products and Warranty".

For additional information concerning cold-weather operation, refer to this Special Publication, "Fuel Specifications" section. Also refer to this Special Publication, "Cooling System Specifications" section.

Before attempting to start the engine, ensure that the oil in the engine is fluid enough to flow. Check the oil by removing the dipstick. If the oil will drip from the dipstick, then the oil should be fluid enough to allow the engine to start. Do not use oil that has been diluted with kerosene. Kerosene will evaporate in the engine. and cause the oil to thicken. Kerosene will cause swelling and softening of the silicone seals. Kerosene will dilute the oil additives. Dilution of the oil additives will reduce the performance, and reduce the engine protection that the additives provide.

If the viscosity of the oil is changed for colder weather, also change the filter element. If the filter is not changed, the filter element and the filter housing can become a solid mass. After you change the oil, operate the engine in order to circulate the thinner oil.

Note: Use the highest oil viscosity grade that is allowed for the ambient temperature when you start the engine. If a different oil viscosity grade is specified in the table, use the viscosity grade that is specified in the table. **In arctic applications, the preferred method of lubrication is to use a properly sized engine compartment heater and a higher viscosity grade oil.** Refer to the "Lubricant Viscosities" article in this Special Publication for further details.

Note: Cold-soaked starts occur when the engine has not been operated for a time. The oil will become more viscous due to cooler ambient temperatures. Supplemental heat is recommended for cold-soaked

starts that are below the minimum ambient temperatures listed in the "Lubricant Viscosities for Ambient Temperatures" tables. Supplemental heat may be required for cold-soaked starts that are above the minimum temperature that is stated, depending on the parasitic load and other factors.

NOTICE

Engines that use fluid or pan heaters, or heated enclosures, or are kept running under load, etc. can, and generally should use higher viscosity oil. The "Lubricant Viscosities for Ambient Temperatures" tables (Maintenance Section) "Minimum" viscosity for ambient temperature recommendations are for cold-soaked conditions. Use the highest viscosity oil that is allowed for the ambient temperature when you start the machine BUT, under Continuous Usage (Multiple Shifts/Day), and/or when using fluid or pan heaters, etc., use a higher viscosity oil, NOT the oil with the minumum recommended viscosity for cold-soaked starting conditions. The higher viscosity oil will maintain the highest possible oil film thickness. Refer to the "Lubricant Viscosities for Ambient Temperatures" tables and the table footnotes for exceptions.

NOTICE

If ambient conditions warrant, a higher viscosity oil of the recommended specification for a given compartment may need to be installed in order to provide adequate film thickness.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05424364

S·O·S Services Oil Analysis

SMCS - 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.

Cat 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 rate
- Oil condition
- Oil contamination
- Oil identification

Component Wear Rate analysis evaluates the wear that is taking place inside the lubricated compartment. The S·O·S Services analyst uses the results of elemental analysis and particle count tests to evaluate the wear. Trend analysis and proprietary wear tables are then used to determine if wear rates are normal or abnormal.

Oil Condition analysis is used to determine if the oil has degraded. Tests are done to look at the oxidation, sulfation, and viscosity of the oil. The S·O·S Services analyst uses established guidelines or trend analysis to determine if the oil has reached the useful life limit.

Oil Contamination tests are performed to determine if anything harmful has entered the oil. This analysis relies on the results from the following tests: elemental analysis, soot, particle count, fuel dilution, water, and glycol. The S·O·S Services program has guidelines for the level of contamination that are allowed in Cat engines.

Oil Identification is another important part of the S·O·S oil analysis program. The wrong oil in an engine can severely damage major components. The S·O·S Services analyst uses elemental analysis and viscosity results to identify key characteristics of the oils.

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 lubricated compartment.

Guidelines that are based on experience and a correlation to failures have been established for these tests. See the following chart for the guidelines. Exceeding one or more of these guidelines could indicate serious fluid degradation or a pending component failure. 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. S·O·S coolant analysis and S·O·S oil analysis provide a complete and accurate method for monitoring the health of all engine systems. Refer to the S·O·S Services coolant analysis information in this Special 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.

Table 1

S·O·S Oil Analysis Guidelines	
Test Parameter	**Guideline**
Oxidation	(1)
Soot	(1)
Sulfation	(1)
Wear Metals	Trend Analysis and Cat Wear Table (1) norms
Water	0.5% maximum
Glycol	0%
Fuel Dilution	based on viscosity (1) and GC (2) fuel dilution in excess of 4%
Viscosity "ASTM D445" measured at 100° C (212° F)	+/-3 centistoke (cSt) change from new oil viscosity.

(1) Acceptable values for these parameters are proprietary to the S·O·S oil analysis program.

(2) Gas Chromatograph

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 engine until the oil is warm and the oil is 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.

There are two acceptable 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 on the pressurized oil manifold.
- Use a sampling gun (vacuum pump) 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 high idle in order to obtain the oil sample.

NOTICE

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

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

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

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

Oil Sampling Interval

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

Recommended interval for engine oil samples is given in Table 2. A 250 hour sampling interval can provide a timely indication of oil contamination and oil degradation.

Measure and record engine oil consumption in order to allow accurate oil analysis. Oil additions during the sampling interval dilute wear metals and other contaminants.

Table 2

S·O·S Oil Sampling Interval for Engine crankcase	
Recommended Interval (1) (2)	Oil Type
Every 250 Service Hours	Cat DEO Cat DEO-ULS

(1) Severe applications may require a more frequent oil sampling interval.

(2) Under certain conditions, the Cat dealer or the Operation and Maintenance Manual may allow a longer interval between oil samplings.

Note: Refer to the Operation and Maintenance Manual for your engine for recommended oil drain intervals.

Consult your Cat dealer for complete information and assistance in order to establish an S·O·S Services program for your engine.

More Frequent S·O·S Sampling Improves Life Cycle Management

Traditionally, the suggested S·O·S sampling intervals for diesel engines have been at 250 hours. However in severe 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 or other severe service indicators exist, sample the engine oil at 125 hour intervals. These additional samples will increase the chance of detecting a potential failure.

Determining Optimum Oil Change Intervals

Sampling the engine oil at every 125 hours provides information for oil condition and for oil performance. This information is used to determine the optimum usable life of a particular oil. Also, more points of data will allow closer monitoring of component wear rates. Close monitoring also allows you to obtain the maximum use of the oil. For detailed information on optimizing oil change intervals, consult your Cat dealer.

This Special Publication does not address recommended oil drain intervals. Refer to your engine Operation and Maintenance Manual, and consult your Cat dealer for additional guidance, including but not limited to guidance on establishing optimized and/or acceptable oil drain intervals.

Note: The use of Cat S·O·S Services oil analysis helps environmental sustainability as the best way to optimize oil life. S·O·S Services will help engines reach expected life. Consult your Cat dealer regarding the testing required to establish a safe, optimized oil drain interval.

Standard oil drain intervals as published in engine Operation and Maintenance Manual are for typical applications:

- Using recommended oils
- Using good fuel
- Using recommended filters
- Using industry standard good maintenance practices

- Following maintenance intervals as published in engine Operation and Maintenance Manual

More severe applications may require shortened oil drain intervals, while less severe applications may allow for longer than standard oil drain intervals. High load factors (above 75%), particularly with high sulfur fuels, can contribute significantly to reducing oil drain intervals below standard oil drain intervals.

Consult your Cat dealer regarding the testing that is required in establishing oil drain intervals that are optimized for your application.

In order to help protect your engine, and help optimize oil drain intervals for engine applications and duty cycles, useCat S·O·S Services oil analysis as follows:

- Recommended as a standard practice
- Recommended in order to determine oil drain intervals when using fuel with sulfur levels between 0.05% (500 ppm) and 0.5% (5000 ppm)
- Required in order to determine oil drain intervals when using fuel with sulfur levels that are above 0.5% (5000 ppm)

Note: Engine operating conditions play a key role in determining the effect that fuel sulfur will have on engine deposits and on engine wear. Consult your Cat dealer for guidance when fuel sulfur levels are above 0.1% (1000 ppm).

Increasing the Oil Change Interval

NOTICE

Refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule" for the proper oil drain interval of your engine.

The time between oil changes can only be increased under the following conditions:

- The results of the S·O·S oil analysis indicate that the oil has not deteriorated and/or has high contamination level as identified by S.O.S analysis.
- The trend lines of the S·O·S Services oil analysis program indicate a constant slope that is stable.
- No apparent engine health issues.
- Occasional inspection of engine components does not show wear, corrosion, or other issues of various engine components.
- Occasional inspection of the oil pan or engine components does not show the formation of sludge or unusual deposits.
- Engines operating under severe conditions as defined in the engine Owning and Operating Manual are generally not recommended to extend the oil drain intervals.

The maximum increment for increasing the oil change interval is 250 service hours. Illustration 1 is a graphic representation of adjusting the oil change interval.

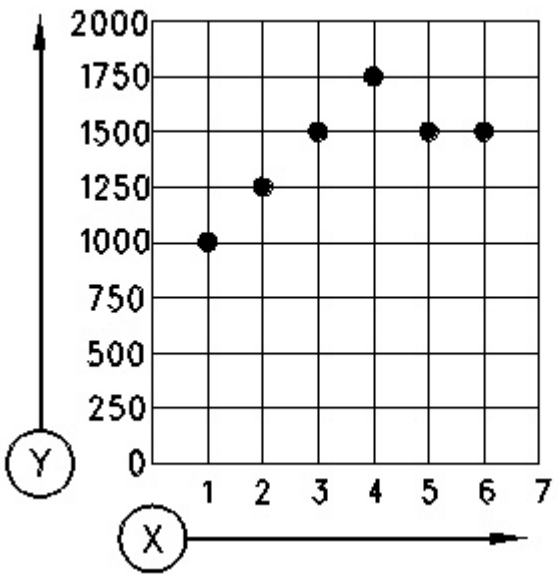

Illustration 1 g00585368

(x) Numbers of oil changes

(y) Service hours

In Illustration 1, the initial oil change was performed after 1000 service hours. The interval was increased in 250 hour increments. At the fourth oil change interval, the oil had deteriorated and/or has high contamination level as identified by S.O.S analysis after 1750 service hours. Therefore, the interval was reduced to 1500 service hours. The results of the oil analysis are acceptable when the oil was used for 1500 service hours.

Follow all the recommendations and follow proper procedure provided in this Special Publication to extend the oil change interval. For applications that are extending the oil drain interval significantly or that are under severe operation conditions, it is recommended to inspect the following components once per year in order to ensure that the wear rates are within specifications: camshaft segments, connecting rod bearings, cylinder liners, main bearings and pistons.

If SOS oil analysis and other factors allow, maximum oil service life for diesel fueled engines is 3000 hours. Maximum oil service life for heavy fuel oil fueled engines is 2000 hours. Refer to the information provided in this S·O·S article for details.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05905023

Lubricating Grease

SMCS - 0645; 1000; 7000; 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 service 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 their 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, viscosity, etc.

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 of the old grease from the joint. Some greases are not chemically compatible. Consult your supplier in order 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.

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.

Cat Utility Grease is formulated to offer a good service life in engine applications. Service Life refers to the percent of change after 100,000 strokes per "ASTM D217".

For more information on Cat Utility Grease, refer to the product information on the package or to the data sheet of this product.

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 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.

Cat Ball Bearing Grease is formulated to offer very good service life in engine applications. Service Life refers to the percent of change after 100,000 strokes per "ASTM D217".

Cat Ball Bearing Grease offers good corrosion protection and good water washout resistance. Corrosion protection is the resistance to salt water per "ASTM B1743". Water washout resistance refers to roll stability with water and the percent of change "ASTM D1264".

For more information on Cat Ball Bearing Grease, refer to the product information on the package or to the data sheet of this product.

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 in order 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.

Note: Cat grease products given above are applicable to marine engines. Refer to Special Publication, SEBU6250, "Caterpillar Machine Fluids Recommendations" for other Cat grease products that include extreme applications and can also be used in marine engines. Consult your Cat dealer for information and for availability.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i04660851

General Fuel Information

SMCS - 1250; 1280

NOTICE

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

The information provided are the latest recommendations for the Cat diesel engines that are covered by this Special Publication. This information supersedes all previous recommendations which have been published for the Cat diesel engines that are covered by this Special Publication. Special fluids are required for some engines and continued will be necessary. 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 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

In order to avoid potential damage to your Cat machine and/or Cat engine, only purchase Cat fluids and Cat 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 Cat filters through other outlets/sources, you are at a very high risk of purchasing counterfeit ("look-alike") products.

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

Counterfeit or "look-alike" products have a very high likelihood of causing and/or allowing engine and/or machine compartment damage.

Follow all industry standard safety practices when operating engines and/or machines and when performing all recommended and/or required maintenance.

Note: Instructions for the installation of the filter are printed on the side of each Cat spin-on filter. For non-Cat filters, refer to the installation instructions that are provided by the supplier of the filter.

NOTICE

In order to meet expected fuel system component life, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with common-rail fuel systems. Also, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with unit injected fuel systems. For all other Cat diesel engines (mostly older engines with pump, line and nozzle type fuel systems), the use of 4 micron(c) absolute or less secondary fuel filtration is strongly recommended. Note that all current Cat diesel engines are factory equipped with Cat Advanced Efficiency 4 micron(c) absolute fuel filters.

In order to obtain additional information on Cat designed and produced filtration products, refer to the "Reference Material" article, "Filters" and "Miscellaneous" topics in this Special Publication. Consult your Cat dealer for assistance with filtration recommendations for your Cat machine.

NOTICE

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

General Recommendations and Guidelines

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

Note: These general recommendations and guidelines concerning maintenance and care of fuel and fuel storage systems are not intended to be all inclusive. **Discuss proper fuel safety and health, handling, and maintenance practices with your fuel supplier.** Use of these general recommendations and guidelines does not lessen the engine owners and/or fuel supplier responsibility. All industry standard practices for fuel storage and for fuel handling must be followed.

Note: Where recommendations for draining water and/or sediment and/or debris are stated, dispose of this

waste according to all applicable regulations and mandates.

Note: Cat filters are designed and built to provide optimal performance and protection of the fuel system components.

- Discuss application-specific fuel concerns, needs, and requirements with a reputable fuel supplier.
- Purchase fuel from a reputable supplier.
- Use fuel that meets or exceeds Cat requirements for distillate diesel fuel. Refer to the "Cat Specification for Distillate Diesel Fuel for Nonroad Diesel Engines" table in this Special Publication, "Distillate Diesel Fuel" article.
- Confirm with the filter manufacturer that the fuel filter/filters to be used are compatible with the fuel type that will be filtered.
- Follow all the "Contamination Control Recommendations for Fuels" that are provided in this chapter. Dispense fuels of "ISO 18/16/13" cleanliness level or cleaner into the machine or engine fuel tank as detailed in the "Contamination Control Recommendations" section.
- Follow all industry standard grounding and other safety practices.
- Test for microbial contamination on a regular basis and take proper corrective action if contamination is present. Properly dispose of cleanup waste according to all applicable regulations and mandates.
- Every 3 months, or sooner if problems are suspected, have a complete analysis of the bulk storage fuel per the "Cat Specification for Distillate Diesel Fuel for Nonroad Diesel Engines" table in this Special Publication, "Distillate Diesel Fuel" article. Take corrective action if necessary. Corrective actions may include treating the fuel, cleaning of the fuel storage tank/system, and replacing the problematic fuel with fresh fuel.
- Keep the fuel storage tank clean of water, debris, and sediment.
- Drain water and sediment from the fuel storage tank weekly. Drain water and sediment before the tank is refilled.
- Keep the area around the fuel tank filler neck clean of debris in order to prevent contamination of the fuel tank.
- As required, clean the inside of the engine fuel tank and the inside of the bulk storage fuel tank.
- Drain water and sediment from the engine fuel tank daily. Drain water and sediment from the tank at the start of each shift. After the fuel tank has been filled, allow the fuel to settle for 10 minutes. The water and sediment will separate from the fuel. Then, drain the water and sediment from the tank.
- Install fuel/water separators at the bulk storage fuel tank dispensing point and install fuel/water separators on the engine. Wire mesh media is NOT recommended.
- Drain the water from the fuel/water separators daily.
- Cat Advanced Efficiency fuel filters are required for distillate fueled diesel engines in order to provide maximum life to the fuel system.

- Change fuel filters at the scheduled interval. Never fill the new secondary fuel filter with fuel before installation. Use the fuel priming pump to remove air from the system.
- Install and properly maintain four micron(c) absolute breather filters on the engine fuel tank vent. Install and properly maintain four micron(c) absolute breather filters on the bulk storage fuel tank vent. Desiccant type breather vent filters are also recommended in order to remove moisture from air entering the fuel tank. Breather filters are typically changed every 6 months, and desiccant type breather filters are typically changed on saturation. Refer to the literature that was included with the filter. Discuss the availability of desiccant breather vent filters for your application with your filter supplier.
- Top off fixed roof fuel tanks as often as practical. Keeping the tank full reduces the amount of condensation generated water.
- Protect fuel tanks from dirt and water entry.

NOTICE

Do not add new engine oil, waste engine oil or any oil product to the fuel unless the engine is designed and certified to burn diesel engine oil (for example Caterpillar ORS designed for large engines). Caterpillar experience has shown that adding oil products to Tier 4 engine fuels (U.S. EPA Tier 4 certified), to EURO Stage IIB and IV certified engine fuels, or to the fuels of engines equipped with exhaust aftertreatment devices, will generally cause the need for more frequent ash service intervals and/or cause loss of performance.

Adding oil products to the fuel may raise the sulfur level of the fuel and may cause fouling of the fuel system and loss of performance.

Note: Cat has four different size coalescer type fuel filters available for bulk storage fuel tank applications that filter both dirt and water. The filter elements are rated at four microns(c) absolute. Consult your Cat dealer for information on the coalescer filters available through Cat.

Note: The fuel storage tanks must be cleaned thoroughly before converting to Ultra Low Sulfur Diesel (ULSD) (15 ppm or less sulfur) and/or biodiesel/biodiesel blends. Conversion to ULSD and/or biodiesel/biodiesel blends can loosen fuel system and fuel storage tank deposits. Bulk tank continuous filtration unit and dispensing point filters, and onboard engine filters change intervals should be shortened to allow for this cleaning effect.

Note: Cat strongly recommends the filtration of distillate diesel fuel and/or biodiesel/biodiesel blends through a filter with a rating of four microns(c) absolute or less. This filtration should be located on the device that dispenses the fuel to the fuel tank for the engine. Also, filter the fuel from the bulk storage tank. Series filtration is recommended.

Note: Follow all fuel storage maintenance practices that are relevant to your application. Cat recommends a maximum of 1 year from production for distillate fuel storage. A maximum of 6 months from production for biodiesel and blended biodiesel storage is recommended. Storage life for biodiesel and biodiesel blends that are greater than B20 may be much shorter than 6 months.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i04242096

Fuel Information for Diesel Engines

SMCS - 1250; 1280

NOTICE

U.S. EPA regulations require the use of Ultra Low Sulfur Diesel fuel (ULSD), ≤0.0015 percent (≤15 ppm (mg/kg)) sulfur, for nonroad and stationary Tier 4 EPA certified engines using fuel sensitive technologies such as SCR systems and particulate filters. Fuels other than ULSD can cause damage in those engines and should not be used.

Consult the U.S. EPA for fuel sulfur regulations and for the ULSD point of sales required dates for various nonroad applications.

European sulfur free fuel ≤0.0010 percent (≤10ppm (mg/kg) sulfur) fuel is required by regulation for use in engines certified to EU nonroad Stage IIIB and newer standards and that are equipped with exhaust aftertreatment systems.

Certain governments/localities and/or applications MAY require the use of ULSD fuel. Consult federal, state, and local authorities for guidance on fuel requirements for your area.

Typical aftertreatment systems include Diesel Particulate Filters (DPF), Diesel Oxidation Catalysts (DOC), Selective Catalytic Reduction (SCR) and/or Lean NOx Traps (LNT). Other systems may apply.

Low sulfur diesel (LSD) fuel (≤500 ppm (mg/kg) sulfur) is strongly recommended for use in engines that are pre-Tier 4 models while diesel fuel with >500 ppm sulfur is acceptable for use in areas of the world where allowed by law. Pre-Tier 4 engines that are equipped with a Diesel Oxidation Catalyst (DOC) require the use of LSD fuel or ULSD fuel.

ULSD fuel or sulfur-free diesel fuel are acceptable in all engines regardless of the engine U.S. EPA Tier or EU Stage requirements.

Use appropriate lubricating oils that are compatible with the engine certification and aftertreatment system and with the fuel sulfur levels. Refer to the "Diesel Fuel Sulfur Impacts" article of this "Fuels Specifications" section and to the "Lubricants Specifications" section

of this Special Publication.

The two basic types of distillate diesel fuel are No. 2 diesel fuel and No. 1 diesel fuel. No. 2 diesel fuel is the most commonly available summer grade diesel fuel. No. 1 diesel fuel is a winter grade diesel fuel. During the winter months fuel suppliers will typically blend No. 1 and No. 2 diesel fuel in various percentages. Blending allows the fuel to meet the historical low ambient temperature cold-flow needs for a given area or region. No. 2 diesel fuel is a heavier diesel fuel than No. 1 diesel fuel. In cold weather, heavier fuels can cause problems with fuel filters, fuel lines, fuel tanks, and fuel storage. Heavier diesel fuels such as No. 2 diesel fuel can be used in diesel engines that operate in cold temperatures with an appropriate amount of a proven pour point depressant additive. For more information on fuels which include blends of No. 1 and No. 2 diesel fuel, consult your fuel supplier.

When you use No. 2 diesel fuel or other heavier fuels, some of the fuel characteristics may interfere with successful cold-weather operation. Additional information about the characteristics of diesel fuel is available. This information contains a discussion on the modification to the characteristics of diesel fuel. There are several possible methods that can be used to compensate for the fuel qualities that may interfere with cold-weather operation. These methods include the use of starting aids, engine coolant heaters, fuel heaters, and de-icers. In addition, the manufacturer of the fuel can add cold flow improvers and/or blend No. 1 and No. 2 diesel in various percentages.

Not all areas of the world classify diesel fuel using the No. 1 and No. 2 nomenclature described above. But, the basic principles of using additives and/or blending fuels of different densities are the same.

Starting Aids

The use of a starting aid is a conventional method of assistance for cold starts in low temperature conditions. Various starting aids are available for Cat engines. Follow the recommendations that are provided by the manufacturer of the starting aid. Refer to the foreword section in this Special Publication, "Aftermarket Products and Warranty" article.

Engine Coolant Heaters

These heaters heat the engine coolant. The heated coolant flows through the cylinder block. The flow of heated coolant keeps the engine warm. A warm engine is easier to start in cold weather. Most coolant heaters use electrical power. A source of electricity is necessary for this type of heater. Other heaters that burn fuel are available as a source of heat. These heaters may be used in place of the electrical heaters.

With either type of heater, starting aids and/or fuels with higher cetane numbers are less important because the engine is warm. Problems with fuel cloud point can cause the plugging of fuel filters. Problems with fuel cloud point cannot be corrected by engine coolant heaters. Some fuel filters are cooled by air flow during operation.

Fuel Heaters

The fuel cloud point is related to problems with fuel filters. The fuel heater heats the fuel above the cloud point before the fuel enters the fuel filter. Heating prevents wax from blocking the filter. Fuel can flow through pumps and lines at temperatures below the cloud point. The cloud point is often above the pour point of a fuel. While the fuel can flow through these lines, the wax in the fuel can still plug the fuel filter.

In some engine installations, small modifications can prevent problems that are caused by the cloud point.

One of the following changes can prevent problems in many conditions: a change in the location of fuel filters and/or supply lines and the addition of insulation. In extreme temperatures, heating of the fuel may be required to prevent the filters from plugging. There are several types of fuel heaters that are available. The heaters typically use either engine coolant or exhaust gas as a heat source. These systems may prevent filter waxing problems without the use of de-icers or cold flow improvers. These systems may be ineffective when the fuel contains a large amount of dirt or of water. Use of a fuel heater can help eliminate some cold-weather problems. A fuel heater should be installed so that the fuel is heated before flowing into the fuel filter.

Note: A fuel heater is not effective for cold-soaked starts unless the fuel heater can be powered from an external power source. External fuel lines may require the use of heaters that circulate the fuel.

Note: Only use properly sized fuel heaters that are controlled by thermostats or use fuel heaters that are self-regulated. Thermostatically controlled fuel heaters generally heat fuel to 15.5° C (60° F). Do not use fuel heaters in warm temperatures.

For distillate fuel configured engines, Cat recommends a fuel viscosity as delivered to rotary fuel injection pumps of between 1.4 cSt and 4.5 cSt. For all other fuel injection pumps, the viscosity must be between 1.4 cSt and 20 cSt.

Note: If a fuel with a low viscosity is used, cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Fuels with a high viscosity might require fuel heaters in order to lower the viscosity to the proper level.

NOTICE

When you use fuel heaters, do not allow the fuel temperature to reach above 52°C (125°F). Never exceed 75°C (165°F) with straight distillate fuel. The high fuel temperatures affect the fuel viscosity. When the fuel viscosity falls below 1.4 cSt, pump damage may occur.

WARNING

Overheating the fuel or the fuel filter can result in personal injury and/or damage to the engine. Use extreme care and caution for heating of the fuel and/or the fuel filter.

Select a fuel heater that is mechanically simple, yet adequate for the application. The fuel heater should also prevent overheating of the fuel. Disconnect the fuel heater or deactivate the fuel heater in warm weather. An unacceptable loss of fuel viscosity and engine power will occur if the fuel supply temperature is allowed to become too hot.

For additional information on fuel heaters, consult your Cat dealer.

De-icers

De-icers lower the freezing point of the moisture in the fuel. De-icers are not needed when fuel heaters are used. If you experience trouble, consult your fuel supplier for recommendations of a compatible

commercial de-icer.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05423989

Characteristics of Diesel Fuel

SMCS - 1250; 1280

Viscosity

The viscosity of the fuel is significant because the fuel serves as a lubricant for fuel system components. Fuels need to have sufficient viscosity. The fuel must lubricate the fuel system in both extremely cold and in extremely hot temperatures. If the kinematic viscosity of the fuel is lower than 1.4 cSt as supplied to the fuel injection pump or unit injectors, excessive scuffing and seizure can occur.

For distillate fuel configured engines, Cat recommends a fuel viscosity as delivered to rotary fuel injection pumps of between 1.4 cSt and 4.5 cSt, and between 1.4 cSt and 20 cSt for all other fuel injection pumps.

If a fuel with a low viscosity is used, cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Fuels with a high viscosity might require heaters to lower the viscosity to either 4.5 cSt or less for rotary fuel injection pumps or 20 cSt or less for all other fuel injection pumps.

Cetane Number

The cetane number of the fuel effects the ability of the engine to start. Also, the cetane number effects the interval of time before the engine runs smoothly. Generally, an increase of ten in the cetane number will allow the engine to be started at a lower temperature. The starting temperature can be improved approximately 7 to 8°C (12 to 15°F) for every increase of ten in the cetane number. After the engine reaches the normal operating temperature, a change in the cetane from 40 to 50 will have a minimal effect on engine performance.

Most fuels that have a cetane number above 40 will permit acceptable engine starts in warmer outside temperatures. The engine will start satisfactorily with this fuel when the engine is kept warm. The engine can be kept warm by using either a heated enclosure or a properly sized coolant heater.

During average starting conditions, direct injection diesel engines require a minimum cetane number of 40. A higher cetane value may be required for operation in high altitudes or for cold-weather operation. The minimum fuel cetane number that is required for the precombustion chamber (PC) diesel engine is 35.

Modifying the Cetane Number

The cetane number of a fuel can be changed if the fuel is mixed with a fuel that has a different cetane number. Generally, the cetane number of the mixture will be in direct relation to the ratio of the fuels that were mixed. Your fuel supplier can provide the information about the cetane number of a particular fuel.

Additives can also be used to improve the cetane number of a fuel. Additives are evaluated through testing in special test engines. However, the fuel characteristics of additives used to improved fuel cetane number are different than the naturally occurring proper cetane fuel. While both fuels may be rated as having the same cetane number, starting may be different.

Cloud Point

Understand that the cloud point of a fuel is different from the pour point. There is no relationship between cloud point and the pour point. The cloud point is the temperature that allows some of the heavier components in the wax to solidify in the fuel. This wax is not a contaminant in the fuel. The wax is an important element of No. 2 diesel fuel. The wax has a high fuel energy content and the wax has a high cetane value. Removal of the heavier wax lowers the cloud point of the fuel. Removal of the wax also increases the cost because less fuel can be made from the same amount of crude oil. Basically, a No. 1 diesel fuel is formulated by removing the wax from a No. 2 diesel fuel.

The cloud point of the fuel is important because the cloud point can limit the performance of the fuel filter. The wax can alter the fuel characteristics in cold weather. Solid wax can fill the fuel filters. The solidified wax will stop the flow of fuel. Fuel filters are necessary in order to remove dirt from the fuel. The filters block foreign material, and the filters protect the parts for the fuel injection system. Since fuel must flow through the filters, installing a fuel heater is the most practical way to prevent the problem. A fuel heater will keep the fuel above the cloud point as the fuel flows through the fuel system. The fuel heater will permit the wax to flow through the filters with the fuel.

Modifying the Cloud Point

You can lower the cloud point of a diesel fuel by mixing the diesel fuel with a different fuel that has a lower cloud point. No. 1 diesel fuel or kerosene may be used to lower the cloud point of a diesel fuel. The efficiency of this method is not good. The ratio of the mixture does not have a direct relation to the improvement in cloud point. The amount of fuel with low cloud point that is required makes the process less preferable to use.

The following illustration contains a table that can be used to find the necessary mixture for two fuels with different cloud points. In order to use the table, know the exact fuel cloud point of each fuel. This specification can change from one purchase of fuel to the next purchase of fuel. This specification is normally available from personnel at the source of the fuel supply. When fuels that have a lower cloud point are not available, this method cannot be used.

The manufacturer of the fuel can add cold flow improvers to the fuel. Cold flow improvers modify the wax crystals in the fuels. The cold flow improvers do not change the cloud point. However, the cold flow improvers keep the wax crystals small enough to pass through standard fuel filters. For mixing precautions, see the section "Pour Point".

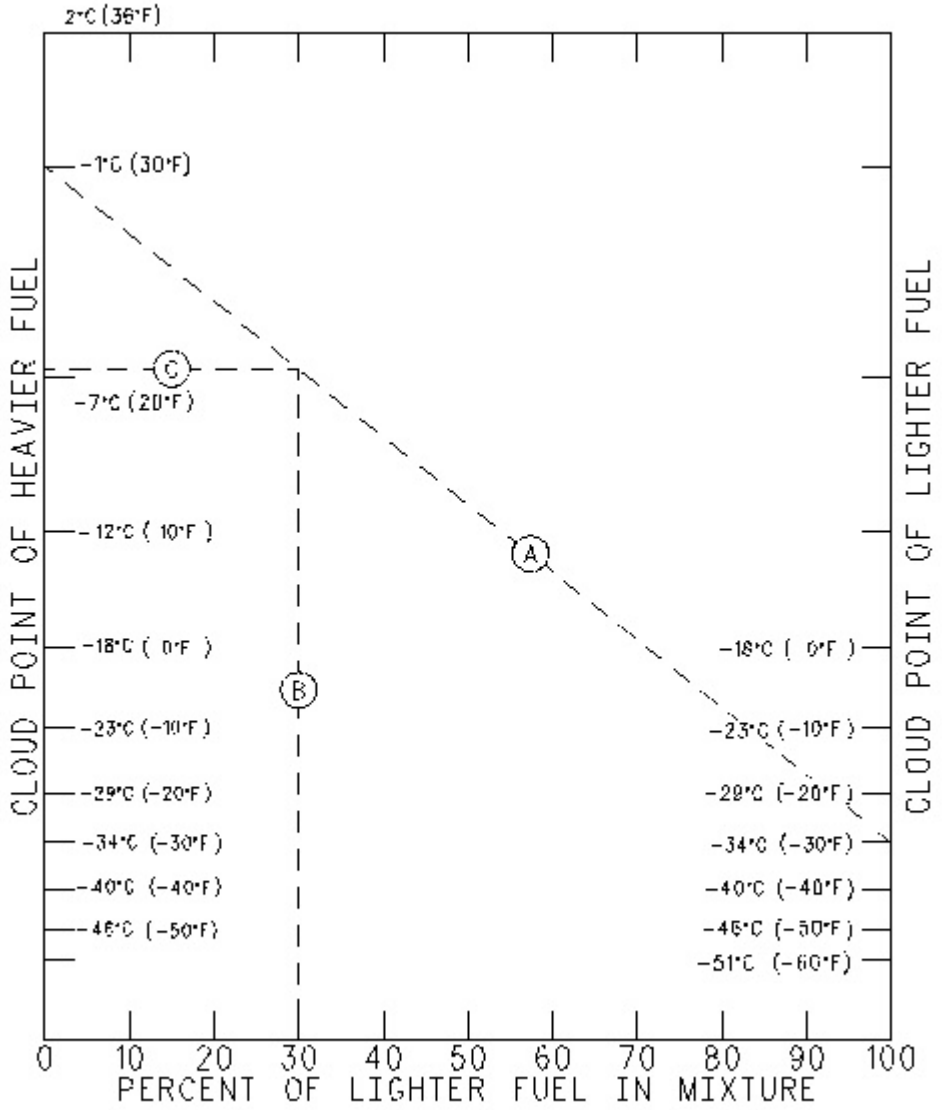

Illustration 1 g00592741

Cloud point of fuel mixtures

Use a fuel heater to prevent problems that are caused by fuel cloud point at low temperatures. In most applications, fuel heaters can be used at a lower cost than fuel mixtures.

Pour Point

The fuel pour point is a temperature below the fuel cloud point. Fuel stops flowing below the pour point. The pour point is the temperature which limits movement of the fuel inside of the pumps.

To measure the pour point, the fuel temperature is lowered below the cloud point in steps of 3°C (5°F) at a time. The temperature is lowered until the fuel does not flow. The pour point is the last temperature that is shown before the flow stops. At the pour point, the wax has solidified out of the fuel. The fuel will be more solid than liquid. The pour point of the fuel can be improved without the removal of important elements. This process is the same process that is used to improve the cloud point of a fuel.

A fuel's pour point should be at least 6°C (10°F) below the lowest ambient temperature that is required for engine start-up and for engine operation. To operate the engine in cold weather, No. 1 fuel or No. 1-D fuel

may be necessary because of these fuels' lower pour points.

Modifying the Pour Point

You can lower the fuel's pour point by using additives. You can also lower the pour point by mixing the diesel fuel with a fuel that has a lower pour point. No. 1 diesel fuel or kerosene may be used to lower the pour point of a diesel fuel. The amount of fuel with low pour point that is required makes the process less preferable to use.

The following illustration contains a table that can be used to find the necessary mixture for two fuels with different pour points. The fuels do not have additives which change the pour point. In order to use the table, know the exact pour point of each fuel. This specification can change from one purchase of fuel to the next purchase of fuel. This specification is normally available from personnel at the source of the fuel supply. When fuels that have a lower pour point are not available, this method cannot be used.

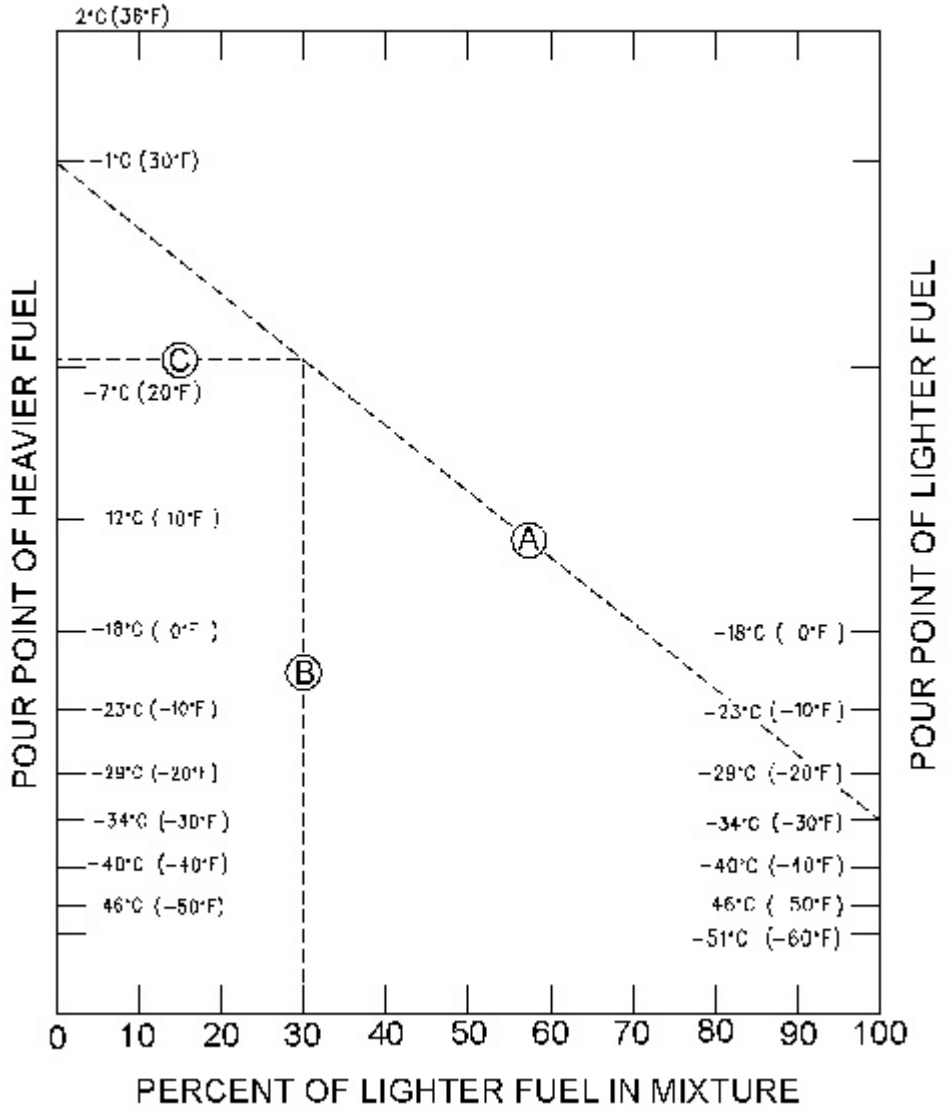

Illustration 2 g01180699

Pour point of fuel mixtures

In order to calculate the amount of lighter fuel that is required to be blended with the heavier fuel,

perform the following steps:

1. Obtain the specification for the cloud point or the pour point of both fuels from your fuel supplier.
2. Locate the cloud point or the pour point of the heavier fuel on the left side of the table. Mark the point on the table.
3. Locate the cloud point or the pour point of the lighter fuel on the right side of the table. Mark the point on the table.
4. Draw a line between the two points that were established. Label this line "A".
5. Determine the lowest outside temperature for machine operation. Find this point on the left side of the table. Mark this point. Draw a horizontal line from this point. Stop the line at the intersection of line "A". Label this new line "C".
6. Line "C" and line "A" intersect. Mark this point. Draw a vertical line from this point. Stop the line at the bottom of the table. Label this line "B". The point at the bottom of line "B" reveals the percentage of lighter fuel required to modify the cloud point or the pour point.

The above example shows that the blending will require a 30 percent mixture of lighter fuel.

Additives are a good method to use in order to lower the pour point of a fuel. These additives are known by the following names: pour point depressants, cold flow improvers and wax modifiers. When the additives are used in the proper concentration, the fuel will flow through pumps, lines, and hoses.

Note: These additives must be mixed thoroughly into the fuel at temperatures that are above the cloud point. The fuel supplier should be contacted in order to blend the fuel with the additives. The blended fuel can be delivered to your fuel tanks.

Lubricity and Low Sulfur Diesel (LSD) and Ultra Low Sulfur Diesel (ULSD) Fuel

In the United States (U.S.), LSD will have 0.05 percent (500 ppm(mg/kg)) maximum sulfur. ULSD will have 0.0015 percent (15 ppm(mg/kg)) maximum sulfur. Refer to this Special Publication, "Distillate Diesel Fuel" article for additional information. Also, refer to the most current revision level of "ASTM D975 (Standard Specification for Diesel Fuel Oils)" for additional information.

Note: "ASTM D975" currently allows up to 5 percent biodiesel blends. Refer to the "Fuel Specifications" section and this Special Publication, "Biodiesel" topic for guidance when biodiesel will be used.

In Europe, sulfur free diesel fuel will have 0.0010 percent (10 ppm(mg/kg)) maximum sulfur. Refer to the most current revision level of "European Standard EN 590 (Automotive Fuels - Diesel - Requirements and Test Methods)" for additional information.

Note: "EN 590" currently allows up to 5 percent biodiesel blends. Refer to the "Fuel Specifications" section and this Special Publication, "Biodiesel" topic for guidance when biodiesel will be used.

Note: The fuel lubricity is important. Consider the fuel lubricity whenever you operate the equipment in temperature extremes, whether hot or cold. Also, consider the fuel lubricity whenever you use fuels that are lower in viscosity or that have been hydrotreated. There are many aftermarket additives that are available to treat fuel. If the fuel lubricity is an issue, consult your fuel supplier for proper recommendations regarding fuel additives. Also, refer to this Special Publication, "Distillate Diesel Fuel"

article, "Aftermarket Fuel Additives" and "Cat Diesel Fuel Conditioner" topics.

The fluid lubricity describes the ability of the fluid to reduce the friction between surfaces that are under load. This ability reduces the damage that is caused by friction. Fuel injection systems rely on the lubricating properties of the fuel. Until fuel sulfur limits were mandated, the fuel lubricity was believed to be a function of fuel viscosity.

In order to determine the lubricity of the fuel, use the "ASTM D6079 High Frequency Reciprocating Rig (HFRR)" test. The maximum allowable wear scar is 0.52 mm (0.0205 inch) at 60° C (140° F). If the lubricity of a fuel does not meet the minimum requirements, consult your fuel supplier. Do not treat the fuel without consulting the fuel supplier. Some additives are not compatible. These additives can cause problems in the fuel system.

The process that is most commonly used to remove sulfur from fuel is called hydro-treatment. This process is also the most economical process. Each source of crude oil contains different amounts of sulfur. Crude oils typically require hydro-treatment to obtain the 0.0015 percent maximum sulfur limit. Crude oils with high sulfur require a more severe treatment.

The hydro-treatment removes the fuel sulfur as well as other components. The treatment removes nitrogen compounds, polar materials, bicyclic aromatics, polycyclic aromatics, and oxygen compounds. While the removal of sulfur has shown no detrimental effects to the engine, the removal of other compounds have lowered the lubricity of the fuel. As a result of the lowered lubricity, the fuel is less tolerant of contamination by water and dirt. The lower fuel lubricity can be seen as abrasive wear of fuel system components. Fuels that have a low lubricity may not provide adequate lubrication to plungers, to barrels, and to injectors. This problem may be compounded in areas that require winter blends of fuel. The lighter winter fuel blend has the following characteristics: lower viscosity, lower cloud point and lower pour point.

When required, the fuel lubricity may be enhanced with additives. Many fuel suppliers treat the fuel with these additives. Do not use a fuel lubricity additive before you consult the fuel supplier. Some aftermarket additives may not be compatible with the additives that are already in the fuel, and some may damage emission control systems. Some additive packages may not be compatible with the seals that are used in fuel systems of some diesel engines. Other additive packages that are supplied by aftermarket manufacturers cannot provide proper performance in high temperature conditions. These additives may leave deposits because of the high temperatures that exist in the fuel systems of diesel engines.

Maximum life of the fuel system can be achieved by performing the following tasks: using a preferred distillate diesel fuel (refer to the "Fuel Recommendations" article in this Special Publication), using a reliable fuel supplier and performing proper maintenance of the fuel system. Cat Advanced Efficiency fuel filters are required for diesel engines that run on diesel fuel in order to provide maximum life to the fuel system.

Note: Lighter fuels are frequently used in arctic temperatures. Lighter fuels may include the following fuels: Jet A, Jet A-1, JP-8, JP-5 and kerosene. The specifications that apply to these fuels do not include a minimum lubricity requirement. Do not assume that a fuel meets the minimum Cat specification. Contact the fuel supplier for proper recommendations on fuel lubricity additives.

Note: The sulfur levels for Jet A, Jet A-1, JP-8, JP-5 and kerosene fuels typically far exceed 15 ppm, the U.S. ULSD fuel and far exceed the EU sulfur free fuel.

Note: For best results, your fuel supplier should treat the fuel when additives are required.

Refer to this Special Publication, "Distillate Diesel Fuel" article, "Aftermarket Fuel Additives", "Cat

Diesel Fuel Conditioner", and "Alternative Fuels - Arctic Applications" topics for guidance.

Diesel Fuel Sulfur

Sulfur is a natural component of diesel fuels. High sulfur in the fuel can be reduced through refining technologies.

Sulfur levels in the fuel affect the durability of engine components and also affect engine exhaust emissions. Modern Cat diesel engines are designed to meet mandated gaseous emissions requirements. To meet these emissions requirements, the engines are tested and developed with specific sulfur levels in the diesel fuel.

The maximum allowable fuel sulfur level is controlled by various emissions laws, regulations, and mandates. Consult federal, state, and local authorities for guidance on fuel requirements for your area.

The list below provides a quick reference for acceptable sulfur levels for diesel fuel that will be used in Cat machine diesel engines but the controlling documents are the engine Operation and Maintenance Manuals, the specific aftertreatment device documentation, and the applicable emissions laws, regulations, and mandates.

- U.S. EPA regulations require the use of Ultra Low Sulfur Diesel fuel (ULSD) , ≤ 0.0015 percent (≤ 15 ppm (mg/kg)) sulfur, for nonroad and stationary Tier 4 EPA certified engines using fuel sensitive technologies such as SCR systems and particulate filters. Fuels other than ULSD can cause damage in those engines and should not be used. Consult the U.S. EPA for fuel sulfur regulations and for the ULSD point of sales required dates for various nonroad applications.
- European sulfur free fuel, 0.0010 percent (= 10 mg/kg) sulfur, fuel is required by regulation for use in engines certified to EU nonroad Stage IIIB and newer standards and that are equipped with exhaust aftertreatment systems.
- Certain governments/localities and/or applications MAY require the use of ULSD fuel. Consult federal, state, and local authorities for guidance on fuel requirements for your area.
- The maximum allowable fuel sulfur level for most pre-Tier 4 engines that are equipped with DOC (Diesel Oxidation Catalyst) is 0.05 percent (500 ppm (mg/kg)). Some DOC equipped engines require the use of fuel with a maximum of 0.005% (50 ppm (mg/kg)) fuel sulfur. Refer to the engine/machine Operation and Maintenance Manual and refer to the aftertreatment device specific documentation for guidance.
- For machine diesel engines that are retrofitted with an aftertreatment device, refer to the aftertreatment device specific documentation.

Typical aftertreatment systems include Diesel Particulate Filters (DPF), Diesel Oxidation Catalysts (DOC), Selective Catalytic Reduction (SCR) and/or Lean NOx Traps (LNT). Other systems may apply.

In addition to the emission regulations, factors that affect maximum allowed and/or acceptable fuel sulfur level include:

- Engine model/design
- Engine application
- Overall fuel quality

- Using recommended fluids, including but not limited to engine oil quality
- Exhaust aftertreatment device type
- Environmental factors and other site specific operating conditions
- Fuel costs versus risk of shortened engine/engine component life
- Fuel costs versus shortened oil drain intervals
- Maintenance intervals and other maintenance practices

Ultra-Low Sulfur Diesel (ULSD)

The United States (U.S.) Environmental Protection Agency (EPA) defines Ultra-Low Sulfur Diesel (ULSD - S15) as a U.S. diesel fuel with a sulfur content not to exceed 15 parts per million (ppm(mg/kg)) or 0.0015 percent by weight.

ULSD was introduced for the U.S. on-highway diesel engine market in October 2006. ULSD is available sinceDecember 2010 for nonroad diesel engines and machines. Refer to the U.S. EPA for the required ULSD point of sales dates for various nonroad applications.

Engines certified to nonroad Tier 4 standards (Stage IV in Europe) and are equipped with fuel sulfur sensitive exhaust aftertreatment systems are designed to run on ULSD only. Use of LSD or fuels higher than 15 ppm (mg/kg) sulfur in these engines will reduce engine efficiency and engine durability and will damage emissions control systems and/or shorten their service interval. Failures that result form the use of fuels are not Cat factory defects. Therefore the cost of repairs would not be overed by a Cat warranty.

ULSD fuel can be used in any engine designed to run on diesel fuel. Cat does not require the use of ULSD in nonroad and machine applications that are not Tier 4/Stage IIIB/Stage IV certified engines and are not equipped with aftertreatment devices. For Tier 4/Stage IIIB/Stage IV certified engines, always follow operating instructions and fuel tank inlet labels, if available, to insure the correct fuels are used.

Note: The removal of sulfur and other compounds in Ultra Low Sulfur Diesel (ULSD) fuel decreases the conductivity of ULSD and increases its ability to store static charge. Refineries may have treated the fuel with a static dissipating additive. However, there are many factors that can reduce the effectiveness of the additive over time. Static charges can build up in ULSD fuel while it is flowing through fuel delivery systems. Static electricity discharge when combustible vapors are present could result in a fire or explosion. Therefore, it is important to ensure that the entire system used to refuel your machine (fuel supply tank, transfer pump, transfer hose, nozzle, and others) is properly grounded and bonded. Consult with your fuel or fuel system supplier to ensure the delivery system is in compliance with fueling standards for proper grounding and bonding practices.

Ultra Low Sulfur Diesel (ULSD) poses a greater static ignition hazard than earlier diesel formulations, with a higher sulfur content, which may result in a fire or explosion. Consult with your fuel or fuel system supplier for details on proper grounding and bonding practices.

Sulfur-free Diesel Fuel

In Europe, ultra low sulfur diesel fuel will have a maximum of 0.0010 percent (10 ppm(mg/kg)) sulfur and is typically referred to as "sulfur-free". This sulfur level is defined in "European Standard EN 590:2004".

Low Sulfur Diesel (LSD)

Low Sulfur Diesel (LSD - S500) is defined by the U.S. EPA as a U.S. diesel fuel with sulfur content not to exceed 500 ppm or 0.05 percent by weight.

Note: Both ULSD and LSD must meet the fuel requirements outlined in the most current revision level of "ASTM D975".

Diesel Fuel Sulfur Impacts

Sulfur in the fuel results in the formation of sulfur dioxide (SO2) and sulfur trioxide (SO3) gases during the combustion process. When combined with water in the exhaust gas SO2 and SO3 can form acids. The acids can impact engine components and engine lubricants.

Sulfur in the exhaust gas can interfere with the operation of aftertreatment devices causing loss of passive regeneration performance, reduced gaseous emission conversion efficiency, and increased particulate matter emissions.

Typical aftertreatment systems include Diesel rticulate Filters (DPF), Diesel Oxidation Catalysts (DOC), Selective Catalytic Reduction (SCR) and/or Lean NOx Traps (LNT). Other systems may apply.

Use of fuels with higher than recommended and/or maximum allowed fuel sulfur levels can and/or will:

- Increase wear of engine components
- Increase corrosion of engine components
- Increase deposits
- Increase soot formation
- Shorten the time period between oil drain intervals (cause the need for more frequent oil drain intervals)
- Shorten the time interval between aftertreatment device service intervals (cause the need for more frequent service intervals)
- Negatively impact the performance and life of aftertreatment devices (cause loss of performance)
- Reduce regeneration intervals of aftertreatment devices
- Lower fuel economy
- Increase overall operating costs

Depending on operating conditions, and depending on maintenance practices, the potential issues stated above may and/or will take place with fuel sulfur levels that are at or below the recommended fuel sulfur

levels, and/or that are at or below the maximum allowable fuel sulfur levels.

Fuel sulfur levels above 0.1% (1000 ppm (mg/kg)) may significantly shorten the oil change interval.

When other factors do no preclude, and understanding that there may be trade-offs such as shortened oil drain intervals, certain commercial and machine diesel engines that are covered by this Special Publication MAY be able to operate satisfactorily on fuels with up to 1 percent (10, 000 ppm(mg/kg)) sulfur if the following conditions are met:

- All emissions laws, regulations and mandates are followed
- The engine/engines are not equipped with aftertreatment device/devices
- All appropriate guidelines and maintenance practices as stated in the engine Operation and Maintenance Manual are followed
- All appropriate guidelines and maintenance practices as stated in this Special Publication are followed
- Operating in otherwise low to moderate severity applications
- Your Cat dealer is consulted and approves
- You refer to this Special Publication, and you refer to your specific Cat commercial engine and/or refer to your specific Cat machine Operation and Maintenance Manual for additional guidance and exceptions

Oil Drain Intervals

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

Fuel sulfur level impacts the oil drain interval. For detailed information, refer to the "S·O·S Services Oil Analysis" section in the "Lubricants Specification" article in this Special Publication.

- Cat S·O·S Services oil analysis is recommended.
- Cat S·O·S Services oil analysis is very strongly recommended to determine oil drain intervals when using fuel with sulfur levels between 0.05% (500 ppm) and 0.5% (5000 ppm).
- Cat S·O·S Services oil analysis is required to determine oil drain intervals when using fuel with sulfur levels above 0.5% (5000 ppm).
- Consult your Cat dealer for guidance when fuel sulfur levels are above 0.1% (1000 ppm).

Moisture Content

Problems with fuel filters can occur at any time. The cause of the problem can be water in the fuel or moisture in the fuel. At low temperatures, moisture causes special problems. There are three types of moisture in fuel: dissolved moisture (moisture in solution), free and dispersed moisture in the fuel and free and settled at the bottom of the tank.

Most diesel fuels have some dissolved moisture. Just as the moisture in air, the fuel can only contain a

specific maximum amount of moisture at any one temperature. The amount of moisture decreases as the temperature is lowered. For example, a fuel could contain 100 ppm(100 mg/kg or 0.010 percent) of water in solution at 18°C (65°F). This same fuel can possibly hold only 30 ppm(30 ppm or 0.003 percent) at 4°C (40°F).

After the fuel has absorbed the maximum amount of water, the additional water will be free and dispersed. Free and dispersed moisture is fine droplets of water that is suspended in the fuel. Since the water is heavier than the fuel, the water will slowly become free and settled at the bottom of the tank. In the above example, when the fuel temperature was lowered from 18°C (65°F) to 4°C (40°F), 70 ppm(mg/kg) of water became free and dispersed in the fuel.

The small drops of water cause a cloudy appearance in the fuel. If the change in temperature is slow, the small drops of water can settle to the bottom of the tank. When the fuel temperature is lowered rapidly to freezing temperature, the moisture that comes out-of-solution changes to fine particles of ice instead of small drops of water.

The particles of ice are lighter than the fuel, and the particles of ice will not settle to the bottom of the tank. When this type of moisture is mixed in the fuel, this moisture will fill the fuel filters. The ice crystals will plug the fuel filters in the same way as wax plugs the fuel filters.

If a filter is plugged and fuel flow is stopped, perform the following procedure to determine the cause:

1. Remove the fuel filters.
2. Cut the fuel filters open.
3. Inspect the fuel filter before the filter warms. This inspection will show that the filter is filled with particles of either ice or wax.

The moisture which is free and settled at the bottom of the tank can become mixed with the fuel. The force of any pumping action will mix the moisture with the fuel whenever fuel is transferred. This moisture then becomes free and dispersed water. This moisture can cause ice in the filters. This moisture can cause other problems with filters at any temperature. Generally, the same force that mixes the water into the fuel will also mix dirt and rust from the bottom of the tank. The result is a dirty mixture of fuel and water which can also fill the filters and stop fuel flow.

Specific Gravity / API Gravity

The specific gravity of diesel fuel is the weight of a fixed volume of fuel in comparison to the weight of the same volume of water at the same temperature. A higher specific gravity correlates into a heavier fuel. Heavier fuels have more energy or power per volume for the engine to use.

Note: The settings for the fuel mixture should not be adjusted in order to compensate for a loss of power with fuels that are lighter. The life of fuel system components can be decreased with light fuels because lubrication will be less effective as a result of the lower viscosity. Sufficient lubricity is a problem. Refer to the "Lubricity and Low Sulfur Fuel Diesel (LSD) and Ultra Low Sulfur Diesel (ULSD) Fuel" topic in this Special Publication, "Characteristics of Diesel Fuel" article.

The API gravity of a fuel is also a measure of the density of the fuel or the relationship of the weight to the volume. The scale for API gravity is inverse to the scale for specific gravity. The API gravity will become higher as the fuel becomes lighter.

Lighter fuels will not produce the rated power. Lighter fuels may also be a blend of ethanol or methanol

with diesel fuel. Blending alcohol or gasoline with diesel fuel will create an explosive atmosphere in the fuel tank. In addition, water condensation in the tank can cause the alcohol to separate in the tank.

WARNING

Mixing alcohol or gasoline with diesel fuel can produce an explosive mixture in the engine crankcase or fuel tank.

Personal injury and damage to the engine may result. Caterpillar recommends against this practice.

NOTICE

Mixing alcohol or gasoline with diesel fuel may cause damage to the engine. Caterpillar recommends against this practice. Water condensation in the fuel tank can cause the alcohol to separate which could cause damage to the engine.

Heavier fuels tend to create more deposits from combustion. Deposits from combustion can cause abnormal cylinder liner and ring wear. Wear is most noticeable in smaller diesel engines that operate at higher speeds.

Gums and Resins

The gums and resins that occur in diesel fuel are the result of dissolved oxidation products in the fuel that do not evaporate easily. The products that are dissolved in the fuel also do not burn cleanly. Excessive gum in the fuel will coat the inside of fuel lines, pumps, and injectors. Excessive gum will also interfere with the close tolerances of the moving parts of the fuel systems. Gum and resin in the fuel will also cause the filter to plug rapidly. Oxidation of the fuel will occur and the formation of additional gums and resins will occur during fuel storage. The storage time for fuel must be minimized in order to help reduce the formation of gums and resins.

Note: Even when all fuel storage maintenance practices are followed, Cat recommends a maximum of 1 year from production for distillate diesel fuel storage, and a maximum of 6 months from production for biodiesel and blended biodiesel storage. Storage life for biodiesel and biodiesel blends that are greater than B20 may be much shorter than 6 months.

The Thermal Stability and Oxidation Stability of Fuel

Diesel fuels can deteriorate rapidly for various reasons. When the fuel is stressed and stored for long intervals, degradation and oxidation can occur. Degradation and oxidation are complex chemical changes. These changes lead to deposits or sediment from certain hydrocarbons and traces of naturally occurring nitrogen and sulfur containing compounds in the fuel. Fuel composition and environmental factors influence the process.

Diesel fuel is being used as a coolant for high-pressure fuel injection systems with high temperature fuel

wetted walls. The fuel in the fuel systemwill be stressed. The thermal stress and an increase in recirculation fuel temperature is often responsible for fuel degradation. Gums, resins, sediment, and deposits will form, which can cause fuel flow restriction through fuel filters and fuel injection systems.

Certain products are often stored for long periods with the fuel in the fuel system. The fuel is exposed to oxygen. Complex reactions between the oxygen and the fuel components can generate fuel particulates. The particulates in the fuel system can turn into the sludge that is found in fuel tanks, fuel lines, and the fuel filters. The performance of the fuel system will deteriorate. Degradation also leads to a plugged fuel filter, a restriction to the fuel line and deposit formation in the fuel injection nozzle.

Biodiesel and blends of biodiesel have poor thermal stability and oxidation stability compared to petroleum distillate diesel fuels. The use of these biodiesels and blends of biodiesel can accelerate the problems that are addressed in this Special Publication. Using biodiesel blends above the maximum level approved for the engine is not recommended.

Thermal and oxidative degradation of diesel fuel can result in a darkening of fuel color. Fuel color is not necessarily an indication of excessive degradation that will lead to the problems outlined in this Special Publication. But darkened fuel color can be an indicator of degradation leading to concerns about the stability of darkened fuel. Thermal oxidation and oxidative stability tests should be run to confirm actual fuel degradation.

Thermal Stability

Cat recommends the use of the "Accelerated Fuel Oil Stability Test (ASTM D6468)". This test method determines the instability of a fuel subjected to a thermal degradation process. This test exposes the fuel to conditions that are similar to actual operating conditions when the fuel cools the injectors during the engine operation.

The test is performed by using a spectrophotometer. The percentage reflectance of fuel should not be less than 80 percent after aging for 3 hours at a temperature of 150° C (302° F).

Oxidative Stability Test

Cat recommends the use of the "Oxidative Stability Test". This test method determines long-term storage of distillate fuels such as home heating oils, kerosene, and diesel oils. The test method is not suitable for highly volatile fuels with flash points under 38° C (100° F). This test method is used for storage stability, with the use of stabilizing additives and without the use of stabilizing additives.

As per the specification "EN590:2004 Automotive Fuels - Diesel", a test for a direct measurement of oxidation stability is the test method "ISO 12205 Petroleum products - Determination of the oxidation stability of middle distillate diesel fuels". The fuel sample is heated at 95° C (203° F) for 16 hours while bubbles of oxygen travel through the sample. The resulting amount of solid oxidation by products is then measured. This test simulates the oxidation of fuel during long-term storage. For diesel fuel the maximum amount of insolubles formed should not exceed 25 g per cubic meter.

Cat recommends that for diesel, biodiesel, or biodiesel blends that are going to be used several months after purchase, artificially aging the fuel to predict the storage stability, followed by an analysis of the fuel. For most distillate fuels that age the fuel for 7 days at 80° C (176° F) can simulate storage for 4 to 8 months at typical ambient storage temperatures. Analysis of this matured fuel per the methods discussed in this document can then be used to aid in predicting the stability of the fuel after numerous months of storage. Analysis of Diesel fuel should include "Thermal Stability - ASTM D6468", "Fuel Gums - ASTM

D381" and "Fuel Sediments - ASTM D473". Analysis of biodiesel fuel and biodiesel fuel blends should include "Oxidation - EN14112", "Acid Value - ASTM D664", "Viscosity - ASTM D445" and "Sediments - ASTM D2709".

A test that can be used to help determine the degradation of biodiesel fuel and biodiesel fuel blends is the measurement of the "Acid Value - ASTM D664" or "EN 14104". This value represents the amount of acid present in the biodiesel fuel or biodiesel blend fuel as a result of degradation. The required limit for B100 biodiesel is given in "Cat Biodiesel specification" in this Special Publication or in "B100 specification - ASTM D6751". The required limit for B6-B20 biodiesel fuel blend is given in "ASTM D7467" specification.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05822686

Fuel Recommendations

SMCS - 1250; 1280

NOTICE

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

Diesel engines may burn a wide variety of fuels. These fuels are divided into two general groups. The two groups are called the preferred fuels and the permissible fuels.

The preferred fuels provide maximum engine service life and performance. The preferred fuels are distillate fuels. These fuels are commonly called diesel fuel, furnace oil, gas oil, or kerosene. These fuels must meet the “Cat Specification for Distillate Diesel Fuel for Off-Highway Diesel Engines” found in this Special Publication, "Distillate Diesel Fuel" article.

The permissible fuels are some crude oils, some blends of crude oil with distillate fuel, and some marine diesel fuel. **These fuels are not suitable for use in all engine applications.** The acceptability of these fuels for use is determined on a case by case basis. A complete fuel analysis is required. Consult your Cat dealer for further information. Biodiesel fuel is permissible for use in Cat engines. Follow all the recommendations and guidelines given in this Special Publication, "Biodiesel" article.

Note: Except for some biodiesel, permissible fuels are not acceptable for use in on-highway applications.

NOTICE

Use of permissible fuels can result in higher maintenance costs and reduced engine service life.

Note: Use of fuels that do not meet at least the minimum performance recommendations and/or requirements may lead to lower compartment performance and/or compartment failure. Problems/failures that are caused by using fuels that do not meet the minimum recommended and/or required performance level are not Cat factory defects and therefore are NOT covered by the Cat warranty. The fuel supplier and customer are responsible.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05424518

Diesel Fuel Recommendations - Tier 4 C280 Marine Engines

SMCS - 1250; 1280

S/N - 8RB1-UP

The information and guidelines given in this Special Publication, "Diesel Fuel" apply to marine engines that use diesel fuels. Follow these guidelines in order to reduce the risk of engine downtime. Refer to your engine Operation and Maintenance Manual for details specific to your marine engine. Consult your Cat dealer for more information.

The International Maritime Organization (IMO) regulates the fuel sulfur level for ocean going ships. Current marine fuels at sea that are regulated by the IMO can have sulfur levels up to 3.5 percent (35,000 ppm) prior to the year 2020. As of January 1, 2020, ships operating in international waters are required to use fuels with sulfur levels below 0.5 percent (5000 ppm).

Furthermore, IMO designates certain areas as Sulfur Emissions Control Areas (SECA). Ships operating within SECA must operate on 1 percent (10,000 ppm) sulfur fuel prior to the year 2015. After January 1, 2015 ships operating within SECA must operate with 0.1 percent (1000 ppm) sulfur fuels. IMO may change areas considered SECA. Review and follow local and IMO requirements and local regulations for planned destinations. Refer to your engine Operation and Maintenance Manualfor appropriate marine fuels for use in your engine.

The US Environmental Protection Agency (EPA) regulates the sulfur level of marine fuels in the US waterways and shores. For vessels operating exclusively within US waters, Ultra Low Sulfur Diesel (ULSD) is required by regulations unless local exceptions exist. Vessels traveling internationally under the US Flag are required to operate on ULSD regardless of destination and location. Refer to the regulations in your area of operation. If your destination does not have ULSD, but your engine can operate on fuel other than ULSD, exemptions can be requested by contacting the EPA at the following address:

complianceinfo@epa.gov

Refer to your engine Operation and Maintenance Manualfor fuels information for your engine.

Foreign flagged vessels operating in the US are required to follow IMO rules while sailing in US waters designated as SECA. Always refer to the local regulations at ports of call to determine fuel requirements as the regulations are subject to change.

Note: ULSD is backwards compatible and can be used in most engine technologies. Diesel fuels with > 0.0015 percent (>15 ppm) sulfur can be used in engines that do not have aftertreatment devices and where permitted by local regulations.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05424510

Diesel Fuel Recommendations - Marine Engines and Certain 3600 Series Stationary Engines

SMCS - 1250; 1280

The fuels discussed in this section are applicable to marine engines. These fuels can also be used in certain stationary 3600 Series engines that have been configured to use marine fuels. Refer to the Operation and Maintenance Manual of your engine for more information.

Many different names are used for marine diesel fuels. The different names often cause misunderstanding. Some specifications for marine diesel fuels seem to be based on the limits of the fuel suppliers. Those specifications may not be as precise as other specifications such as ASTM fuel specifications.

Four types of marine diesel fuel are recognized. These four types of marine diesel fuel are available at bunkering ports around the world. Not all of the types are available at every station.

Be aware of the fuel supplier specifications for a fuel. Do not use residual fuel or fuel that is blended with residual fuel in diesel engines that are configured to use distillate fuel.

NOTICE

Heavy fuel oil, residual fuel, or blended fuel can be used only in Cat 3600 Series engines that are configured to use heavy fuel oil.

DO NOT use these types of fuel in diesel engines that are configured to use distillate diesel fuel. Do not use these types of fuel in engines that are Tier 4 EPA certified. Failure to follow this recommendation will result in severe wear of components and engine failure.

Gas Oil - A light distillate fuel which does not contain residual fuel. Gas oil is approximately ASTM No.1 diesel fuel.

Marine Diesel - A distillate fuel that boils at a higher temperature than gas oil. This fuel varies from ASTM No.2 to ASTM No.4. The composition can vary within the following range: ASTM No.2 diesel fuel, No.2 that is contaminated with heavier fuel in the bottom of a tanker and No.2 that is blended with as much as 20 percent of residual fuel.

NOTICE

Do NOT use fuel that is blended with residual fuel in diesel engines that are configured to use distillate fuel. Severe component wear and component failures will result if this type of fuel is used in diesel engines that are configured to use distillate fuel.

Table 1 lists some permissible marine diesel fuels.

Blended Fuel Oil - A blend of distillate and residual fuel. This fuel is blended to the viscosity that is requested by the operator or the manufacturer of the engine. Blended fuel is also referred to as heavy fuel oil (HFO).

Note: Do NOT use blended fuel in Cat diesel engines that are configured to use distillate fuel. Severe component wear and component failures will result if this type of fuel is used in diesel engines that are configured to use distillate fuel.

Residual Fuel - A residue from the distillation of crude oil in a refinery. Residual fuel is also referred to as heavy fuel oil (HFO).

Note: DO NOT use residual fuel in Cat diesel engines that are configured to use distillate fuel. Severe component wear and component failures will result if this type of fuel is used in diesel engines that are configured to use distillate fuel.

DO NOT use fuels that are classified as CIMAC DC or ISO 8217F-DMC.

The use of fuels that are classified as CIMAC DC or ISO 8217F-DMC can reduce the service life of components.

Only use fuels that meet or exceed Cat recommendations. The use of fuels that are not recommended can reduce the service life of components.

The classifications that are listed in Table 1 are established by the International Standards Organization (ISO). Fuels which meet the classifications that are listed in Table 1 are permissible for use in Cat 3600 Series diesel engines that are configured to use distillate fuel. Fuels classified by the Council International Des Machines a Combustion (CIMAC) that are equivalent to the ISO Classifications indicted in Table 1 are also permissible for use in Cat 3600 and C280 Series engines.

Table 1

Marine Distillate Diesel Fuels That Are Permissible for Use In Caterpillar 3600 Series and C280 Series Diesel Engines
"ISO 8217-DMA"
"ISO 8217-DMZ"
"ISO 8217-DMB"
"ISO 8217-DMX"

Note: Use of permissible fuels can result in higher maintenance costs and reduced engine service life.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05331155

Distillate Diesel Fuel

SMCS - 1280

Note: For on-highway diesel engine fluids requirements, refer to specific engine Operation and Maintenance Manuals, and also refer to the most current revision level of Special Publication, SEBU6385, "Caterpillar On-Highway Diesel Engine Fluids Recommendations". Also consult your Cat dealer.

Cat is not in the position to evaluate continuously and monitor all of the many worldwide distillate diesel fuel specifications and on-going revisions that are published by governments and technological societies.

The "Cat Specification for Distillate Fuel for Nonroad Diesel Engines" provides a known, reliable baseline to judge the expected performance of distillate diesel fuels that are derived from conventional sources (crude oil, shale oil, oil sands) when used in Cat diesel engines.

Use the Cat distillate diesel fuel specification as the baseline. Determine any potential economic and/or performance trade-offs and overall acceptability when using fuels of varying characteristics and quality levels.

- When required, have the diesel fuel that either is being used or is planned to use, tested per the Cat distillate diesel fuel specification.
- Use the Cat distillate diesel fuel specification as a fuel quality baseline for comparison of distillate diesel fuel analysis results. Also, use the specification as a baseline for comparison of other distillate diesel fuel specifications.
- Typical fuel characteristics can be obtained from the fuel supplier.

Fuel parameters outside of the Cat fuel specification limits have explainable consequences.

- Some fuel parameters that are outside of the specification limits can be compensated for (for example, fuel can be cooled to address low viscosity).
- Some fuel parameters that are outside of specification limits may improve with the use of appropriate amounts of proven fuel additives. Refer to this Special Publication, "Distillate Diesel Fuel" article, "Aftermarket Fuel Additives" and "Cat Diesel Fuel Conditioner" topics for guidance.

To help ensure optimum engine performance, a complete fuel analysis should be obtained before engine operation. The fuel analysis should include all of the properties that are listed in the "Cat Specification for Distillate Fuel for Nonroad Diesel Engines", Table 1.

Note: The diesel fuel cannot have any visually apparent sediment, suspended matter, or undissolved water.

Diesel Fuels that meet the specifications in table 1 will help provide maximum engine service life and performance.

In North America, diesel fuels that are identified as meeting the latest version of "ASTM D975" Grades No. 1-D or No. 2-D (all listed sulfur levels) generally meet the table 1 requirements.

In Europe, diesel fuels that are identified as meeting the latest version of "European Standard EN590" generally meet the table 1 requirements.

Table 1 is for diesel fuels that are distilled from conventional sources (crude oil, shale oil, oil sands). Diesel fuels from other sources could exhibit detrimental properties that are not defined or controlled by this specification.

NOTICE

Ultra Low Sulfur Diesel (ULSD) fuel 0.0015 percent (≤15 ppm (mg/kg)) sulfur is required by regulation for use in engines certified to nonroad Tier 4 standards (U.S. EPA Tier 4 certified) and that are equipped with exhaust aftertreatment systems.

European ULSD 0.0010 percent (≤10ppm (mg/kg)) sulfur fuel is required by regulation for use in engines certified to European nonroad Stage IIIB and newer standards and are equipped with exhaust aftertreatment systems.

Certain governments/localities and/or applications MAY require the use of ULSD fuel. Consult federal, state, and local authorities for guidance on fuel requirements for your area.

Typical aftertreatment systems include Diesel Particulate Filters (DPF), Diesel Oxidation Catalysts (DOC), Selective Catalytic Reduction (SCR) and/or Lean NOx Traps (LNT). Other systems may apply.

Low sulfur diesel (LSD) fuel 0.05 percent (≤500 ppm (mg/kg) sulfur) is strongly recommended for use in engines that are pre-Tier 4 models, while diesel fuel with > 0.05 percent (500 ppm (mg/kg)) sulfur is acceptable for use in areas of the world where allowed by law. Pre-Tier 4 engines that are equipped with a Diesel Oxidation Catalyst (DOC) require the use of LSD fuel or ULSD fuel.

ULSD fuel or sulfur-free diesel fuel are applicable for use in all engines regardless of the engine Tier or Stage.

Use appropriate lubricating oils that are compatible with the engine certification and aftertreatment system and with the fuel sulfur levels. Refer to the "Diesel Fuel Sulfur Impacts" article of this "Fuels Specifications" section and to the "Lubricants Specifications" section of this Special Publication.

The overall quality of the fuel is critical to the successful operation of engines.

Engine operating conditions play a key role in determining the effect that fuel sulfur will have on engine deposits and on engine wear. Using fuels with higher than recommended fuel sulfur levels can or will cause various negative impacts. For information on fuel sulfur and fuel sulfur impacts refer to the Diesel Fuel Sulfur article in this Fuel Specifications section.

NOTICE

Do not add new engine oil, waste engine oil or any oil product to the fuel unless the engine is designed and certified to burn diesel engine oil (for example Caterpillar ORS designed for large engines). Caterpillar experience has shown that adding oil products to Tier 4 engine fuels (U.S. EPA Tier 4 certified), to EURO Stage IIB and IV certified engine fuels, or to the fuels of engines equipped with exhaust aftertreatment devices, will generally cause the need for more frequent ash service intervals and/or cause loss of performance.

Adding oil products to the fuel may raise the sulfur level of the fuel and may cause fouling of the fuel system and loss of performance.

Cat does not require the use of ULSD in Nonroad and machine applications that are not Tier 4/Stage IIIB/ Stage IV certified engines. These engines that are not equipped with aftertreatment devices do not require ULSD. For Tier 4/Stage IIIB/Stage IV certified engines, always follow operating instructions and fuel tank inlet labels to insure the correct fuels are used.

ULSD and any other fuel used in Cat engines have to be properly formulated by the fuel supplier. Fuels must meet Special Publication, "Caterpillar Specification for Distillate Diesel Fuel for Off-Highway Diesel Engines". Fuels that are defined as "ASTM D975" Grade No. 1-D S15 or "ASTM D975" Grade No. 2-D S15 generally meet Cat requirements for ULSD.

Refer to this Special Publication, "Characteristics of Diesel Fuel" article for additional pertinent information concerning fuel lubricity, fuel oxidation stability, fuel sulfur, and aftertreatment devices. Also refer to "ASTM D975-08a", to the specific engine Operation and Maintenance Manual, and to aftertreatment device documentation for guidance.

Note: Cat strongly recommends the filtration of distillate fuel and/or biodiesel/biodiesel blends through a fuel filter with a rating of four microns(c) absolute or less. This filtration should be located on the device that dispenses the fuel to the fuel tank for the engine, and also on the device that dispenses fuel from the bulk storage tank. Series filtration is recommended.

Note: The owner and the operator of the engine has the responsibility of using the correct fuel that is recommended by the manufacturer and allowed by the U.S. EPA and, as appropriate, other regulatory agencies.

NOTICE

Operating with fuels that do not meet Cat recommendations can cause the following effects: starting difficulty, reduced fuel filter service life,

poor combustion, deposits in the fuel injectors, reduced service life of the fuel system, deposits in the combustion chamber and reduced service life of the engine.

NOTICE

The footnotes are a key part of the "Caterpillar Specification for Distillate Diesel Fuel" Table. Read ALL of the footnotes.

For additional guidance related to many of the fuel characteristics that are listed, refer to "Cat Specification for Distillate Fuel for Nonroad Diesel Engines", table 1.

The values of the fuel viscosity given in table 1 are the values as the fuel is delivered to the fuel injection pumps. For ease of comparison, fuels should also meet the minimum and maximum viscosity requirements at 40° C (104° F) that are stated by the use of either the "ASTM D445" test method or the "ISO 3104" test method. If a fuel with a low viscosity is used, cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Fuels with a high viscosity might require fuel heaters in order to lower the viscosity to either 4.5 cSt or less for rotary fuel injection pumps or 20 cSt viscosity or less for all other fuel injection pumps.

The lubricity of a fuel is a concern with low sulfur and ultra low sulfur fuel. To determine the lubricity of the fuel, use the "ASTM D6079 High Frequency Reciprocating Rig (HFRR)" test. There are many aftermarket additives that are available to treat fuel. If the lubricity of a fuel does not meet the minimum requirements, consult your fuel supplier for proper recommendations regarding fuel additives. Also, refer to this Special Publication, "Characteristics of Diesel Fuel" article, "Aftermarket Fuel Additives" and "Cat Diesel Fuel Conditioner" topics. Do not treat the fuel without consulting the fuel supplier. Some additives are not compatible. These additives can cause problems in the fuel system.

Table 1

Cat Specification for Distillate Fuel for Nonroad Diesel Engines			
Specifications	**Requirements**	**ASTM Test**	**ISO Test**
Aromatics	35% maximum	"D1319"	"3837"
Ash	0.01% maximum (weight)	"D482"	"6245"
Carbon Residue on 10% Bottoms	0.35% maximum (weight)	"D524"	"4262"
Cetane Number (1)	40 minimum (DI engines)	"D613" or "D6890"	"5165"
	35 minimum (PC engines)		
Cloud Point	The cloud point must not exceed the lowest expected ambient temperature.	"D2500"	"3015"
Copper Strip Corrosion	No. 3 maximum	"D130"	"2160"

Distillation	10% at 282 °C (540 °F) maximum	"D86"	"3405"
	90% at 360 °C (680 °F) maximum (2)		
	90% at 350 °C (662 °F) maximum (2)		
Flash Point	legal limit	"D93"	"2719"
Thermal Stability	Minimum of 80% reflectance after aging for 180 minutes at 150 °C (302 °F)	"D6468"	No equivalent test
API Gravity (3)	30 minimum	"D287"	No equivalent test
	45 maximum		
Pour Point	6 °C (10 °F) minimum below ambient temperature	"D97"	"3016"
Sulfur	(4)	"D5453" or "D2622"	"20846" or "20884"
Kinematic Viscosity	1.4 cSt minimum and 20.0 cSt maximum as delivered to the fuel injection pumps	-	-
	1.4 cSt minimum and 4.5 cSt maximum as delivered to the rotary fuel injection pumps		
Water and Sediment	0.05% maximum	"D1796" or "D2709"	"3734"
Water	0.05% maximum	"D6304"	No equivalent test
Sediment	0.05% maximum (weight)	"D473"	"3735"
Gums and Resins (5)	10 mg per 100 mL maximum	"D381"	"6246"
Lubricity	0.52 mm (0.0205 inch) maximum at 60 °C (140 °F)	"D6079"	No equivalent test
Cleanliness	(6)	"D7619"	"4406"

(1) Alternatively, to ensure a minimum cetane number of 35 (PC engines), and 40 (DI engines), distillate diesel fuel should have a minimum cetane index of 37.5 (PC engines), and 44.2 (DI engines) when the "ASTM D4737-96a" test method is used. A fuel with a higher cetane number may be required for operation at a higher altitude or in cold weather.

(2) Distillation of 90% at 350°C (662°F) maximum is recommended for Tier 4 engines and preferred for all engines. Distillation of 90% at 350°C (662°F) is equivalent to 95% at 360°C (680°F).Distillation of 90% at 360°C (680°F) maximum is acceptable for Pre-Tier 4 engines.

(3) Via standards tables, the equivalent kg/m^3 (kilograms per cubic meter) using the "ASTM D287" test method temperature of 15.56° C (60° F) for the minimum API gravity of 30 is 875.7 kg/m^3, and for the maximum API gravity of 45 is 801.3 kg/m^3.

(4) Follow the federal, state, local, and other governing authorities for guidance concerning the fuel requirements in your area. Follow the engine Operation and Maintenance Manual and the details provided in this Fuel section. ULSD 0.0015% (<15 ppm S) is required by law for Tier 4 engines and engines with aftertreatment devices. ULSD and LSD 0.05% (≤500 ppm S) are recommended for pre-Tier 4 engines. Diesel fuel with > 0.05% (>500 ppm) sulfur is acceptable for use where allowed by law. Consult your Cat dealer for guidance when sulfur levels are above 0.1% (1000 ppm). Certain Cat fuel systems and engine components can operate on fuel with a maximum sulfur content of 3%. Refer to the specific engine Operation and Maintenance Manual and consult your Cat dealer.

(5) Follow the test conditions and procedures for gasoline (motor).

(6) Recommended cleanliness level for fuel as dispensed into machine or engine fuel tank is "ISO 18/16/13" or cleaner per "ISO 4406" or "ASTM D7619". Refer to the "Contamination Control" section in this Special Publication.

There are many other diesel fuel specifications that are published by governments and by technological societies. Usually, those specifications do not review all the requirements that are addressed in the "Cat Specification for Distillate Fuel for Nonroad Diesel Engines", Table 1. To help ensure optimum engine performance, a complete fuel analysis should be obtained before engine operation. The fuel analysis should include all of the properties that are listed in the "Cat Specification for Distillate Fuel for Nonroad Diesel Engines", Table 1.

NOTICE

In order to meet expected fuel system component life, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with common-rail fuel systems. Also, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with unit injected fuel systems. For all other Cat diesel engines (mostly older engines with pump, line and nozzle type fuel systems), the use of 4 micron(c) absolute or less secondary fuel filtration is strongly recommended. Note that all current Cat diesel engines are factory equipped with Cat Advanced Efficiency 4 micron(c) absolute fuel filters.

In order to obtain additional information on Cat designed and produced filtration products, refer to this Special Publication, "Reference Material" article, "Filters" and "Miscellaneous" topics, and then contact your Cat dealer for assistance with filtration recommendations for your Cat machine.

WARNING

Mixing alcohol or gasoline with diesel fuel can produce an explosive mixture in the engine crankcase or fuel tank.

Personal injury and damage to the engine may result. Caterpillar recommends against this practice.

Contamination Control Recommendations for Fuels

Fuels of "ISO 18/16/13" cleanliness level or cleaner as dispensed into the engine or machine fuel tank should be used in order to reduce power loss, failures, and related down time of engines. This cleanliness level is particularly important for new fuel system designs such as Common Rail injection systems and unit injection systems. These new injection system designs utilize higher fuel pressures and are designed with tight clearances between moving parts in order to meet required stringent emissions regulations. Peak injection pressures in current fuel injection systems may exceed 30,000 psi. Clearances in these systems are less than 5 µm. As a result, particle contaminants as small as 4 µm can cause scoring and scratching of internal pump and injector surfaces and of injector nozzles.

Water in the fuel causes cavitation, corrosion of fuel system parts, and provides an environment where microbial growth in the fuel can flourish. Other sources of fuel contamination are soaps, gels, or other compounds that may result from undesirable chemical interactions in the fuels, particularly in Ultra Low Sulfur Diesel (ULSD). Gels and other compounds can also form in biodiesel fuel at low temperatures or if biodiesel is stored for extended periods. The best indication of microbial contamination, fuel additives, or cold temperature gel is very rapid filter plugging of bulk fuel filters or machine fuel filters.

In order to reduce downtime due to contamination, follow these fuel maintenance guidelines in addition to the "General Contamination Control Recommendations or Practices" given above in this Chapter:

- Use high-quality fuels per recommended and required specifications (refer to the "Fuel" chapter in this Special Publication).
- Fill machine fuel tanks with fuels of "ISO 18/16/13" cleanliness level or cleaner, in particular for engines with common rail and unit injection systems. When you refuel the machine, filter the fuel through a 4 µm absolute filter (Beta 4 = 75 up to 200) in order to reach the recommended cleanliness level. This filtration should be located at the device that dispenses the fuel to the engine or machine fuel tank. In addition, filtration at the dispensing point should have the ability to remove water to ensure fuel is dispensed at 500 ppm water or less.
- Caterpillar recommends the use of bulk fuel filter / coalescer units which remove both particulate contamination and water in a single pass. These units have the ability to clean fuel to "ISO 16/13/11" or cleaner and remove free water to 500 ppm (mg/kg) or less. Cat offers heavy-duty filter / coalescer units to accommodate fueling rates from 50 to 300 gpm (gallons per minute). Cat custom designs filter / coalescer units specifically for the conditions of fuel at the worksite if needed.
- Ensure that you use Cat Advanced Efficiency Fuel Filters. Change your fuel filters per recommended service requirements or as needed.
- Drain your water separators daily per the Operation and Maintenance Manual of your machine.
- Drain your fuel tanks of sediment every 500 hours or 3 months per the Operation and Maintenance Manual of your machine.
- Install and maintain a properly designed bulk filter / coalescer filtration system. Continuous bulk filtration systems may be required to ensure that dispensed fuel meets the cleanliness target. Refer to your Cat dealer for availability of bulk filtration products.
- Centrifugal filters may need to be used as a pre-filter with fuel that is severely contaminated with gross amounts of water or large particulate contaminants. Centrifugal filters can effectively remove

large contaminants, but may not be able to remove the very small abrasive particles required to achieve the recommended "ISO" cleanliness level. Bulk filter / coalescers are necessary as a final filter in order to achieve the recommended cleanliness level.

- Install desiccant type breathers of 4 µm or less absolute efficiency with the ability to remove water on bulk storage tanks.
- Follow proper practices of fuel transport and filtration from storage tank to the machine in order to allow the delivery of clean fuel to machine tank. Fuel filtration can be installed at each transport stage in order to keep the fuel clean.
- Cover, protect, and ensure cleanliness of all connection hoses, fittings, and dispensing nozzles.

NOTICE

In order to meet expected fuel system component life, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with common-rail fuel systems. Also, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with unit injected fuel systems. For all other Cat diesel engines (mostly older engines with pump, line and nozzle type fuel systems), the use of 4 micron(c) absolute or less secondary fuel filtration is strongly recommended. Note that all current Cat diesel engines are factory equipped with Cat Advanced Efficiency 4 micron(c) absolute fuel filters.

Consult your local Cat dealer for additional information on Cat designed and produced filtration products.

Refer to the "Contamination Control" chapter in this Special Publication for more details.

Heavy Fuel Oil, Residual Fuel, Blended Fuel

NOTICE

Heavy Fuel Oil (HFO), Residual fuel, or Blended fuel must NOT be used in Caterpillar diesel engines (except in 3600 Series HFO engines). Blended fuel is residual fuel that has been diluted with a lighter fuel (cutter stock) so that they will flow. Blended fuels are also referred to as heavy fuel oils. Severe component wear and component failures will result if HFO type fuels are used in engines that are configured to use distillate fuel.

Alternative Fuels - Cold Weather Applications

In extreme cold ambient conditions, you may choose to use the distillate fuels that are specified in table 2. However, the fuel that is selected must meet the requirements that are specified in the "Cat Specification

for Distillate Diesel Fuel for Nonroad Diesel Engines", Table 1. These fuels are intended for use in operating temperatures that are down to −54 °C (−65 °F).

Note: The fuels that are listed in table 2 typically have much higher sulfur levels than the 15 ppm maximum sulfur allowed for ULSD. The sulfur levels for these fuels typically far exceed 15 ppm. These fuels typically will not be acceptable for use in areas that restrict maximum fuel sulfur levels to 15 ppm of less.

Note: The fuels that are listed in table 2 typically have much higher sulfur levels than the 50 ppm maximum sulfur allowed in the European Standard "EN 590:2004". The sulfur content of these fuels typically far exceeds 50 ppm. These fuels typically will not be acceptable for use in areas that restrict maximum fuel sulfur levels to 50 ppm or less.

The fuel that is selected must meet the requirements that are specified in "Cat Specification for Distillate Diesel Fuel for Nonroad Diesel Engines", table 1. Cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Consult the supplier for the recommended additives in order to maintain the proper fuel lubricity.

This table lists fuel specifications for fuel additives that have not been tested by Cat for use in Cat fuel systems. The use of these specifications allowed and/or recommended fuel additives are at the risk of the user.

Jet A is the standard fuel used by U.S. commercial airlines when operating within the U.S.. Jet A-1 is the standard fuel used by commercial airlines worldwide. Per "ASTM D1655-08a, Table 1 (Detailed Requirements of Aviation Turbine Fuels)".Jet A and Jet A-1 have identical requirements except for freezing point. Jet A has a freeze point requirement of −40 °C (−40 °F) versus the Jet A-1 has a freeze point requirement of −47 °C (−52.6 °F), but the fuel purchaser and the fuel supplier may agree on other freezing points.

Table 2

Alternative Distillate Fuels - Cold Weather Applications	
Specification	**Grade**
"MIL-DTL-5624U"	JP-5
"MIL-DTL-83133F"	JP-8
"ASTM D1655-08a"	Jet A, Jet A-1

These fuels are lighter than the No. 2 grades of fuel. The cetane number of the fuels in table 2 must be at least 40. If the viscosity is below 1.4 cSt at 40 °C (104 °F), use the fuel only in temperatures below 0 °C (32 °F). Do not use any fuels with a viscosity of less than 1.2 cSt at 40 °C (104 °F).

Note: Fuel cooling may be required in order to maintain the minimum viscosity of 1.4 cSt at the fuel injection pump.

Note: These fuels may not prove acceptable for all applications.

Renewable and Alternative Fuels

Renewable fuels are derived from renewable resources such as planted crops and crop residues (referred to as biomass), waste, algae, cellulosic material, yard, and food waste, and so on. Renewable fuels reduce

the carbon footprint of the fuels compared to fossil fuels on a Life Cycle Analysis basis. Cat, through sustainability initiatives, supports the development and use of renewable fuels.

Renewable fuels (other than biodiesel) and alternative fuels (such as but not limited to Gas-to-Liquid fuel) are typically hydrocarbons (composed of carbon and hydrogen). An exception is biodiesel, which is an oxygenated renewable fuel. Biodiesel is discussed in a separate article in this Fuel section. Significant research is on going to develop renewable fuels and production economy.

Cat is not in a position to test all varieties of renewable and alternative fuels that are advertised in the market place. Before operating on any fuels other than diesel fuel or biodiesel (as discussed in this Fuels section), consult with the fuel supplier and with your Cat dealer. Due to the nature of the hydrocarbons that make up some alternative fuels in the marketplace, the fuel may inherently have poor lubricity, poor cold-weather performance. The fuel may potentially have compatibility issues with fuel system elastomers.

If a renewable or alternative fuel fulfills the performance requirements described in Cat Fuel Specification, the latest version of "ASTM D975" or the latest version of "EN 590", then this fuel or a blend of this fuel (blended with appropriate distillate diesel fuel) can be used as a direct replacement of petroleum diesel in Cat engines.

Cat is following the development of renewable and alternative fuels and the respective fuel specifications to ensure successful application of these fuels in the engines. Information and guidelines will be published as the production of these fuels becomes established.

Aftermarket Fuel Additives

There are many different types of fuel additives that are available to use. Cat does not generally recommend the use of fuel additives.

In special circumstances, Cat recognizes the need for fuel additives. Fuel additives should be used with caution. The additive may not be compatible with the fuel. Some additives may precipitate. This action causes deposits in the fuel system. The deposits may cause seizure. Some additives may plug fuel filters. Some additives may be corrosive, and some additives may be harmful to the elastomers in the fuel system. Some additives may damage emission control systems. Some additives may raise fuel sulfur levels above the maximum allowed by the United States (U.S.) Environmental Protection Agency (EPA) or other regulatory agencies. Consult your fuel supplier for those circumstances when fuel additives are required. Your fuel supplier can make recommendations for additives to use and for the proper level of treatment.

Note: Metallic fuel additives can cause fuel system/injector fouling and after treatment device fouling. Cat discourages the use of metallic fuel additives in most applications. Metallic fuel additives should only be used in applications where the use is recommended by Cat.

Note: Diesel fuel additives/conditioners may not improve markedly poor diesel fuel properties enough to make the fuel acceptable for use.

Note: For best results, your fuel supplier should treat the fuel when additives are needed.

Cat Diesel Fuel Conditioner

Note: Cat Diesel Fuel Conditioner, part number 256-4968, is the only fuel additive available to the end user that is tested and approved by Cat for use in Cat diesel engines.

Cat Diesel Fuel Conditioner is a proprietary metal and ash free formulation that has been extensively tested for use with distillate diesel fuels for use in Cat diesel engines. Cat Diesel Fuel Conditioner helps address many of the challenges that various fuels worldwide present in regards to fuel life/stability, engine startability, injector deposits, fuel system life, and long-term engine performance.

Note: Diesel fuel additives/conditioners may not improve markedly poor diesel fuel properties enough to make the fuel acceptable for use.

Note: For maximum overall benefits, ask your fuel supplier to add Cat Diesel Fuel Conditioner at the recommended treat rate before fuel delivery. You may add Cat Diesel Fuel Conditioner at the recommended treat rate during the early weeks of fuel storage. Follow all applicable national, regional, and local laws, mandates, and regulations concerning the use of diesel fuel conditioners/additives.

Cat Diesel Fuel Conditioner is a proven high performance, multipurpose diesel fuel conditioner that is designed to improve:

- Fuel economy (through fuel system cleanup)
- Lubricity
- Oxidation stability
- Detergency/dispersancy
- Moisture dispersancy
- Corrosion protection
- Cetane (typically 2-3 cetane numbers)

Cat Diesel Fuel Conditioner has been validated through lab and field tests to improve/reduce diesel fuel consumption and emissions for typical fleets through fuel system/injector cleanup. The conditioner helps maintain new engine performance by keeping fuel systems clean. While fuel system/injector cleanup takes place over time, maintaining fuel system/injector cleanliness is an ongoing process.

Data indicates that average fuel economy improvements across typical fleets may be in the 2-3+ percentage range. Improvements may vary based on factors such as engine model, age and condition of the engine, and application.

Cat Diesel Fuel Conditioner also reduces the formation of gums, resins, and sludge, and disperses insoluble gums. The conditioner can dramatically improve fuel storage life, reduce fuel-related engine deposits and corrosion, and extend fuel filter life.

NOTICE

Use of Cat Diesel Fuel System Cleaner or Cat Diesel Fuel System Conditioner does not lessen the responsibility of the engine owner and/or responsibility of the fuel supplier to follow all industry standard maintenance practices for fuel storage and for fuel handling. Refer to the "General Fuel Information" article in this Special Publication for additional information. Additionally, use of Cat Diesel Fuel System Cleaner or Cat Diesel Fuel System Conditioner does NOT lessen the

responsibility of the owner of the engine to use appropriate diesel fuel. Refer to the "Fuel Specifications" section in this Special Publication (Maintenance Section) for guidance.

Cat strongly recommends the use of Cat Diesel Fuel Conditioner with biodiesel and biodiesel blends. Cat Diesel Fuel Conditioner is suitable for use with biodiesel/biodiesel blends that meet Cat biodiesel recommendations and requirements. **Not all fuel additives are suitable for use with biodiesel/biodiesel blends.** Read and follow all applicable label usage instructions. Also, refer to this Special Publication, "Distillate Diesel Fuel" article and also refer to the "Biodiesel" article, which includes Cat biodiesel recommendations and requirements.

Cat Diesel Fuel Conditioner has proven to be compatible with existing and U.S. EPA 2007 on-highway certified diesel engine emission control catalysts and particulate filters.

Note: When used as directed, Cat Diesel Fuel Conditioner will not raise fuel sulfur levels measurably in the final fuel/additive blend. In the U.S. the current formulation of Cat Diesel Fuel Conditioner must be blended in at the recommended treat-rate at the fuel supplier/distributor level for use in on-highway or other applications where use of ULSD fuel is mandated (15 ppm or less fuel sulfur). Follow all applicable national, regional, and local laws, mandates, and regulations concerning the use of diesel fuel conditioners/additives.

NOTICE

When used as directed Cat Diesel Fuel Conditioner will not raise fuel sulfur levels measurably in the final fuel/additive blend. Follow all applicable national, regional, and local laws, mandates, and regulations concerning the use of diesel fuel conditioners/additives.

Cat Diesel Fuel System Cleaner

Note: Cat Diesel Fuel System Cleaner, part number 343-6210, is the only fuel system cleaner available to the end user that is tested and approved by Cat for use in Cat diesel engines.

Cat Diesel Fuel System Cleaner is a proven high performance detergent product designed for cleaning deposits that form in the fuel system. Deposits in the fuel system reduce system performance and can increase fuel consumption. Cat Diesel Fuel System Cleaner addresses the deposits formed due to the use of degraded diesel fuel, poor quality diesel fuel, and diesel fuel containing high quantities of high molecular weight compounds. Cat Diesel Fuel System Cleaner addresses deposits formed due to the use of biodiesel, biodiesel blends, and biodiesel that does not meet the appropriate quality specifications. Continued use of Cat Diesel Fuel System Cleaner is proven to inhibit the growth of new deposits.

Cat Diesel Fuel System Cleaner can be added directly to diesel fuel, biodiesel, or biodiesel blends. Cat Diesel Fuel System Cleaner is a United States Environmental Protection Agency registered fuel additive that can be used with Ultra Low Sulfur Diesel Fuel. In addition this cleaner is appropriate for use with other ultra low, low, and higher sulfur diesel fuels around the world.

Cat Diesel Fuel System Cleaner is a proven high performance cleaner that is designed to perform the following:

- Clean performance-robbing fuel system deposits
- Restore fuel economy losses resulting from injector deposits
- Restore power losses resulting from injector deposits
- Eliminate visible black exhaust smoke resulting from injector deposits
- Prevent the formation of new fuel-related deposits

For engines experiencing problems such as power loss, increased fuel consumption, or black smoke due to the presence of fuel-related deposits in fuel injectors, a high-strength cleaning cycle is recommended. Add one 0.946L (32 oz.) bottle of Cat Diesel Fuel System Cleaner per 250 L (65 gal) of fuel. One bottle corresponds to a treat rate of 0.4% by volume. Prior to refueling, pour Cat Diesel Fuel System Cleaner directly into the fuel tank, then refill with fuel. The refilling process should give satisfactory mixing of the cleaner. The cleaner will begin to be effective immediately. Testing has shown most deposits are cleaned and related issues are resolved after 30 hours of operating the engine on fuel with the cleaner. For maximum results, continue to use at this treat rate for up to 80 hours.

To prevent the return of fuel-related deposits, Cat Diesel Fuel System Cleaner, add the cleaner to the fuel at a 0.2% treat rate. In this case, one 0.946L (32 oz.) bottle will treat 500 L (130 gallons) of fuel. Cat Diesel Fuel System Cleaner can be used on an on-going basis with no adverse impact on engine or fuel system durability.

NOTICE

Use of Cat Diesel Fuel System Cleaner or Cat Diesel Fuel System Conditioner does not lessen the responsibility of the engine owner and/or responsibility of the fuel supplier to follow all industry standard maintenance practices for fuel storage and for fuel handling. Refer to the "General Fuel Information" article in this Special Publication for additional information. Additionally, use of Cat Diesel Fuel System Cleaner or Cat Diesel Fuel System Conditioner does NOT lessen the responsibility of the owner of the engine to use appropriate diesel fuel. Refer to the "Fuel Specifications" section in this Special Publication (Maintenance Section) for guidance.

Cat strongly recommends that Cat Diesel Fuel System Cleaner be used with biodiesel and biodiesel blends. Cat Diesel Fuel System Cleaner is suitable for use with biodiesel/biodiesel blends that meet Cat biodiesel recommendations and requirements. Not all fuel cleaners are suitable for use with biodiesel/biodiesel blends. Read and follow all applicable label usage instructions. Also, refer to this Special Publication, "Distillate Diesel Fuel", article and also refer to the "Biodiesel" article, which includes Cat biodiesel recommendations and requirements.

Cat Diesel Fuel System Cleaner has proven to be compatible with existing and U.S. EPA Tier 4 nonroad certified diesel engine emission control catalysts and particulate filters.

Note: When used as directed, Cat Diesel Fuel System Cleaner will not raise fuel sulfur levels measurably in the final fuel/additive blend. Follow all applicable national, regional, and local laws, mandates, and regulations concerning the use of diesel fuel conditioners/additives.

NOTICE

When used as directed Cat Diesel Fuel System Cleaner will not raise fuel sulfur levels measurably in the final fuel/additive blend. But, in the U.S., aftermarket fuel additives (retail consumer level versus bulk fuel additives used at the fuel supplier/distributor level) with more than 15 ppm sulfur are NOT allowed to be used in applications where ULSD usage is mandated (15 ppm or less fuel sulfur). Note that Cat Diesel Fuel System Cleaner contains less than 15 ppm of sulfur and is acceptable for use with ULSD fuel.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05423977

Biodiesel

SMCS - 1280

NOTICE

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

Biodiesel is a fuel that can be made from various renewable resources that include vegetable oils, animal fat, and waste cooking oil. Soybean oil and rapeseed oil are the primary vegetable oil sources. The raw oils or animal fats are chemically processed (esterified) to form a fatty acid methyl ester (referred to as FAME). The esterified product (FAME) is biodiesel fuel that can be used in compression ignition engines. Without the chemical processing referred to as esterification, the oils or fats are not suitable for use as fuel in compression ignition engines. To use any of the oils or fats listed above as fuel, the oil or fat must be esterified and the water and contaminants removed.

Fuel made of 100 percent FAME is referred to as B100 biodiesel or neat biodiesel.

Biodiesel can be blended with distillate diesel fuel. The blends can be used as fuel. The most commonly available biodiesel blends are B5, which is 5 percent biodiesel and 95 percent distillate diesel fuel, and B20, which is 20 percent biodiesel and 80 percent distillate diesel fuel. Note the percentages are volume-based.

U.S. distillate diesel fuel specification "ASTM D975-09a" includes up to B5 (5 percent) biodiesel. Currently, any diesel fuel in the U.S. may contain up to B5 biodiesel fuel.

European distillate diesel fuel specification "EN 590" includes up to B5 (5 percent) and in some regions up to B7 (7 percent) biodiesel. Any diesel fuel in Europe may contain up to B5 or in some regions up to B7 biodiesel fuel.

Note: The user of the engine has the responsibility of using the correct fuel that is recommended by the manufacturer. The fuel must be allowed by the U.S. EPA and other appropriate regulatory agencies.

Cat is not in a position to evaluate the many variations of biodiesel and the long-term effects on performance, durability, or compliance to emissions standards for Cat products.

Note: In order to align Cat recommendations with the latest revision of "ASTM D7467" specification for B6-B20 blends and to ensure that biodiesel fuel meets defined quality standards, Cat recommendations for acceptable biodiesel blend for most engines have been changed to B20. Details on the use of higher blends are given in this "Biodiesel" section of this Special Publication.

NOTICE

Failures that result from the use of any fuel are not Caterpillar factory defects. Therefore, the cost of repair would NOT be covered by the Caterpillar warranty for materials and/or the warranty for workmanship.

Recommendations for the Use of Biodiesel in Cat Nonroad Engines

Refer to table 2 and 3 to the details provided in this section for biodiesel fuel requirements.

In order to be acceptable for blending, the biodiesel constituent must meet the requirements that are listed in "Cat Specification for Biodiesel Fuel" in this Special Publication, the latest edition of "ASTM D6751", and/or the latest edition of "EN14214".

Biodiesel blends of up to B5 must meet the requirements for the distillate diesel fuel that are listed in the "Cat Specification for Distillate Diesel Fuel for On-Highway Engines" in this Special Publication, the latest edition of "ASTM D975", and/or the latest edition of "EN 590".

Biodiesel blends of B6 to B20 must meet the requirements listed in the latest edition of "ASTM D7467" (B6 to B20) **and** must be of an API gravity of 30-45.

Distillate diesel fuels that meet the requirements of "Cat Specification for Distillate Diesel Fuel for On-Highway Engines" in this Special Publication, the "National Conference on Weights and Measures "(NCWM) Premium Diesel definition, the latest edition of "ASTM D975 S15" designation, and/or the latest edition of "EN 590", sulfur free designation. No. 1-D and No. 2-D are examples of fuels that are acceptable for creating biodiesel blends.

For Tier 4 applications in the U.S., the diesel fuel portion of the final blend must meet the requirements of S15 fuels (15 ppm sulfur) designations in the latest edition of "ASTM D975" specification. For Stage IIIB and later applications in EU, the diesel fuel portion of the final blend must meet the requirements for sulfur free (10 ppm sulfur) designation in the latest edition of "EN 590". The final blend must have 15 ppm sulfur.

Table 1

Recommendations for biodiesel fuel application in Cat Off-Highway engines		
Production year/Tier /Stage	**Engine model**	**Biodiesel acceptable blend levels**
Tier 2 / Stage II or earlier Emissions Regulations	3003-3034, 3044, 3046, 3054, 3056, 3064, and 3066, 3054C (mechanical), 3054E (electronic) and 3056E (electronic). C0.5, C0.7, C1.1, C1.5, C1.6, C2.2, C3.4, C2.6, C3.3B. Certain C4.4 (S/N 44400001-04303), Certain C6.6 (S/N CE600001-14623 (Machines) and S/N 66600001-09015 (Industrial))	Up to B5 (1)

Tier 4 Interim / Stage IIIa (without aftertreatment)	C1.8, C2.4, C3.3B, C3.4	
Tier 4 Interim / Stage IIIb (with aftertreatment devices)	C3.8	
Tier 4 Interim / Stage IIIb and beyond (with aftertreatment devices)	ACERT engines: C3.4B, C4.4, C6.6, C7.1, C9.3, C13, C15, C18, C27, and C32	Up to B20
All years post Tier 2/Stage II	C0.5 through C2.2 (2) Certain C4.4 ACERT (S/N C4E05524-Up (Machines) and 44404304 -Up (Industrial)), C4.4 (Mechanical), C6.4, and certain C6.6 ACERT (S/N CE614624-Up (Machines) and 66609016-Up (Industrial))	Up to B20 (For use of higher blend levels up to B100, consult your Cat dealer)
All years	3114, 3116, 3126, 3176, 3196, 3208, 3306 3406, 3408, 3412, 3456, 3406E, 3408E, 3412E, 3500 Series, and 3600 Series C-9, C10, C-12, C-15, C-16, C-18, C280 Series, CM20, CM25, and CM32 ACERT engines (1)sure C7, C9, C9.3, C11, C13, C15, C18, C27, C32, and C175	

(1) Up to B7 can be used in these engines. B7 has to be per Cat distillate diesel fuel specification, "ASTM D975 or EN590".

(2) Models without aftertreatment only

Table 2

Fuel Recommendations for Cat Nonroad Engines		
Biodiesel Blend Stock	Final Blend	Distillate Diesel Fuel used for blending
Cat biodiesel specification, (1) "ASTM D6751" or "EN14214"	B5: Cat distillate diesel fuel specification, (2) "ASTM D975" or "EN590"	Cat distillate diesel fuel specification, "ASTM D975" or "EN590"
	B20: "ASTM D7467" and "API" gravity 30-45	

(1) Refer to Table 4 in the Biodiesel section of this Special Publication.

(2) Refer to "Cat Specification for Distillate Diesel Fuel for On-Highway Engines" in the Fuel section of this Special Publication.

Note: For Tier 4 certified/ Stage IIIB and newer engine models that are equipped with aftertreatment devices, use only the biodiesel blend levels that are recommended in "Recommendations for biodiesel fuel application in Cat Nonroad Engines" in this Special Publication, table 1. Use of biodiesel blend levels higher than the recommendations provided in table 1 can adversely affect engine and aftertreatment components due to contaminants. The repair of any engine or aftertreatment components due to such contamination or due to other biodiesel impacts would not be covered under the Cat warranty. Refer to

"Additional Maintenance Requirements" topic in this Special Publication, "Biodiesel" article.

Note: For 2006 and older engine models, for use of blends of biodiesel above B20 (20 percent), refer to "Guidelines and potential impacts associated with the use of biodiesel and biodiesel blends" table 3 in this Special Publication for the guidelines and impacts of using high biodiesel blends. Consult your Cat dealer for guidance. Use the Cat S·O·S Services oil analysis program when biodiesel or blends of biodiesel that are B20 (20 percent) or above are used.

Either "ASTM D7371" - "Test Method for Determination of Biodiesel (Fatty Acid Methyl Esters) Content in Diesel Fuel Oil Using Mid Infrared Spectroscopy (FTIR-ATR-PLS Method)" or "EN 14078" "- Liquid Petroleum Products - Determination of fatty acid methyl esters (FAME) in middle distillates -Infrared spectroscopy method" can be used for determining the volume percent biodiesel in a biodiesel blend.

For applications running biodiesel or biodiesel blends, the recommendation is to use either Cat Diesel Fuel System Cleaner (Part number 343-6210) or Cat Diesel Fuel Conditioner (Part number 256-4968). Cat Diesel Fuel System Cleaner, used as needed or on an on-going basis, is most effective at cleaning and preventing the formation of fuel-related deposits. Cat Diesel Fuel Conditioner can be used to improve fuel stability and can help prevent the formation of fuel-related deposits.

Additional maintenance requirements

When biodiesel fuel is used, crank case oil and aftertreatment systems may be influenced. This influence is due to the chemical composition and characteristics of biodiesel fuel such as density and volatility. Chemical contaminants can be present in this fuel, such as phosphorous, alkali, and alkaline metals (sodium, potassium, calcium, and magnesium).

- Crankcase oil fuel dilution can be higher when biodiesel and/or biodiesel blends are used. This increased level of fuel dilution when using biodiesel and/or biodiesel blends is related to the typically lower volatility of biodiesel. In-cylinder emissions control strategies utilized in many of the latest engine designs may lead to a higher level of biodiesel concentration in the sump. The long-term effect of biodiesel concentration in crankcase oil is currently unknown. **The use of Cat S·O·S Services oil analysis is recommended when up to B20 (20 percent) and lower biodiesel blends are used. Analysis is required when using biodiesel/biodiesel blends that are B20 or above.** When requesting oil analysis, be sure to note the level of biodiesel being used (B5, B20, and so on).

- Biodiesel fuel contains metal contaminants (phosphorous, sodium, potassium, calcium, and/or magnesium) that form ash products upon combustion in the diesel engine. The ash can affect the life and performance of aftertreatment emissions control devices and can accumulate in Diesel Particulate Filters (DPF). The ash accumulation may cause the need for more frequent ash service intervals and/or cause loss of performance.

Fuel System Deposits

Biodiesel and biodiesel blends are known to cause an increase in fuel system deposits, most significant of which are deposits within the fuel injector. These deposits can cause a loss in power due to restricted or modified fuel injection or cause other functional issues associated with these deposits. Cat Diesel Fuel System Cleaner (part number 343-6210) is most effective in cleaning and preventing the formation of deposits. Cat Diesel Fuel Conditioner (part number 256-4968) helps to limit deposit issues by improving the stability of biodiesel and biodiesel blends. The production of new deposits is also inhibited. **Therefore, the use of Cat Diesel Fuel System Cleaner and/or Cat Diesel Fuel Conditioner is**

recommended when running any biodiesel or biodiesel blends. Refer to this Special Publication, "Distillate Diesel Fuel", article, "Cat Diesel Fuel Conditioner" and "Cat Diesel Fuel System Cleaner" topics in this Special Publication, "Distillate Diesel Fuel" for additional information.

Consult your Cat dealer for availability of Cat Diesel Fuel System Cleaner and Cat Diesel Fuel Conditioner.

Guidelines

Biodiesel that meets the requirements that are listed in the "Cat Specification for Biodiesel Fuel", the latest edition of "ASTM D6751", or the latest edition of "EN 14214" is not expected to pose major problems when blended with an acceptable distillate diesel fuel at the maximum stated percentages. However, the following recommendations should be followed:

Note: For these recommendations, the cautions, guidelines, and recommendations applicable to biodiesel (B100) are also applicable to biodiesel blends (B2, B5, B20, and so on). The impacts of biodiesel blends higher than B20 are, in general, more severe than the impacts of biodiesel blends of B20 or lower. Refer to Table 3 of this Biodiesel section for more details.

Note: Fuel storage tanks need to be cleaned thoroughly before converting to biodiesel/biodiesel blends. Conversion to biodiesel/biodiesel blends can loosen fuel system and fuel storage tank deposits. All tank filters and engine filters must shorten the change intervals for an extended time in order to allow for this cleaning effect.

In North America, the use of biodiesel from "BQ-9000" accredited producers and marketers is required. Look for the "BQ-9000" biodiesel quality accreditation program certification logo that is available to distributors that meet the requirements of "BQ-9000". For more information on the "BQ-9000" program, go to "www.BQ-9000.org".

In other areas of the world, the use of biodiesel that is "BQ-9000" accredited and certified, or that is accredited and certified by a comparable biodiesel quality body to meet similar biodiesel quality control standards, is required.

Information provided in this table refers to biodiesel and biodiesel blends that fully comply with the appropriate specifications as described in the "Biodiesel" section of this Special Publication and to handling and maintenance procedures that follow recommended guidelines.

Table 3

Risks and Guidelines associated with the use of biodiesel and biodiesel blends (1)				
Paragraph reference	Risk/Recommendation	B5	B6-B20	B21-B100
1	Risk of reduction of oil change interval	Negligible	Low	Medium
2	Risk of fuel filters compatibility	Negligible	Low	Medium
3	Risk of reduction of fuel filter change interval	Negligible	Medium	High

4	Bulk filtration of biodiesel	≤4 microns absolute	≤4 microns absolute	≤4 microns absolute
5	Energy content of biodiesel	Similar to Diesel	Minor loss of 1-2 percent	Detectable loss of 5-8 percent
6	Compatibility with elastomers	Low	Low-Medium	High
7	Risk of low ambient temperature problems for both storage and operation.	Medium	Medium-High	High
8	Feedstock impact	Medium	Medium	High
9	Risk of oxidation stability and Injector deposits	Low	Medium	High
10	Oxidation stability-Duration of storage	Similar to Diesel fuel	8 months (2)	4 months (3)
11	Use in engines with limited operational time	Maximum allowed	Unacceptable	Unacceptable
12	Risk of microbial contamination and growth	Medium	High	High
13	Need for water removal	Medium	High	High
14	Oil-side seal incompatibility	Negligible	Medium	High
15	Metal incompatibility	Negligible	Low	High

(1) Refer to the paragraph reference number for details of each listed Risk/Recommendation.

(2) Testing of B20 blends is recommended at 4 months of storage and on a monthly basis thereafter. Tests should include oxidation, acid number, viscosity, and sediments.

(3) B100 stored for over 2 months should be tested every 2 weeks to ensure that the fuel is not degraded. Tests should include oxidation, acid number, viscosity, and sediments. The use of appropriate additives is required if B100 is stored more than 4 months. Consult your fuel supplier for more information. In addition, B100 should be stored at temperatures of 3 degrees C to 6 degrees C (5 degrees F to 10 degrees F) above the cloud point.

The following are the paragraph reference numbers:

1. The oil change interval can be negatively affected by the use of biodiesel. Use S·O·S Services oil analysis in order to monitor the condition of the engine oil. S·O·S Services oil analysis will also help determine the oil change interval that is optimum.

2. Confirm with the filter manufacturer that the fuel filter/filters to be used are compatible with biodiesel. Fuel water separators are preferred when biodiesel is used.

   Note: Cat fuel filters and Cat fuel water separators are compatible with biodiesel fuel.

3. Conversion to biodiesel can loosen fuel system deposits. Fuel filter change intervals must be shortened for an extended time in order to allow for this cleaning effect. Filter change interval of 50 hours or less is recommended following the initial conversion to B20 biodiesel blend.

4. Filter biodiesel and biodiesel blends through a fuel filter with a rating of four microns(c) absolute or less. Filters should be located on the device that dispenses the fuel to the fuel tank for the engine.

Filters should be located on the device that dispenses fuel from the bulk storage tank. Series filtration is recommended.

5. In a comparison of distillate fuels to biodiesel, neat biodiesel (B100) typically provides less energy per gallon by 5 percent to 8 percent. Do NOT attempt to change the engine rating in order to compensate for the power loss. Engine problems may occur when the engine is converted back to 100 percent distillate diesel fuel. Any adjustments to the engine to compensate for the power loss may result in violation of emissions regulations such as the U.S. EPA anti-tampering provisions.

6. Compatibility of the elastomers with biodiesel is currently being monitored. The condition of seals and hoses should be monitored regularly. Biodiesel may soften, degrade, or leak from some types of elastomers used in seals and hoses. The higher biodiesel blend has a greater the risk of elastomer-related issues.

    a. In general, Cat engines built early to mid 90s use Viton seals and Viton O-rings in the fuel system. Viton is compatible with biodiesel.

    b. Nitrile hoses typically used in some fuel transfer lines are not compatible with biodiesel. Monitor the condition of the hoses and confirm with the hose manufacturer that the hoses are compatible with the biodiesel blend used. If necessary, replace with hoses of compatible materials.

7. Biodiesel may pose low ambient temperature problems for both storage and operation. At low ambient temperatures, biodiesel fuel may need to be stored in a heated building or a heated storage tank. The fuel system may require heated fuel lines, filters, and tanks. Filters may plug and fuel in the tank may solidify at low ambient temperatures if precautions are not taken. Consult your biodiesel supplier for assistance in the blending and attaining of the proper cloud point for the fuel.

    Note: The performance of cold flow improvers can be reduced in the presence of biodiesel fuel. Consult the fuel supplier for appropriate cold flow improvers if needed.

8. Biodiesel can be produced using various renewable sources. The source used can affect product performance. Two of the fuel characteristics affected are cold flow and oxidation stability. Cold flow affects filter plugging and oxidation stability affects deposit formation and biodiesel fuel storage duration and life. Consult your fuel supplier for guidance.

9. Biodiesel has poor oxidation stability, which may accelerate fuel oxidation in the fuel system. Engines with an electronic fuel system operate at higher temperatures, which may accelerate fuel oxidation. Oxidized fuel can form deposits in fuel injection systems and in fuel systems in general. Refer to this Special Publication, "Distillate Diesel Fuel" article, "Aftermarket Fuel Additives", "Cat Diesel Fuel Conditioner", and "Cat Diesel Fuel System Cleaner" topics for information concerning oxidation stability and other fuel additives.

10. Poor oxidation stability of biodiesel can result in long-term storage problems. Biodiesel should be used within a limited time from production. In order to ensure appropriate storage duration, testing of the stored biodiesel is recommended. Tests should include oxidation, acid number, viscosity, and sediments. Tests should be conducted periodically to ensure that biodiesel is per specification. Antioxidants are recommended to improve stability of biodiesel. Cat Diesel Fuel Conditioner, part number 256-4968, or appropriate commercial additives are recommended. Consult your fuel supplier for more information.

    a. B20 biodiesel blend can generally be stored up to 8 months. Testing of B20 blends is recommended at 4 months of storage and on a monthly basis thereafter to ensure that the fuel

has not degraded.

b. B100 biodiesel can generally be stored up to 4 months. Testing of B100 is recommended at 2 months of storage and every two weeks thereafter to ensure that the fuel has not degraded. The use of appropriate additives is required if B100 is stored more than 4 months. Consult your fuel supplier for more information.

c. B100 should be stored at temperatures of 3 degrees C to 6 degrees C (5 degrees F to 10 degrees F) above the cloud point.

11. Due to poor oxidation stability and other potential issues, Cat recommends that engines with limited operational time (such as seasonal use or standby power generation) either not use biodiesel/biodiesel blends or, while accepting some risk, limit biodiesel to a maximum of B5. Examples of applications that should limit the use of biodiesel are the following: Standby Generator sets and certain emergency vehicles. For more information, refer to the "Seaconal Operation" section.

    a. Addition of Cat Diesel Fuel Conditioner, part number 256-4968, or an appropriate commercial additive containing antioxidants/oxidation stability improvers, is recommended for standby generator sets and emergency vehicles using biodiesel/biodiesel blends. The conditioner should be added when the engine is fueled or as early as possible when the fuel is delivered and stored. Preferably, the conditioner or additive should be added as soon as possible after the fuel is produced.

    b. For standby generator sets and emergency vehicles that use biodiesel, sample the fuel in the engine tank monthly. Test the fuel for acid number and oxidation stability. If the test results show that the fuel is degraded and that the fuel is not per the appropriate specifications (provided in Table 4 in this "Biodiesel" section), drain the tank, flush the engine by running using high-quality fuel. Repeat the process until the system is clean. Refill with high-quality fuel following the recommendations provided in this "Fuel" section

    c. For standby generator sets and emergency vehicles that use biodiesel, Cat recommends that the fuel oxidation stability is 10 hours or more per "EN 14112" test method.

12. Biodiesel is an excellent medium for microbial contamination and growth. Microbial contamination and growth can cause corrosion in the fuel system and premature plugging of the fuel filter. Consult your supplier of fuel and additive for assistance in selecting appropriate anti-microbial additives.

13. Care must be taken in order to remove water from fuel tanks. Water accelerates microbial contamination and growth. When biodiesel is compared to distillate fuels, water is naturally more likely to exist in the biodiesel.

14. Biodiesel dilution of engine oil may result in oil side leaks due to incompatibility of the seals that are typically used on the oil side. Liner seals and oil cooler seals may be affected by biodiesel dilution. Monitor the condition of the oil side seals and consult your Cat dealer for appropriate replacement if needed.

15. Biodiesel is not compatible with some metals. Biodiesel of blends higher than B20 will oxidize and form sediments upon long-term contact with lead, zinc, tin, copper, and copper alloys such as brass and bronze. Consult your dealer for more information.

Note: The use of biodiesel at a B2 level improves the lubricity of the final blend by an estimated 66 percent. Increasing the blend level higher than B2 does not improve the lubricity any further.

Seasonal Operation

Cat recommends that seasonally operated engines have the fuel systems, including fuel tanks, flushed with conventional diesel fuel before prolonged shutdown periods. Applications that should seasonally flush the fuel system include school buses (U.S.) and farm machinery.

Perform the following process before shutting down the engine for prolonged periods:

1. Operate the engine until the fuel level in the tank is low.
2. Refill the fuel tank with high quality conventional distillate diesel fuel.
3. Repeat steps 1 and 2 a minimum of two times before the engine is shut down for prolonged periods.

If distillate fuel is not available to operate the engine as described above, while accepting some risk, limit biodiesel to a maximum of B5. Follow the recommendations provided in this section and the guidelines given below to reduce the risk:

- Addition of Cat Diesel Fuel Conditioner, part number 256-4968, or an appropriate commercial additive containing antioxidants/oxidation stability improvers, is recommended prior to engine shutdown for prolonged periods. The conditioner should be added when the engine is fueled. Preferably, the conditioner is added to the fuel as soon as possible after the fuel production.
- Addition of Cat Diesel Fuel System Cleaner, part number 343-6210, or an appropriate commercial cleaner is recommended when the engine is first operated after the prolonged shutdown period and preferably for a total of two tanks of fuel. Follow the recommendations provided in the Cat Diesel Fuel System Cleaner section in the "Fuel" article in this Special Publication.

Consult your Cat dealer for the availability of Cat Diesel Fuel Conditioner and Cat Diesel Fuel System Cleaner.

Biodiesel Specification

Biodiesel fuel used that is used for blending must meet the requirements in the following table.

The final blend of biodiesel as used in the engine must meet the requirements that are stated in table 2 this "Biodiesel" article.

B100 intended for blending into diesel fuel that is expected to give satisfactory vehicle performance at fuel temperatures at or below -12° C (10.4° F) shall comply with a cold soak filterability limit of 200 seconds maximum. Passing the "ASTM D6751" 200 seconds Cold Soak Filterability test limit does not guarantee cold performance for all biodiesel blends at all possible fuel temperatures, but biodiesel that fails this Cold Soak Filterability test requirement will produce biodiesel blends that will likely plug fuel filters when fuel temperatures are below -12° C (10.4° F).

Table 4

Cat Specification for Biodiesel Fuel				
Property	**Test Method**	**Test Method**	**Units**	**Limits**

	United States	**International**	**Specific Properties of Fuel**	
Density at 15°C	"ASTM D1298"	"ISO 3675"	g/cm^3	0.86-0.90
Viscosity at 40°C	"ASTM D445"	"ISO 3104"	mm^2/s (cSt)	1.9-6.0
Flash Point	"ASTM D93"	"ISO 3679"	°C	93 minimum
Pour Point - Summer - Winter	"ASTM D97"	"ISO 3016"	°C	6 °C (10 °F) minimum below ambient temperature
Cloud Point	"ASTM D2500"		°C	Report
Sulfur Content	"ASTM D5453"	"ISO 20846" "ISO 20884"	percent weight	0.0015 maximum
Distillation - 10 percent Evaporation - 90 percent Evaporation	"ASTM D1160"		°C	To Be Determined 360
Carbon Residue, Conradson (CCR)	"ASTM D4530"	"ISO 10370"	percent weight	0.05 maximum
Cetane Number	"ASTM D613"	"ISO 5165"		45 minimum
Sulfated Ash	"ASTM D874"	"ISO 3987"	percent weight	0.02 maximum
Water/Sediment Content	"ASTM D2709"	"ISO 12937"	percent volume	0.05 maximum
Copper Corrosion	"ASTM D130"	"ISO 2160"		No. 1
Oxidation Stability	"EN 14112"	"EN 14112"	hours	3 minimum
Esterification	"EN 14103"	"EN 14103"	percent volume	97.5 minimum
Acid Value	"ASTM D664"	"EN 14104"	mg KOH/g	0.5 maximum

Methanol Content	"EN 14110"	"EN 14110"	percent weight	0.2 maximum
Monoglycerides	"ASTM D6584"	"EN 14105"	percent weight	0.8 maximum
Diglycerides	"ASTM D6584"	"EN 14105"	percent weight	0.2 maximum
Triglycerides	"ASTM D6584"	"EN 14105"	percent weight	0.2 maximum
Free Glycerin	"ASTM D6584"	"EN 14105"	percent weight	0.02 maximum
Total Glycerin	"ASTM D6584"	"EN 14105"	percent weight	0.240 maximum
Phosphorus Content	"ASTM D4951"	"EN 14107"	percent weight	0.001
Calcium and Magnesium combined	"EN 14538"	"EN 14538"	ppm	5 maximum
Sodium and Potassium combined	"EN 14538"	"EN 14538"	ppm	5 maximum
Cold Soak Filterability	"ASTM D7501"	--	seconds	360 maximum
Cleanliness	"ASTM D7619"	"ISO 4406"	--	(1)

(1) Recommended cleanliness level for fuel as dispensed into machine or engine fuel tank is "ISO 18/16/13" or cleaner per "ISO 4406" or "ASTM D7619". Refer to the "Contamination Control" section in this Special Publication.

Note: Fuels that meet the most current revision level of "ASTM D6751" or "EN 14214" may be used for blending with an acceptable distillate fuel. The conditions, recommendations, and limits that are noted in this Biodiesel section apply.

Referenced Documents

Refer to the "Reference Material - Fuel" section of this Special Publication for the reference material for the information in this section.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05423971

Crude Fuel Oil

SMCS - 1280

Cat 3600 Series diesel engines and C280 Series diesel engines can operate with crude oil as fuel. Table 1 lists the requirements for crude oil that is acceptable for use in standard 3600 and C280 diesel engines. Do not use crude fuel oil in engines that are Tier 4 EPA certified.

Table 1

Crude Oil Specification for Cat 3600 and C280 Series Diesel Engines			
Specifications	**Requirements**	**ASTM Test**	**ISO Test**
Aromatics	35% maximum	"D1319"	"ISO 3837"
Ash	0.1% maximum (weight)	"D482"	"ISO 6245"
Carbon residue on 10% bottoms	3.5% maximum (weight)	"D524"	"ISO 4262"
Cetane number	40 minimum (1)	"D613" or "D6890"	"ISO 5165"
Cloud point	The maximum cloud point must not exceed the lowest expected ambient temperature.	-	-
Copper strip corrosion	No. 3 maximum	"D130"	"ISO 2160"
Distillation	10% at 282 °C (540 °F) maximum	"D86"	"ISO 3405"
	90% at 380 °C (716 °F) maximum		
	minimum of 60% cracking		
	10% maximum residue		
Reid Vapor pressure	138 kPa (20 psi) maximum	"D323"	"ISO 3007"
Salt	45.6 kg per 159 kL (100 lb per 1000 bbl)	"D3230"	-

	maximum		
Flash point	legal limit	"D93"	"ISO 2719"
API gravity	30 minimum 45 maximum	"D287"	-
Specific gravity (2)	0.8762 minimum 0.8017 maximum	(2)	(2)
Lighter fractions (3)	30% maximum	-	-
Fraction of kerosene and distillate (4)	30% minimum	-	-
Pour point	6 °C (10 °F) minimum below ambient temperature	"D97"	"ISO 3016"
Sulfur (5)	(5)	"D2622" or "D5453"	"ISO 20846" or "ISO 20884"
Viscosity (6)	1.4 cSt minimum and 20.0 cSt maximum as delivered to the fuel injection pumps	(6)	(6)
Water and sediment	0.5% maximum (volume)	"D1796"	"ISO 3734"
Vanadium	4 ppm maximum	"D5185-02"	-
Sodium	10 ppm maximum	"D5185-02"	-
Nickel	1 ppm maximum	"D5185-02"	-
Aluminum	1 ppm maximum	"D5185-02"	-
Silicon	1 ppm maximum	"D5185-02"	-
Gums and resins (7)	10 mg per 100 mL (5.8 grains/US gal) maximum	"D381"	"ISO 6246"
Lubricity (8)	0.52 mm (0.0205 inch) maximum at 60 °C (140 °F)	"D6079"	-

(1) A fuel with a higher cetane number may be required for operation at a higher altitude or in cold weather.

(2) The specific gravity limits are determined by the standards tables using the "ASTM D287" test method temperature of 15.56 °C (60 °F). Also by the standards tables, the equivalent kg/m^3 (kilograms per cubic meter) using the "ASTM D287" test method temperature of 15.56 °C (60 °F) for the minimum gravity of 30 is 875.7 kg/m^3, and for the maximum API gravity of 45 is 801.3 kg/m^3.

(3) Fractions that are boiled off at temperatures below 200 °C (392 °F)

(4) Fractions that are boiled off at temperatures between 200 °C (392 °F) and the cracking point.

(5) Sulfur in the fuel should be per the International Maritime Organization (IMO) regulations or as specified by the applicable jurisdiction. Refer to the specific engineOperation and Maintenance Manual to determine the maximum level of sulfur permissible where allowed by the applicable jurisdiction. Fuel sulfur levels affect exhaust emissions. High sulfur fuels increase the potential for corrosion of internal components. Fuel sulfur levels above 1% may significantly shorten the oil change interval. Caterpillar strongly recommends that S·O·S Services oil analysis is used to determine oil change intervals when the fuel sulfur levels are above 1%. For additional information, see this Special Publication, Engine Oil and Special Publication, SoOoS Services Oil Analysis topic. When the sulfur levels are above1%, consult your Cat dealer for guidance.

(6) The values of the fuel viscosity are the values as the fuel is delivered to the fuel injection pumps. For ease of comparison, fuels should also meet the minimum and maximum viscosity requirements at 40 °C (104 °F) that are stated, by the use of either the "ASTM D445" test method or the "ISO 3104" test method. If a fuel with a low viscosity is used, cooling of the fuel may be required in order to maintain a 1.4 cSt or greater viscosity at the fuel injection pump. Fuels with a high viscosity might require fuel heaters in order to lower the viscosity to 20 cSt or less at the fuel injection pumps.

(7) Follow the test conditions and procedures for gasoline (motor).

(8) The lubricity of a fuel is not typically a concern with crude oil fuel. Lubricity is a concern with certain fuels, including low and ultra low sulfur diesel (ULSD) fuel, Jet A, Jet A-1, JP-5, JP-8, and other lighter fuels.

NOTICE

Operating with fuels that do not meet Caterpillar's recommendations can cause the following effects: starting difficulty, poor combustion, deposits in the fuel injectors, reduced service life of the fuel system, deposits in the combustion chamber and reduced service life of the engine.

NOTICE

Cold-soaked starts occur when the engine has not been operated for a time, allowing the crankcase oil and the fuel to become more viscous due to cooler ambient temperatures. Consult the factory if the viscosity of the cold-soaked fuel in the fuel system will be above 20 cSt.

If a particular crude oil exceeds the limits that are listed in Table 1, 3600 Series diesel engines that are configured to use heavy fuel oil may be utilized. Consult your Cat dealer or Customer Service for information about fuel that exceeds the limits that are listed in Table 1.

Note: The Crude Oil Specification for Cat 3600 and C280 Series Diesel Engines is applicable to 3500 Series Diesel Engines. Consult your Cat dealer for guidance.

NOTICE

Use of permissible fuels, such as some crude oils, some blends of crude oil with distillate fuel, some biodiesel, and some marine diesel fuel, can

result in higher maintenance costs and reduced engine life.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05423729

Heavy Fuel Oil

SMCS - 1280

Recommendations for Heavy Fuel Oil

Cat 3600 Series engines can burn a wide range of heavy fuel oils. The 3600 Series engines that are configured for using heavy fuel oil have a special fuel system. The engines also have special components for the combustion chamber. These features help to resist the corrosive elements that are found in heavy fuel oil. Because of those special features, DO NOT use heavy fuel oil in 3600 Series engines that are configured to use distillate fuel. DO NOT use heavy fuel oil in C280 Series diesel engines.

NOTICE

Heavy fuel oil, residual fuel, or blended fuel can be used in Caterpillar 3600 Series diesel engines that are configured to use heavy fuel oil.

DO NOT use these types of fuel in 3600 Series diesel engines that are configured to use distillate diesel fuel. DO NOT use heavy fuel oil in C280 Series diesel engines. Failure to follow this recommendation will result in severe wear of components and engine failure.

Do not use these types of fuel in engines that are Tier 4 EPA certified.

3600 Series engines that are properly configured can operate on fuel which is within the specifications that are listed in Tables 1 and 2. Table 1 lists recommended specifications for heavy fuel oil that will help to provide maximum service life and performance. Table 2 lists the maximum bunkered fuel limits. If the fuel exceeds the limits that are listed in the Tables, Cat recommends diluting the heavy fuel oil with a distillate diesel fuel.

NOTICE

Cold-soaked starts occur when the engine has not been operated for a time, allowing the crankcase oil and the fuel to become more viscous due to cooler ambient temperatures. Consult the factory if the viscosity of the cold-soaked fuel in the fuel system will be above 20 cSt.

Note: All fuel grades listed in Tables 1 and 2 require appropriate fuel treatment prior to delivery to the injector. For information on fuel treatment see "CIMAC Background Design and Operation of Heavy Fuel

Treatment Plants for Diesel Engines".

Note: For more information on operating a 3600 Series engine with heavy fuel oil, see Special Instruction, REHS0104, "Guidelines for 3600 Heavy Fuel Oil (HFO) Engines".

Table 1

Acceptable "ISO8217 RMG180 and 380" and "CIMAC G 380" Specifications for Heavy Fuel Oil For Use In Cat 3600 Series Engines That Are Configured To Use Heavy Fuel Oil				
Characteristic	**ASTM Test**	**ISO Specification**	**Bunkered Fuel "ISO8217 RMG180 and 380" and "CIMAC G 380"**	**Fuel that is Delivered to the Unit Injectors**
Kinematic Viscosity	"D445"	"3104"	35 cSt at 100 °C (212 °F) maximum	10 to 20 cSt at 135 °C (275 °F) maximum (1)
Density	"D287"	"3675"	991 kg/m^3 maximum at 15 °C (59 °F) (2)	
		"12185"		
Flash point	"D93"	"2719"	60 °C (140 °F) minimum	
Pour point	"D97"	"3016"	30 °C (86 °F)	
Carbon residue	-	"10370"	18% maximum (weight)	
Calculated Carbon Aromaticity Index (CCAI) (3)	-	-	850 maximum	
Hydrogen Sulfide (H_2S)			2 mg per kg maximum	
Acid Number	"D664"	-	2.5 mg KOH/g max	
Ash	"D482"	"6245"	0.15% maximum (mass)	0.10% maximum (mass)
Total sediment after settling	-	"10307-2"	0.10% maximum (mass)	
Water	"D1744"	"3733"	0.5% maximum (mass)	0.1% maximum (mass)
Sulfer	"D2622" or "D5453"	"8754"	(4)	
Vanadium (5)	"D5185-02"	"14597"	300 ppm maximum	
Sodium	"D5185-02"	"-"	100 mg/kg (2)	50 mg/kg maximum

Ratio of Vandium over Sodium (Va/Na) (5)		-		five minimum
Calcium	"D5185-02"	-		30 mg/kg maximum
Phosphorous	"D5185-02"			15 mg/kg maximum
Zinc	"D5185-02"	-		10 mg/kg maximum
Aluminum and silicon	"D5185-02"	"10478"	60 mg/kg (2)	5 mg/kg maximum
Asphaltenes	"D1319"	-		10% max (mass)
Water and Sediment	"D1796"	"3734"		0.10% max (mass)

(1) The temperature of the fuel at the fuel inlet to the engine must not exceed 135 °C (275 °F).

(2) This limit is ONLY for engines that have a suitable system for treatment of the fuel.

(3) For applications with loads that are less than 50 percent of the rated output (kW) and for applications with load cycling, the CCAI limit is 840.

(4) Sulfur in the fuel should be per the International Maritime Organization (IMO) regulations or as specified by the applicable jurisdiction. Refer to the specific engine Operation and Maintenance Manual to determine the maximum level of sulfur permissible where allowed by the applicable jurisdiction. Fuel sulfur levels affect exhaust emissions. High sulfur fuels increase the potential for corrosion of internal components. Fuel sulfur levels above 1% may significantly shorten the oil change interval. Caterpillar strongly recommends that S·O·S Services oil analysis is used to determine oil change intervals when the fuel sulfur levels are above 1%. For additional information, see this Special Publication, Engine Oil and Special Publication, SoOoS Services Oil Analysis. When the sulfur levels are above 1%, consult your Cat dealer for guidance.

(5) Compounds of vanadium and sodium are corrosive at high temperatures. See the Vanadium and Sodium topic. Consult the factory about fuel that has more than 200 ppm of vanadium. Also consult the factory about fuel that has more than 30 ppm of sodium. Consult the factory in order to ensure that the system for treatment of the fuel and the engine are equipped properly for the fuel.

Table 2

Maximum Limits for Fuel Specifications as Bunkered (1) Heavy Fuel Oil for Cat 3600 Series Engines That Are Configured To Use Heavy Fuel Oil			
Characteristic	**ASTM Test**	**ISO Specification**	**Bunkered "ISO8217 RMK 700"**
Kinematic viscosity	"D445"	"3104"	55 cSt at 100 °C (212 °F) maximum
Density	"D287"	"3675" "12185"	1010 kg/m^3 (63 lb/ft^3) maximum (2)
Flash point	"D93"	"2719"	60 °C (140 °F) minimum
Pour point	"D97"	"3016"	30 °C (86 °F)

Carbon residue	-	"10370"	22% maximum (weight)
Ash	"D482"	"6245"	0.15% maximum (weight)
Total sediment after settling	-	"10307-2"	0.10% maximum (weight)
Water	"D1744"	"3733"	0.5% maximum (volume)
Sulfur (3)	"D2622" or "D5453"	"8754"	4.5% maximum (mass)
Vanadium (4)	"D5185-02"	"14597"	450 ppm maximum
Aluminum and silicon	"D5185-02"	"10478"	80 mg maximum per kg (2)
Calcium	"D5185-02"	-	30 mg/kg maximum
Phosphorous	"D5185-02"		30 mg/kg maximum
Zinc	"D5185-02"	-	30 mg/kg maximum

(1) Bunkered fuels with higher viscosity than the acceptable fuels listed in Table 1, up to "The International Council On Combustion Engines CIMAC K380" or "International Standard Organization ISO8217 RMK 700" limits, will be considered and reviewed by the factory. The temperature limit for the fuel to the engine may affect the allowable bunkered fuel viscosity that is stated in this table.

(2) This limit is ONLY for engines that have a suitable system for treatment of the fuel.

(3) Sulfur in the fuel should be per the International Maritime Organization (IMO) regulations or as specified by the applicable jurisdiction. Refer to the specific engine Operation and Maintenance Manual to determine the maximum level of sulfur permissible where allowed by the applicable jurisdiction. Fuel sulfur levels affect exhaust emissions. High sulfur fuels increase the potential for corrosion of internal components. Fuel sulfur levels above 1% may significantly shorten the oil change interval. Caterpillar strongly recommends that S·O·S Services oil analysis is used to determine oil change intervals when the fuel sulfur levels are above 1%. For additional information, see this Special Publication, Engine Oil and Special Publication, SoOoS Services Oil Analysis. When the sulfur levels are above 1%, consult your Cat dealer for guidance.

(4) Compounds of vanadium and sodium are corrosive at high temperatures. See the "Vanadium and Sodium" topic. Consult the factory about fuel that has more than 200 ppm of vanadium. Also consult the factory about fuel that has more than 30 ppm of sodium. Consult the factory in order to ensure that the system for treatment of the fuel and the engine are equipped properly for the fuel.

NOTICE

The viscosity of the fuel at the engine must be between 10 cSt and 20cSt. The temperature of the fuel at the engine must not exceed 135 °C (275 °F).

Vanadium and Sodium

Compounds of vanadium and sodium are corrosive at high temperatures. The limits that are listed in

Tables 1 and 2 are ONLY for engines that have the proper components and equipment for treatment of the fuel.

If a fuel analysis reveals that the fuel has more than 200 ppm of vanadium and/or 30 ppm of sodium, the customer is encouraged to consult the Cat Engine factory. Analysis can ensure that the engine has the proper configuration and equipment for the fuel.

In addition to the limits on vanadium and sodium in ppm, limits are established for the comparative concentrations of these elements. Compounds of vanadium and sodium are especially corrosive when the concentration of sodium is more than 20 percent of the concentration of vanadium. Table 3 shows examples for calculating the percentage of sodium to vanadium.

Table 3

Examples for Calculating the Percentage of Sodium (Na) to Vanadium (V)							
	50 ppm Na	=	0.083	×	100	=	8.3% (1)
	600 ppm V						
	50 ppm Na	=	0.25	×	100	=	25% (2)
	200 ppm V						

(1) The concentration of sodium is less than 20 percent of the vanadium. This is an acceptable percentage.

(2) The concentration of sodium is more than 20 percent of the vanadium. This percentage is NOT acceptable.

The concentration of vanadium and sodium can also be expressed as a ratio. A ratio of vanadium to sodium that is five or more is acceptable. Table 4 shows examples for calculating the ratio of vanadium to sodium.

Table 4

Examples for Calculating the Ratio of Vanadium (V) to Sodium (Na)			
	600 ppm V	=	12 (1)
	50 ppm Na		
	200 ppm V	=	4 (2)
	50 ppm Na		

(1) The result of the calculation is more than five. This ratio is acceptable.

(2) The result of the calculation is less than five. This ratio is NOT acceptable.

Note: Vanadium levels over 300 ppm will require a request for a special rating. A ratio of vanadium to sodium that is less than five will also require a request for a special rating.

Treatment of Heavy Fuel Oil (HFO)

Note: When HFO will be used, also refer to Special Instruction, REHS0104, "Guidelines for 3600 Heavy Fuel Oil (HFO) Engines".

Operation of a 3600 Series Engine with heavy fuel oil requires attention to maintenance intervals and inspections. Trained personnel are required for the treatment of the fuel and maintenance of the equipment.

The use of heavy fuel oil can involve these procedures:

- Storing of the fuel
- Filtering of the fuel
- Heating of the fuel
- Centrifuging of the fuel
- Centrifuging of the lube oil
- Cooling of the fuel injector tips

Additionally, the engine is modified for the use of heavy fuel oil. Extra engine maintenance is required.

For information on the systems for treatment and storage of heavy fuel oil, see the Special Instruction, REHS0104, "Guidelines For 3600 Heavy Fuel Oil (HFO) Engines".

Centrifuging of the Fuel

Fuel from the settling tank must be centrifuged continuously for proper treatment. Continuous centrifuging of the fuel provides these benefits:

- The fuel is maintained at a constant level in the day tank.
- The foaming of fuel in the day tank is minimized.
- Air and vapor that is contained in the return fuel has a constant distance for separating from the fuel.
- The cleanest fuel from the top of the day tank flows to the fuel conditioning module and the engine.
- Warm fuel is continuously supplied to the day tank reducing the need to heat the fuel. The convection currents are eliminated that originate at the heater coils. The impurities are allowed to settle.
- Fuel that returns to the settling tank from the lower portion of the day tank will have the most impurities. This fuel can be centrifuged again in order to remove the impurities.

Centrifuging of the Lube Oil

Heavy fuel oil introduces more combustion products into the crankcase than distillate fuel. The combustion products contaminate the lube oil. A remote mounted centrifugal separator will help to clean the engine crankcase oil increasing the service life of the oil. Continuous separation is required.

The flow rate is determined primarily by the engine power output. If the centrifuge is simultaneously receiving oil and discharging sediment, the minimum flow rate is 0.3 L/bkW hr (.026 gal/bhp hr).

Cooling of the Fuel Injector Tips

During engine operation with heavy fuel oil, the fuel injector tips are cooled. This helps to prevent wear and the formation of deposits.

For fuels with a maximum viscosity of 40 cSt at 50 °C (122 °F), excess fuel is routed through the tips in order to cool the tips. For this "series circuit" cooling, the engine is equipped with the required hardware. Additional external plumbing is not necessary.

For fuels with a viscosity that is above 40 cSt at 50 °C (122 °F), an external module for cooling the fuel injector tips is required. The module consists of several parts that include these components:

- Piping
- Tank with a sight gauge
- Filter for the coolant
- Differential pressure gauge (filter)
- Valves
- Pump
- Pressure gauge
- One temperature gauge before the engine and one temperature gauge after the engine
- An alarm for low coolant pressure
- Heat exchanger

A thermostatic regulator may also be required. For the coolant that recirculates from the engine, select a control valve that will maintain the temperature of the coolant between 50 to 65 °C (122 to 149 °F). Normally, the coolant is SAE 10W to SAE 30 grade diesel engine oil.

Maintain the coolant to the fuel injectors under the following conditions:

- Temperature of 55 to 65 °C (131 to 149 °F)
- Pressure of 276 to 441 kPa (40 to 64 psi)
- Flow rate of 6 liters per minute for each fuel injector

Do not operate the module before starting the engine. Regardless of the type of fuel that is used, always operate the module when the engine is running. Fresh coolant is constantly supplied to the fuel injector tips. High temperatures at the fuel injectors cause degradation of the coolant.

Note: Check the coolant level, the temperature, and the pressure frequently.

Filtering of the Fuel

The quality of the fuel is an important consideration for maintenance of the fuel filters. A poor quality of fuel can reduce the service life of the fuel filter elements by 50 percent or more. To increase the service life of fuel filter elements, use a good quality of fuel. Monitor the readings of the fuel gauges and service the fuel filters at the recommended intervals.

The secondary fuel filters that are supplied by Cat are mounted remotely from the engine. The filters are installed in the fuel supply line directly before the engine.

NOTICE

For heavy fuel oil with a viscosity of 40 cSt at 50 °C (122 °F), the viscosity of the fuel must be reduced prior to the fuel filters. This will allow fuel to pass through the filter elements without causing the elements to collapse. Reduce the viscosity to a range that is between 15 and 20 cSt at 50 °C (122 °F).

WARNING

Overheating the fuel or the fuel filter can result in personal injury and/or damage to the engine. Use extreme care and caution for heating of the fuel filter.

Heating of the fuel filter will enable the viscosity to be reduced. The fuel temperature and warm-up time depend on the type of fuel and installation.

NOTICE

The viscosity of the fuel at the engine must be between 10 cSt and 20cSt. The temperature of the fuel at the engine must not exceed 135 °C (275 °F).

Heating of the Fuel

Precise temperature control of heavy fuel oil is critical for the most complete combustion, centrifugal cleaning, and settling of contaminants. If the temperature is not properly controlled, sludge and vapors can form. This material inhibits the treatment of the fuel. Also, combustion of the fuel is reduced. The result is a reduction of the service life of the fuel system components and the engine.

Note: The temperatures that are required for controlling sludge and vapor mainly depend on the fuel quality. An analysis of the fuel is necessary to determine the proper temperature for both treatment and viscosity.

The following parameters can be used as initial indications of improper temperature control:

- Variation of the exhaust port temperatures
- Viscosity of the fuel
- Knocking
- Fuel temperature
- Opacity of the exhaust smoke

Use the jacket water heaters before starting an engine with heavy fuel oil. Use of the jacket water heaters will reduce the viscosity of the fuel in the fuel injectors. Startability will be improved.

Table 5 lists the jacket water temperatures that are appropriate for different fuel viscosities.

Table 5

Fuel Viscosity and Jacket Water Temperature	
Fuel Viscosity	**Jacket Water Temperature**
Less than 40 cSt at 50 °C (122 °F)	45 °C (113 °F)
More than 40 cSt at 50 °C (122 °F)	65 °C (149 °F)

Normally, deactivate the jacket water heaters after the engine has started.

Analysis of Heavy Fuel Oil

Caterpillar Inc. does not provide analyses of heavy fuel oil. Chemical labs throughout the world can evaluate fuel properties on a regular basis. Analyses of heavy fuel oil may also be obtained from these organizations: independent testing laboratories, oil companies and marine regulating agencies. For accurate results, the analysis of heavy fuel oil must be performed at a laboratory with personnel that is familiar with this type of fuel. The following are some of the laboratories that can provide fuel analyses.

Det Norske Veritas (DNV)

DNV Petroleum Services
Regional Office & Laboratory
27 Changi South Street 1
Singapore 486071
Telephone:: +65 6779 2475Facsimile:: +65 6779 5636Telex:: RS 39659/38597 DNVPSE-mail:: singapore@dnvps.com

DNV Petroleum Services
Branch Office & Laboratory
Fujairah, UAE
Port of Fujairah
P O Box 1227
United Arab Emirates
Telephone:: +971 9 2228152Facsimile:: +971 9 2228153E-mail:: fujairah@dnvps.com

DNV Petroleum Services
Regional Office & Laboratory
Rotterdam, The Netherlands
Haastrechtstraat 7
3079 DC Rotterdam
P.O. Box 9599
3007 AN Rotterdam
The Netherlands
Telephone:: +31 10 292 2600Facsimile:: +31 10 479 7141E-mail:: rotterdam@dnvps.com

DNV Petroleum Services
Regional Office
London, UK
Palace House
3, Cathedral Street
London SE1 9DE
United Kingdom
Telephone:: +44 0207 357 6080Facsimile:: +44 0207 716 6736E-mail:: london@dnvps.com

DNV Petroleum Services
Regional Office & Laboratory
Oslo, Norway
Veritasveien 1
N-1322 HØvik,Norway
Telephone:: +47 67 57 9900Facsimile:: +47 67 57 9393Telex:: 76192 VERITNE-mail:: dnvps.oslo@dnv.com

DNV Petroleum Services
Branch Office & Laboratory
Houston, Texas, USA
318 North 16th Street
La Porte, Texas 77571, USA
Telephone:: +1 281 470 1030Facsimile:: +1 281 470 1035E-mail:: houston@dnvps.com

Lloyd's Register Laboratory

Lloyd's Register EMEA
71 Fenchurch Street
London EC3M 4BS, UK
Telephone:: +44 (0)20 7709 9166Facsimile:: +44 (0)20 7423 2057E-mail:: emea@lr.org

Lloyd's Register Asia
Suite 3501 China Merchants Tower
Shun Tak Centre
168-200 Connaught Road Central
Hong Kong, SAR of PRC
Telephone:: +852 2287 9333Facsimile: +852 2526 2921E-mail:: asia@lr.org

Lloyd's Register Americas, Inc.
1401 Enclave Parkway
Suite 200
Houston, Texas, 77077
USA
Telephone: +1 (1)281 675 3100Facsimile: +1 (1)281 675 3139E-mail:: americas@lr.org

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05423717

General Coolant Information

SMCS - 1350; 1395

WARNING

The cooling system operates under pressure which is controlled by the radiator pressure cap. Removing the cap while the system is hot may allow the escape of hot coolant and steam, causing serious burns.

Before you remove the radiator cap, allow the system to cool. Use a thick cloth and turn the radiator cap slowly to the first stop to allow pressure to escape before fully removing the cap.

Avoid contact with coolant.

NOTICE

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

The information that is provided is the latest recommendations for the Cat diesel engines that are covered by this Special Publication. This information supersedes all previous recommendations which have been published for the Cat diesel engines that are covered by this Special Publication. Special fluids may be required for some engines. 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 Operation and Maintenance Manual.

NOTICE

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

NOTICE

In order to avoid potential damage to your Cat machine and/or Cat engine, only purchase Cat fluids and Cat 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 Cat filters through other outlets/sources, you are at a very high risk of purchasing counterfeit ("look-alike") products.

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

Counterfeit or "look-alike" products have a very high likelihood of causing and/or allowing engine and/or machine compartment damage.

NOTICE

Commercial products that make generic claims of meeting "Cat" requirements without listing the specific Cat recommendations and requirements that are met may not provide acceptable performance. Commercial products may cause reduced engine and/or machine fluid compartment life. Refer to this Special Publication and refer to product specific Operation and Maintenance Manual for Cat fluids recommendations and requirements.

NOTICE

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

NOTICE

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

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.

If you operate the engine without the regulator, some coolant bypasses the radiator. This may cause overheating.

Note: Refer to the specific engine Operation and Maintenance Manual, "Maintenance Interval Schedule" for the correct interval for the replacement of the thermostat.

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

Many engine failures are related to the cooling system. The following problems are related to cooling system failures:

- Overheating
- Leakage of the water pump
- Plugged radiators or heat exchangers
- Pitting of the cylinder liners

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

A coolant that is ready to use in the engine can also be referred to as "finished coolant". A finished coolant is a coolant that has been diluted with appropriate amount of acceptable quality water.

Coolant is normally composed of the following elements:

- water
- additives
- glycol
- Embitterment: in coolants containing ethylene glycol to make the coolant taste bad.

Technical information for each of the coolant elements is provided in this Special Publication.

Water

NOTICE

Never use water alone as a coolant. Water alone is corrosive at engine operating temperatures. In addition, water alone does not provide adequate protection against boiling or freezing.

Note: In glycol-based coolants, Cat strongly recommends a minimum of 30 percent glycol in diesel engine cooling systems, with a minimum of 50 percent glycol recommended. Use only glycol-based coolants that meet one or more of the coolant specifications that are defined as preferred or acceptable in this Special Publication and that also comply with any additional requirements that are stated in this Special Publication (that is, chemical composition, the use of SCA, the use of Extender). Refer to the Operation and Maintenance Manual for your engine for any exceptions, and refer to Table 1 for marine engine exceptions.

NOTICE

All Cat engines that are equipped with a Cat NOx Reduction System require a minimum of 50 percent glycol to help prevent cavitation damage and boiling of the engine coolant. These engines include Tier 4 engines.

Table 1

Special Requirements (1)	
Cat 3618 engine model	Water based ELI is recommended. Water based SCA is acceptable. Glycol-based coolants are NOT allowed.

(1) Water based ELI and SCA are not recommended for use in applications that require freeze protection. Water based coolants are glycol-free.

C7-C32 heat exchanger cooled marine engines require a minimum of 30 percent glycol to prevent cavitation of cooling system components, with a minimum of 50 percent glycol recommended.

Note: For engines that require a maximum of 20% glycol, make sure that the amount of additive in the final mix is appropriate. Example of mixing a 20% glycol solution is given in Table 2.

Table 2

Example of Mixing Up a 20% Glycol Coolant (1)			
Total Volume of the Cooling System	Add the Following:		
	ELC Concentrate	ELI Concentrate	Water
10 Gallons	2 Gallons	0.5 Gallons	7.5 Gallons

(1) Volumes can also be in liters as long as all the volume units are consistent

Water in the water/glycol coolants is more effective than glycol alone in transferring heat.

Distilled water or deionized water is recommended to add to glycol or to water based coolants in engine cooling systems.

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

If distilled water or deionized water is not available, use water that meets or exceeds the minimum

acceptable water requirements that are listed in Table 3.

Table 3

Cat Minimum Acceptable Water Requirements		
Property	**Maximum Limit**	**ASTM Test**
Chloride (Cl)	40 mg/L (2.4 grains/US gal)	"D512", "D4327"
Sulfate (SO_4)	100 mg/L (5.9 grains/US gal)	"D516" "D4327"
Total Hardness	170 mg/L (10 grains/US gal)	"D1126"
Total Solids	340 mg/L (20 grains/US gal)	"D1888" "Federal Method 2504B" (1)
Acidity	pH of 5.5 to 9.0	"D1293"

(1) Total dissolved solids dried at 103° C (217° F) - 105° C (221° F), "Standard Method for the Examination of Water and Wastewater", "American Public Health Association", "www.apha.org", "www.aphabookstore.org", (888) 320-APHA.

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

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

Periodic analysis of water that is used to add to the coolant is recommended. Water quality can be affected by various factors including malfunctioning purification equipment, earthquakes, and droughts.

Additives

Additives help to protect the metal surfaces of the cooling system and can improve coolant performance. A lack of coolant additives, insufficient amounts of additives, or improper additives for the application can cause 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. Additives that can be added:

- ELC Extender to Cat ELC (Extended Life Coolant)
- ELC Extender to Cat ELI (Extended Life Inhibitor)
- Cat SCA (Supplemental Coolant Additive) to Cat DEAC (Diesel Engine Antifreeze/Coolant)
- · Cat SCA to Cat SCA in water finished coolant

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

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

Glycol

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

- Boiling
- Freezing
- Water pump cavitation (ATAAC equipped engines)

For optimum performance, Cat recommends a 50 percent by volume of glycol in the finished coolant (also referred to as 1:1 mixture).

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

Most conventional heavy-duty coolant/antifreezes use ethylene glycol. Propylene glycol may also be used. In a 50 percent by volume of glycol in the finished coolant, ethylene and propylene glycol provide similar protection against freezing and boiling. Refer to tables 4 and 5.

Table 4

Ethylene Glycol Concentration		
Concentration	**Freeze Protection**	**Boil Protection** [1]
20 Percent	−8° C (18° F)	102° C (216° F)
50 Percent	−37 °C (−34 °F)	106 °C (223 °F)
60 Percent	−52 °C (−62 °F)	111 °C (232 °F)

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

Do not use propylene glycol in concentrations that exceed 50 percent glycol because of the reduced heat transfer capability. Use ethylene glycol in conditions that require additional protection against boiling or freezing. Do not use ethylene glycol in concentrations that exceed 60 percent glycol.

Table 5

Propylene Glycol Concentration		
Concentration	**Freeze Protection**	**Boil Protection (1)**
50 Percent	−32 °C (−26 °F)	106 °C (223 °F)

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

Propylene glycol coolant that is used in the cooling systems for Cat diesel engines must meet ASTM D6210-06"Fully-Formulated Glycol-Based Engine Coolant for Heavy-Duty Engines". When propylene glycol coolant is used in heavy-duty diesel engines, a regular addition of SCA is required for protection against liner cavitation. Consult your Cat dealer for additional information.

Ethylene or propylene glycols used in cooling systems for Cat diesel engines must meet ASTM E1177-06"Standard Specification for Engine Coolant Grade Glycol".

Testing the Concentration of Glycol

To check the concentration of glycol, use the **245-5829** Coolant/Battery Tester/Refractometer or 360-0774 refractometer. The tester can be used with ethylene or propylene glycol.

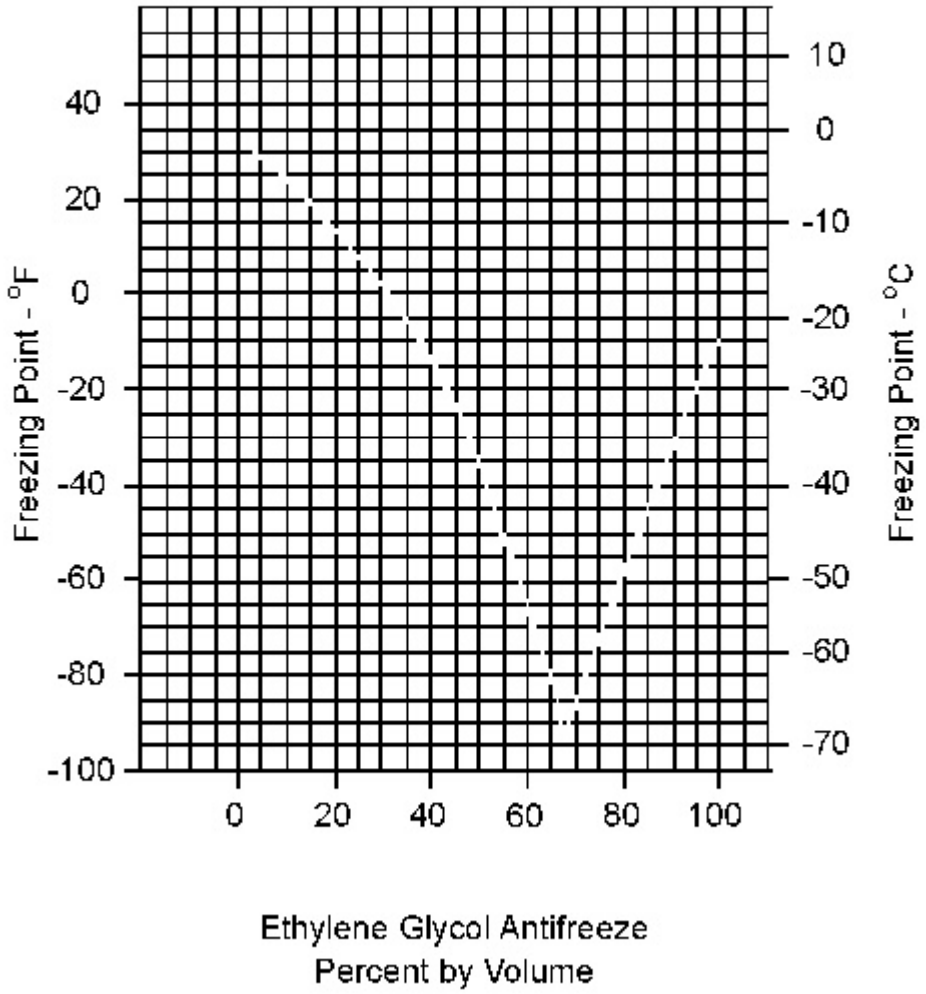

Illustration 1 g01189253

Approximate curve of the freezing point for a typical ethylene glycol solution.

Table 6

Freeze Protection for Antifreeze Concentrations (1)	
Protection to:	**Concentration**
−8° C (18° F)	20% glycol 80% water
−15 °C (5 °F)	30% glycol 70% water
−24 °C (−12 °F)	40% glycol 60% water
−37 °C (−34 °F)	50% glycol 50% water

−52 °C (−62 °F)	60% glycol 40% water

(1) Ethylene glycol-based antifreeze.

Alternative products that are used to protect from boiling or freezing of the engine coolant include:

- "1,3 propandiol" (PDO)
- glycerin
- mixtures of these alternative products with glycol

At the time of publication of this document, there currently exists no ASTM"specifications" for coolants using these chemicals. **Until specifications are published and then evaluated by Cat, use of PDO and glycerin or glycerin/glycol coolants are not recommended in Cat cooling systems.**

Embitterment

Ethylene glycol is a toxic chemical with a naturally sweet taste. In order to avoid accidental excessive ingestion by humans or animals, coolants may contain embittering agents that make the coolant taste bad. **All Cat glycol containing coolants (Cat ELC, Cat DEAC, and Cat NGEC) are embittered.** Embittering agents have no beneficial or detrimental effect on coolant performance or characteristics.

Coolant Terminology

Extended Life Coolant (ELC) - A coolant that relies largely on organic inhibitors for corrosion and cavitation protection. Carboxylate is an example of organic corrosion and cavitation inhibitors. Cat ELC and Cat ELI in water are extended life coolants that also include nitrites and molybdates for increased cavitation protection.

- Commercial extended life coolants containing silicate do not meet the additional requirements set in this Special Publication for coolants claiming to meet Cat EC-1 specification.
- Do not use commercial extended life coolants with more than 125 ppm silicon (present in the coolant in the form of silicate)
- Extended life coolants that meet "ASTM D4985-05" or "ASTM D6210-06" may be used at the recommended maximum coolant service life intervals stated in this Special Publication for coolants that meet the ASTM specifications.

Conventional coolant - A coolant that relies largely on inorganic inhibitors for corrosion and cavitation protection. Silicates and nitrites are examples of inorganic inhibitors. Conventional coolants are also referred to as heavy-duty coolants, heavy-duty fully formulated coolants, or traditional coolants. In order to be used in most Cat cooling systems, conventional coolants must meet "ASTM D4985-05" or "ASTM D6210-06". Cat DEAC and Cat SCA in water (also referred to as SCA/Water coolant) are conventional coolants

Supplemental Coolant Additive (SCA) - SCA is a general term for a concentrated inorganic inhibitor package. SCA is used for three different purposes:

- to precharge a new conventional coolant that is not fully Formulated. Cat DEAC is fully formulated and does not require SCA

- to provide corrosion protection in water/SCA cooling systems
- to recharge an in service conventional coolant on a maintenance basis to maintain proper inhibitor levels

Extender - An inhibitor package that is added to extended life coolants, to recharge an in-service coolant. Extenders, typically, only should be added at one half the service life of the coolant.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05423702

Coolant Recommendations - General Maintenance

SMCS - 1350; 1352; 1395

The finished coolants that are recommended or acceptable for use in Cat diesel engines are given in Table 1 below:

Table 1

Recommendations for Finished Coolants for use in Cat engines				
Coolant Type	**Recommendations**	**Product**	**Service hours (1) (2)**	**Required Maintenance (3)**
Cat ELC, Cat ELI, or commercial coolant that meets Cat EC-1	Preferred	Cat ELC	12000 hours or 6 years	Add Cat ELC Extender at 6000 service hours or one half of service life
		Cat ELI (water based) (4)	12000 hours or 6 years	Add Cat ELC Extender at 6000 service hours or one half of service life
	Min requirements	Cat EC-1 specification and "ASTM D6210" and Organic Additive Technology (OAT) based on a combination of a monocarboxylic acid and a dicarboxylic acid Phosphate, borate, and silicate free Tolyltriazole: minimum typical concentration of 900 ppm Nitrite: minimum typical concentration	6000 hours or 6 years	Add Extender at 3000 service hours or one half of service life

		of 500 ppm in new coolants		
Cat DEAC, Cat SCA, conventional coolants and commercial extended life coolants that do not meet EC-1	Acceptable	Cat DEAC	3000 hours or 3 years	SCA at maintenance intervals
		Cat SCA (water based) (4)	3000 hours or 2 years	SCA at maintenance intervals
	Min requirements for fully formulated Heavy Duty Commercial coolants	"ASTM D6210" and Nitrite (as NO2) concentration: Minimum of 1200 ppm (70 grains/US gal) and maximum of 2400 ppm (140 grains/US gal) Silicon concentration: minimum of 100 ppm and maximum of 275 ppm	3000 hours or 2 years	SCA at maintenance intervals
	Min requirements for Commercial coolants requiring SCA precharge	"ASTM D4985" and (4) Nitrite (as NO2) concentration: Minimum of 1200 ppm (70 grains/US gal) and maximum of 2400 ppm (140 grains/US gal) Silicon concentration: minimum of 100 ppm and maximum of 275 ppm	3000 hours or 1 year	SCA at initial fill and SCA at maintenance intervals
	Min requirements for SCA and water (5)	Commercial supplemental coolant additive and water having Nitrite (as NO2) concentration: Minimum of 1200 ppm (70 grains/US gal) and maximum of 2400 ppm (140 grains/US gal) Silicon	3000 hours or 1 year	Per manufacturer recommendations

		concentration: minimum of 100 ppm and maximum of 275 ppm		

(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 Chapter. For applications that allow the use of Cat ELI in water, a minimum of 7.5 percent of Cat ELI is recommended. 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 engines that have NOx reduction aftertreatment devices, in engines that have AATAC, and in marine engines that have SWAC. Water based coolants are glycol-free.

(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.

Table 2

Special Requirements (1)	
Cat 3618 engine model	Water-ELI is recommended. Water-SCA is acceptable. Glycol-based coolants are NOT allowed.

(1) For freezing protection of −5° C (23° F) temperatures and lower, consult your Cat dealer for guidance.

When referring to the Service Life in table 1, use the interval that occurs first. These coolant change intervals are only achievable with annual S·O·S Services Level 2 coolant sampling analysis.

Refer to the engine Operation and Maintenance Manual for the correct interval for replacement of the cooling system water temperature regulator.

Note: For engines that require a maximum of 20% glycol, make sure that the amount of additive in the final mix is appropriate. Example of mixing a 20% glycol solution is given in Table 3.

Table 3

Example of Mixing Up a 20% Glycol Coolant (1)			
Total Volume of the Cooling System	Add the Following:		
	ELC Concentrate	ELI Concentrate	Water
10 Gallons	2 Gallons	0.5 Gallons	7.5 Gallons

(1) Volumes can also be in liters as long as all the volume units are consistent

Extended life coolants require the one time maintenance addition of an extender at coolant service mid-life. For commercial coolants, do NOT use an extender with a coolant unless the extender has been approved by the coolant manufacturer for use with the coolant. The coolant manufacturer is responsible to ensure compatibility and acceptable performance. Failure to follow these recommendations can result in shortened cooling system component life.

Conventional coolants require the maintenance addition of SCA throughout the expected life. For commercial coolants, do NOT use an SCA unless approved by the coolant supplier for use with the coolant. The coolant manufacturer is responsible to ensure compatibility and acceptable performance.

"ASTM D4985" and "ASTM D6210" require coolants that are properly dosed with SCA and that are in a properly maintained cooling system in normal service to be suitable for use for a maximum of 1 year ("ASTM D4985") and 2 years ("ASTM D6210"). **The suitability for use requirement is the direct responsibility of the coolant manufacturer and SCA manufacturer.** Consult with the coolant and/or SCA manufacturer concerning the suitability of the products for use in a given application.

Cat DEAC does not require a treatment with an SCA at the initial fill.

A commercial heavy-duty coolant/antifreeze that meets the "ASTM D6210"specification does not require a treatment with an SCA at the initial fill.

A commercial heavy-duty coolant/antifreeze that only meets "ASTM D4985", WILL require a treatment with an SCA at the initial fill and has to fulfill all the requirements listed in the "Technical Requirements for Commercial Extended Life Coolants" table. The user and the coolant manufacturer are responsible to ensure the SCA is compatible. Compatibility is based on the recommendations provided by the coolant manufacturer and SCA manufacturer. For example, an extended life coolant that meets the "ASTM D4985" specification may not be compatible with an SCA designed for use with conventional coolants. The coolant manufacturer is responsible to provide sources of compatible SCAs. The coolant manufacturer and SCA manufacturer are responsible to demonstrate a positive influence on reducing cavitation corrosion in an operating diesel engine.

Read the label or the instructions that are provided by the manufacturer of the commercial heavy-duty coolant/antifreeze.

When adding SCA at initial fill to a coolant/antifreeze that only meets "ASTM D4985", the user and the coolant manufacturer must ensure the SCA is compatible with the antifreeze/coolant. The addition must be based on the recommendations provided by the coolant manufacturer and SCA manufacturer. One of the test methods required to be used to help ensure SCA compatibility with the antifreeze/coolant concentrate is "ASTM D5828-97". Follow the test procedure using the antifreeze/coolant of interest to compare the SCA of interest with the reference SCA. The ratio of insoluble for SCA to reference SCA must be < 1. Total insoluble should not exceed 4.0 mL for a 6% SCA mixture. The SCA manufacturer is responsible for ensuring the SCA is compatible with water meeting the "Caterpillar Minimum Acceptable Water Quality Requirements" as found in this Special Publication, and is found in "ASTM D6210", Table X1.1.

The coolant manufacturer and the SCA manufacturer are responsible to ensure that the products will not cause cooling system harm.

Cat ELC can be recycled into conventional coolants.

Cat ELC, Cat ELI, Cat DEAC, Cat Extender, and Cat SCA are available in several container sizes. The availability of part numbers will vary by the region. Consult your Cat dealer.

In stationary and marine engine applications that do not require protection from boiling or freezing, except as noted in Table 2, Cat ELI in water or SCA and water are acceptable. **Caterpillar recommends a minimum of 7.5 percent concentration of Cat ELI in those cooling systems using Cat ELI. Caterpillar recommends a minimum of 6 percent to a maximum of 8 percent concentration of Cat SCA in those cooling systems using Cat SCA.** Distilled water or deionized water is preferred in those systems. If distilled or deionized water is not available, use water that meets or exceeds the minimum acceptable water requirements that are listed in this Special Publication, "General Coolant Information" article.

After the addition of water and proper mixing, the concentration of Cat ELI can be determined using the

360-0744 digital Brix refractometer. Refer to the tool operating manual for that refractometer for more information. The concentration of a sample of in-use Cat ELI taken from the cooling system can also be determined using this refractometer

NOTICE

All Cat engines that are equipped with a Cat NOx Reduction System require a minimum of 50 percent glycol to help prevent cavitation damage and boiling of the engine coolant. These engines include Tier 4 engines.

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.

Caterpillar recommends a 50 volume percent glycol and water of proper quality. This mixture will provide optimum heavy-duty performance as a coolant/antifreeze. Some marine engines are an exception as indicated in Table 2.

Maintain a concentration level of nitrites in the cooling system that is between 1200 ppm (70grains/US gal) and 2400 ppm (140 grains/US gal). S·O·S coolant analysis is the preferred method to check SCA concentration. Alternatively, nitrite levels can be tested with the following tools:

- 4C-9301 nitrite level test strips, English instructions only, use with glycol-based coolants such as Cat DEAC
- 286-2578 nitrite level test strips, English, French, and Spanish instructions, use with glycol-based coolants such as Cat DEAC
- 298-5311 nitrite level titration kit, subject to regional availability, use only with mixtures of water and SCA. Not for use with glycol-based coolants.

Frequently check the concentration of glycol in glycol-based coolant. Use a coolant/battery tester. Two products are available from Cat dealers. 245-5829 is an analogue refractometer that shows the freeze protection level of the coolant in both degrees Celsius and degrees Fahrenheit. 360-0774 is a digital Brix refractometer.

Maintain the proper concentrations of glycol and additives in the coolant. Lowering the concentration of glycol or additives will lower the ability of the coolant to protect the system from pitting, from cavitation, from erosion, and from deposits.

Do not top off the cooling system with water unless there is a specific need to adjust the water/glycol ratio. Compatible 50/50 (water/glycol) coolant is typically used and recommended when cooling system top off is required.

Clean the cooling system for the following reasons:

- Contamination of the cooling system
- Overheating of the engine
- Foaming of the coolant
- Changing from conventional heavy-duty coolant/antifreeze to Cat ELC or ELC-1 coolant

Note: Air pockets can form in the cooling system if the cooling system is filled at a rate that is greater than 20 L (5 US gal) per minute. The maximum recommended cooling system fill rate for some smaller engine models will be less. Refer to the engine Operation and Maintenance Manual for exceptions.

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

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i04330169

Extended Life Coolant

SMCS - 1350; 1352; 1395

Cat ELC

Caterpillar provides Cat ELC (Extended Life Coolant) for use in the following applications:

- Heavy-duty diesel engines
- Automotive applications

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

Cat ELC extends the service life of the coolant to 12000 service hours or 6 years. Cat ELC does not require the frequent addition of the Cat ELC Extender additive. An Extender is the only additional maintenance that is needed at 6000 service hours or one half of the Cat ELC service life.

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

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

Containers of several sizes are available. Refer to this Special Publication, "Coolant Recommendations" article for available quantities and part numbers.

Note: Cat ELC can be used in most diesel and gasoline OEM engines. Cat ELC meets the performance requirements of "ASTM D4985" and "ASTM D6210" for heavy-duty low silicate antifreeze/coolants. Cat ELC also meets the performance requirements of "ASTM D3306" for automotive applications.

Commercial Extended Life Coolant

NOTICE

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

In order to be used in Cat diesel engine cooling systems at the published service intervals, select a

commercial extended life coolant that meets all the requirements given in Table 1 in this Special Publication.

Table 1

Technical Requirements for Commercial Extended Life Coolants	
Specifications	Cat EC-1 and "ASTM D6210"
Additional Requirements	Organic Additive Technology (OAT) based on a combination of a monocarboxylic acid and a dicarboxylic acid
	Phosphate, borate, and silicate free
	Minimum typical tolyltriazole level of 900 ppm for new coolants
	Minimum typical nitrite level of 500 ppm in new coolants"
Maintenance	One time addition of an extender at the mid-life of the coolant in order to maintain the coolant nitrite level between 300 - 600 ppm

Note: The Cat EC-1 specification describes the minimum requirements for extended life coolants.

Use an extender that is recommended by the EC-1 coolant supplier at mid-life of the coolant.

Commercial coolants that do not meet the minimum requirements defined in this Special Publication are not allowed for use in Cat engines.

Commercial extended life coolant used in Cat engines must meet all requirements given in Table 1. If the ELC does meet the requirements, the service interval listed in this Special Publication may not be used. Follow the maintenance guidelines for the coolant from the supplier of the commercial extended life coolant. Follow the Cat guidelines for the quality of water and the specified coolant change interval.

Note: Coolants must be tested against the Cat EC-1 specification requirements. Coolants that only claim to meet the performance requirements of the Cat EC-1 specification may not meet all the minimum requirements.

In order to be marketed as a product that meets Cat EC-1, all Cat EC-1 specification requirements must be met. Requirements include, but are not limited to the following:

- Physical and Chemical Properties
- Compatibility Characteristics
- Bench Testing
- Field Testing

The field test includes the use of the following requirements:

- Radiator types
- Minimum field test duration
- Minimum number of diesel engines

- Cat diesel engine models of the required minimum power rating

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 Publication Date -01/11/2013 Date Updated -18/11/2013

i04330170

Extended Life Coolant Cooling System Maintenance

SMCS - 1350; 1352; 1395

Proper Additions to the Cat ELC (Extended Life Coolant)

NOTICE

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

Use only Cat ELC Extender with Cat ELC.

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

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

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

Test the glycol concentration in the coolant and test the nitrite concentration in the coolant. Follow the maintenance information provided in this Special Publication, "Coolant and General Maintenance Recommendations" section.

During daily maintenance, use the premixed Cat ELC as a cooling system top-off. This top-off will bring the coolant up to the proper level. Use Cat ELC Concentrate to restore the proper glycol concentration in the coolant system. This addition should be done before the engine is exposed to freezing temperatures. Do not use a conventional coolant to top-off a cooling system that is filled with Cat ELC.

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

Cat ELC Extender

Cat ELC Extender is added to the cooling system halfway through the Cat ELC or Cat ELI service life. Treat the cooling system with Cat ELC Extender at 6000 hours or one half of the coolant service life. Refer to your machine Operation and Maintenance Manual for exceptions. Refer to the "Part Number of

Coolant" table in this Special Publication, "Coolant Recommendations" article for available quantities and part numbers.

Use the formula in Table 1 to determine the proper amount of Cat ELC Extender for your cooling system. Refer to Operation and Maintenance Manual, "Refill Capacities and Recommendations" in order to determine the capacity of the cooling system.

Table 1

Formula For Adding Cat ELC Extender To Cat ELC
V × 0.02 = X
V is the total capacity of the cooling system.
X is the amount of Cat ELC Extender that is required.

Table 2 is an example for using the formula that is in Table 1. This example is based on the capacity of a D8R Track-Type Tractor with a cooling system capacity of 92 L (24.3 US gal).

Table 2

Example Of The Equation For Adding Cat ELC Extender To Cat ELC		
Total Volume of the Cooling System (V)	**Multiplication Factor**	**Amount of Cat ELC Extender that is Required (X)**
946 L (250 US gal)	× 0.02	19 L (5 US gal)

NOTICE

When using Cat ELC, do not use conventional SCAs, or, if equipped, SCA maintenance elements. In order to avoid SCA contamination of an ELC system, remove the SCA element base and plug off or bypass the coolant lines.

Cat ELC Cooling System Cleaning

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

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

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

Recycling Cat ELC

Cat ELC can be recycled into conventional coolants. The drained coolant mixture can be distilled in order to remove the ethylene glycol and the water. The ethylene glycol and the water can be reused. The distilled material does not contain the additives that are required as either Cat ELC or Cat DEAC. Consult your Cat dealer for more information. Recycled coolants should meet the most current revision level of "ASTM D6210".

Changing to Cat ELC

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

NOTICE

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

Refer to Special Publication, NENG2500, "Caterpillar Dealer Service Tool Catalog" and to Special Publication, PECJ0003, "Cat Shop Supplies and Tools" for tools and supplies suitable to collect and contain fluids on Cat products.

Dispose of all fluids according to applicable regulations and mandates.

---

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

NOTICE

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

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

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

---

4. Flush the system with clean water in order to remove any debris.
5. Use Cat Quick Flush Cooling System Cleaner for cooling systems in order to clean the system. Cat

Quick Flush Cooling System Cleaner is available in various sizes. Part numbers are 4C-4609 (0.5 L (0.125 US gal)) through 4C-4613 (208.2 L (55 US gal)). Follow the instructions on the label using a 6-10% concentration of cleaner in water.

6. Drain the cleaner into a suitable container. Flush the cooling system with clean water.

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

7. In systems with heavy deposits, disconnecting the hoses may be necessary. Clean the deposits and debris from the hoses and the fittings. Install the hoses and tighten the hose fittings. Refer to Specifications, SENR3130, "Torque Specifications" for the proper torques. Pipe threads may also need to be cleaned and sealed. Seal the threads with **5P-3413** Pipe Sealant .

   Note: Replace hoses that are cracked, soft, or that have other signs of damage. Tighten all hose clamps and fittings.

8. Fill the cooling system with clean water and operate the engine until the engine is warmed to 49 °C to 66 °C (120 °F to 151 °F).

NOTICE

Improper or incomplete rinsing of the cooling system can result in damage to copper and other metal components.

To avoid damage to the cooling system, make sure to completely flush the cooling system with clear water. Continue to flush the system until all signs of the cleaning agent are gone.

---

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

NOTICE

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

---

10. Repeat Steps 8 and 9 until the system is clean.

11. Fill the cooling system with the Cat ELC.

12. Operate the engine until the engine is warmed. While the engine is running, inspect the engine for leaks. Tighten hose clamps and connections in order to stop any leaks.

13. Attach the Special Publication, PMEP5027, "Label" to the cooling system filler for the engine in order to indicate the use of Cat ELC.

    Note: Clean water is the only flushing agent that is required when Cat ELC is drained from a properly maintained cooling system.

Cat ELC Cooling System Contamination

NOTICE

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

Cat ELC cooling systems can withstand contamination to a maximum of 10 percent of conventional heavy-duty coolant/antifreeze and/or SCA. The advantages of Cat ELC are reduced. If the contamination exceeds 10 percent of the total system capacity, perform ONE of the following procedures:

- If the cooling system contamination is caused by cooling system damage, follow the procedures under the "Changing to Cat ELC" heading. Also follow the procedures if the engine has been operated since being contaminated with more than 10 percent conventional heavy-duty coolant/antifreeze and/or SCA. Certain types of cooling system contamination may require disassembly of the cooling system and manual cleaning of system components.
- If the cooling system is contaminated with more than 10 percent conventional heavy-duty coolant/antifreeze and/or SCA, but the engine has not been operated, drain the cooling system into a suitable container. Dispose of the coolant according to local regulations. Thoroughly flush the system with clean water. Fill the system with the Cat ELC.
- Maintain the system as a conventional DEAC (Diesel Engine Antifreeze/Coolant) or other conventional coolant. Submit a coolant sample for Level 2 S·O·S Coolant Analysis to determine the coolant condition. Maintain a 3 to 6 percent SCA concentration in the coolant. Change the coolant at the interval that is recommended for Cat DEAC or at the interval that is recommended for the conventional commercial coolants.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i06519602

Extended Life Inhibitor (ELI)

SMCS - 1350; 1352; 1395

Cat Extended Life Inhibitor (ELI) is water-based coolant that does not contain glycol. Cat ELI is for applications that do not require freeze protection. Exceptions are listed here. Failure to follow these recommendations can or will result in failures.

Cat ELI is a corrosion inhibitor concentrate that is mixed to approximately 7.5 % by volume with water. Cat ELI has the following characteristics:

- Based on the same organic additive technology that is used in Cat Extended Life Coolant (ELC)
- Does not contain glycol. Designed for use in applications that do not require freeze protection.
- Provides superior corrosion and cavitation protection compared to SCA mixed with water.
- Provides an extended drain interval of up to 6 years or 12,000 hours. The drain interval may be longer as determined by using Cat S·O·S coolant analysis.
- Requires little maintenance compared to conventional SCA mixed with water.

Cat ELI can replace SCA/Water coolant in engine applications that do not require freeze protection.

Exceptions for use of water-based ELI or SCA coolants are listed in this Special Publication, "Coolant Recommendations - Special Requirements Table".

Additional information is available from your Cat Dealer. Refer to Information Release Memo, PELJ1212, "Cat ELI – PERFORMANCE LIKE Cat ELC FOR APPLICATIONS NOT REQUIRING FREEZE PROTECTION". Refer to Table 1 for information about Cat ELI.

Table 1

Part Number	Container Size	Volume of Finished Coolant Produced
351-9431	3.8 L (1 US gal)	50.5 L (13.3 US gal)
351-9432	20 L (5.3 US gal)	267 L (70.5 US gal)
351-9433	208 L (55 US gal)	2773 L (733 US gal)
366-2753 (1)	1000 L (264 US gal)	13333 L (3523 US gal)

(1) NACD and LACD only

Mixing Cat ELI

The recommended water for mixing with Cat ELI concentrate is distilled or deionized water. Water must meet requirements of ASTM 1193, "Type IV Reagent Water Specification". If distilled or deionized water is not available, water should meet the “Caterpillar Minimum Acceptable Water Requirements” provided in this Special Publication.

To ensure a proper concentration, the preferred method is to mix Cat ELI concentrate with water. Then, add the mixed coolant to the engine cooling system. Add the proper amounts of water and Cat ELI into a clean container and mix thoroughly by manual stirring or mechanical agitation.

If the preferred method cannot be performed, a Cat ELI mixture can be made by adding Cat ELI concentrate directly into engine cooling system. Add good quality water until the dilution level is approximately 7.5%. Adequate mixing is attained by operating the engine for at least 30 minutes.

Appropriate mixing rates for available ELI container sizes are provided in Table 1.

After the addition of water and proper mixing, the concentration of Cat ELI can be determined using the 360-0744 digital Brix refractometer.

Changing to Cat ELI

For cooling systems previously running Cat ELC or an extended life coolant that meets Cat EC-1 requirements, drain the cooling system and flush with water. Then refill the cooling system with a mixture of 7.5% Cat ELI in water that meets the “Caterpillar Minimum Acceptable Water Requirements”.

For cooling systems previously running a conventional heavy-duty coolant or a water/SCA mixture, follow the steps listed in this Special Publication, "Changing to Cat ELC". Then refill the cooling system with a mixture of 7.5% Cat ELI in water that meets the “Caterpillar Minimum Acceptable Water Requirements”.

Cat ELI Maintenance

Maintenance of Cat ELI is similar to Cat ELC. A coolant sample should be submitted for S·O·S Level 2 Coolant Analysis after the first 500 hours of operation and then annually thereafter.

Cat ELC Extender should be added at the midpoint of service life (typically 6,000 hours), or as recommended by S·O·S Coolant Analysis results.

Analysis and interpretation of Cat ELI S·O·S results is similar to the analysis and interpretation of Cat ELC. There will be no glycol and glycol oxidation products, which do not apply to Cat ELI.

The concentration of a sample of in-use Cat ELI taken from the cooling system can also be determined using the 360-0744 digital Brix Refractometer.

Note: Clean water is the only flushing agent that is required when Cat ELI is drained from a properly maintained cooling system.

Mixing Cat ELI and Cat ELC

Since Cat ELI and Cat ELC are based on the same corrosion inhibitor technology, Cat ELI can be mixed with Cat ELC. Mixing may be desired when only low level of freeze protection is required. Consult your local Cat dealer to ensure proper mixing of the products to provide adequate freeze protection and

corrosion protection.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i06519604

Diesel Engine Antifreeze/Coolant - DEAC

SMCS - 1350; 1352; 1395

Follow the maintenance information provided in this Special Publication, "Coolant and General Maintenance Recommendations"section.

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

Cat DEAC is formulated with the correct amount of Cat SCA (Supplemental Coolant Additive). Do not use Cat SCA at the initial fill when Cat DEAC is used at the recommended 50 percent by volume glycol or higher concentration with recommended water.

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

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

Note: Mix the concentrated Cat DEAC and water thoroughly prior to filling the cooling system.

SCA is added to cooling systems that use conventional coolants for one of three reasons:

- to precharge a new conventional coolant that is not fully Formulated. Cat DEAC is fully formulated and does not require SCA
- to provide corrosion protection in water/SCA cooling systems
- to recharge an in service conventional coolant on a maintenance basis to maintain proper inhibitor levels

Conventional coolants typically require SCA additions at approximately 250-300 service hours. 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

Containers of Cat SCA are available in several sizes. Refer to this Special Publication, "Conventional Coolant/Antifreeze Cooling System Maintenance" article for available quantities and part numbers.

Note: Do not exceed a 6 percent maximum concentration of SCA. Maintain a 3 to 6 percent SCA concentration in the coolant.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i06519609

Conventional Coolant/Antifreeze Cooling System Maintenance

SMCS - 1350; 1352; 1395

NOTICE

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

NOTICE

Use Only Approved SCAs. Conventional coolants require the maintenance addition of SCA throughout their expected life. Do NOT use an SCA with a coolant unless specifically approved by the coolant supplier for use with their coolant. It is the responsibility of the coolant manufacturer to ensure compatibility and acceptable performance.

Failure to follow the recommendations can result in shortened cooling system component life.

Cat SCA is compatible with Cat DEAC. If you use non-Cat brand conventional coolants, consult with the coolant manufacturer for information on a compatible SCA.

NOTICE

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

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

If non-Cat conventional coolants that meet Cat minimum published requirements are used, confirm with the coolant manufacturer before using Cat SCA that Cat SCA is acceptable for use with the coolant. Do not exceed the 6 percent maximum concentration. Check the concentration of SCA with a SCA test kit, or check the concentration of SCA with Cat S·O·S coolant analysis.

Cat engine cooling systems should be tested at 250 hour intervals or at the PM Level 1 intervals for the concentration of SCA (Supplemental Coolant Additive).

Note: Acceptable conventional heavy-duty coolant/antifreeze of all types REQUIRE periodic additions of SCA.

Follow the maintenance information provided in this Special Publication, "Coolant and General Maintenance Recommendations" section.

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

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

Do not exceed the 6 percent maximum concentration. Check the concentration of SCA with a SCA test kit, or check the concentration of SCA with Cat S·O·S coolant analysis.

Adding the SCA to Pure Water or a Pure Water/Glycol Mixture at Initial Fill

For initial fill, Cat SCA added to pure water provides corrosion protection of the system. Ensure that the water meets quality requirements detailed in the Table “Cat Minimum Acceptable Water Requirements”, found in this Special Publication, "General Coolant Information". Also, ensure that the water or water/glycol mixture have not had additives previously added. Use the equation in Table 1 to determine the volume of the Cat SCA that is needed. The initial concentration of the SCA is recommended to be 7 percent. Once the coolant has been in service, maintain the SCA to a 3 to 6 percent range. Refer to the maintenance section for details.

Table 1

Equation For Adding The Cat SCA To Water At The Initial Fill (1)
V × 0.07 = X
V is the total volume of the cooling system.
X is the amount of Cat SCA that is required.

(1) For fluids that only meet the "ASTM D4985" specification

Table 2 is an example for using the equation that is in Table 1.

Table 2

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

Adding the SCA to Conventional Coolant/Antifreeze For Maintenance

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

Test the coolant/antifreeze periodically for the concentration of SCA. For the interval, see the Operation and Maintenance Manual, "Maintenance Interval Schedule", for your engine. SCA test kits are available from your Cat dealer. Test the concentration of SCA or submit a coolant sample to your Cat dealer. Refer to this Special Publication, "S·O·S Services Coolant Analysis", article.

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

Table 3

Equation for the Addition of Cat SCA To Water For Maintenance
V × 0.023 = X
V is the total volume of the cooling system.
X is the amount of Cat SCA that is required.

Table 4 is an example for using the equation that is in Table 3.

Table 4

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

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

Cleaning the System of Heavy-Duty Coolant/Antifreeze

Before Cat SCA can be effective, the cooling system must be free from rust, scale, and other deposits. Preventive cleaning helps avoid downtime caused by expensive out-of-service cleaning required forextremely dirty and neglected cooling systems.

Cat Cooling System Cleaners

- Dissolves or depresses mineral scales, corrosion products, light oil contaminations, and sludges
- Cleans the cooling system after used coolant is drained or before the cooling system is filled with new coolant
- Cleans the cooling system whenever the coolant is contaminated or whenever the coolant is foaming
- The “Standard” version of the Cat Cooling System Cleaners clean the cooling system while still in service.

- Reduces downtime and cleaning costs
- Helps avoid costly repairs from pitting and other internal problems caused by improper cooling system maintenance
- Can be used with glycol-based antifreeze
- For the recommended service interval, refer to the Operation and Maintenance Manual, "Maintenance Interval Schedule" for your engine.

Cat Standard Cooling System Cleaners are designed to clean the cooling system of harmful scale and corrosion without removing the engine from service. The cleaners, both “Standard” and “Quick Flush” can be used in all Cat engine cooling systems. Consult your Cat dealer for part numbers.

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

Prior to performing a cleaning of the cooling system, take a 1-liter (1-quart) sample of coolant from the engine while in operation into a clear container. Take the sample shortly after start-up while the coolant is not yet hot. The coolant should be adequately mixed by the water pump. Allow the sample to sit for 2 hours. If a visible oil layer is present, neither the Standard cleaners nor Quick Flush cleaner will be fully effective. First, drain the coolant and then perform the procedure given below (using non-foaming dish detergent), followed by the procedure for the Quick Flush cleaner.

Procedure for Cleaning an Oil Contaminated Cooling System

1. Drain the cooling system.
2. Fill the cooling system with acceptable quality water.

   Note: Refer to the “Caterpillar Minimum Acceptable Water Quality Requirements” in this Special Publication.
3. Start the engine and run the engine until the thermostat opens.
4. Add 0.473 L (0.5 qt) of 269-1948 non-foaming detergent. If the cooling system capacity exceeds 113.6 L (30 US gal), add enough detergent to equal approximately 2-3% cooling system capacity.

   Note: Pre-dissolve the detergent in approximately 19 L (5 US gallons) of acceptable quality water. Add this mixture directly to the cooling system and top off the cooling system with water.
5. Run the engine for at least 30 minutes. Drain the cooling system.
6. Remove a small sample of the detergent solution from the cooling system. Allow the solution to sit for at least 30 minutes and check for signs of a visible oil layer on top. If oil is still present, repeat the procedure.

   Note: Corrosion of the metal can occur if the detergent solution is left in the cooling system for longer than 1 hour.
7. Flush the cooling system, if there is no visible oil layer in the solution. Fill the cooling system with acceptable quality water. Run the engine for 20 minutes and then drain the water.
8. Perform the cleaning procedure found in this Special Publication for “Cat Cooling System Cleaner -

Quick Flush”, if additional removal of scale, rust, and inhibitor deposits from the previous coolant is needed.

9. If additional cleaning is not needed, refill the cooling system with new coolant.

Table 5

Cat Cooling System Cleaner for use with Quick Flush Method	
Cleaner part number	Size of Container
4C-4609	0.5 L (0.125 US gal)
4C-4610	1 L (0.25 US gal)
4C-4611	3.8 L (1 US gal)
4C-4612	19 L (5 US gal)
4C-4613	208 L (55 US gal)

Procedure for using Cat Cooling System Cleaner - Quick Flush

1. Drain the cooling system.
2. Refill the cooling system to 90-94% capacity with acceptable quality water.

   Note: Refer to the “Caterpillar Minimum Acceptable Water Quality Requirements” as found in this Special Publication.

3. Top off the cooling system with Cat Cooling System Cleaner - Quick Flush cleaner so that the solution is 6-10% cleaner.
4. Run the engine for 1.5 hours.
5. After allowing adequate time for the system to cool, drain the cooling system.

   Note: Corrosion of the metals can occur if the Quick Flush cleaning solution is in the cooling system for longer than 2 hours.

6. Flush the cooling system.

   a. Fill the cooling system with acceptable quality water.

   b. Run the engine for 20 minutes.

   c. Drain the water.

7. Refill the cooling system with new coolant.

Table 6

Cat Cooling System Cleaner - Standard		
Part Number	Volume	Availability
6V-4511	1.89 L (0.5 US gal)	North and South America

185-5121	1.89 L (0.5 US gal)	Europe, Africa, Middle East

Procedure for using Cat Cooling System Cleaner - Standard

1. If necessary, drain off coolant from the cooling system for the amount of the cleaner.
2. Add 1 bottle (1.89 L (0.5 US gal)) of Cat Cooling System Cleaner - Standard for each 30 L of cooling system capacity. Add the cleaner directly to the coolant.
3. Run the engine as usual.
4. After 30 days, drain the cooling system.
5. Flush the cooling system.
    a. Fill the cooling system with acceptable quality water.
    b. Run the engine for 20 minutes.
    c. Drain the water.
6. Refill the cooling system with new coolant.

Recycling Cat DEAC

Cat DEAC can be recycled. The drained coolant mixture can be distilled to separate the ethylene glycol and water. The ethylene glycol and the water can be reused. The distilled material does not contain the additives that are classified as either Cat ELC or Cat DEAC. Consult your Cat dealer for more information.

When recycled coolants are used, use only coolants that have been recycled from extended life, heavy-duty, or automotive coolants. Use coolants that were originally manufactured from virgin ethylene or propylene glycol.

Recycled coolants should meet the latest revision of "ASTM D6210".

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i04902207

Commercial Heavy-Duty Coolant/Antifreeze and SCA (Supplemental Coolant Additive)

SMCS - 1350; 1352; 1395

NOTICE

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

NOTICE

Do NOT mix brands or types of SCA. Do NOT mix SCAs and extenders.

Failure to follow the recommendations can result in shortened cooling system component life.

NOTICE

Use Only Approved SCAs. Conventional coolants require the maintenance addition of SCA throughout their expected life. Do NOT use an SCA with a coolant unless specifically approved by the coolant supplier for use with their coolant. It is the responsibility of the coolant manufacturer to ensure compatibility and acceptable performance.

Failure to follow the recommendations can result in shortened cooling system component life.

Follow the maintenance information provided in the “Coolant and General Maintenance Recommendations” section in this Special Publication.

Select a commercial diesel engine antifreeze coolant that meets all the requirements given in Table 1. The table contains the requirements for coolant to meet the published service intervals.

The provided requirements are applicable to finished coolants and not for the concentrates. When concentrated coolant/antifreeze is mixed, Cat recommends mixing the concentrate with distilled water or

with deionized water. If distilled water or deionized water is not available, water which has the required properties may be used. For the water properties, refer to this Special Publication, "General Coolant Information" article.

Coolant/antifreezes for heavy-duty applications that meet "ASTM D6210" do not require treatment with SCA at the initial fill. Use the recommended 1:1 or higher concentration with recommended water. Treatment with SCA is required on a maintenance basis.

The SCA manufacturer is responsible for ensuring the SCA is compatible with water meeting the “Caterpillar Minimum Acceptable Water Quality Requirements” as found in this Special Publication, and "ASTM D6210-08, Table X1.1". The coolant manufacturer and the SCA manufacturer are responsible to ensure that the products will not cause cooling system harm.

Do not mix brands or types of coolants with different brands or types of SCA or extender.

If using non Cat coolants, refer to the coolant manufacturer for information on a compatible SCA.

Treat the compatible commercial coolant with 3 to 6 percent Cat SCA by volume. Maintain a 3 to 6 percent concentration level of SCA in the cooling system. For more information, refer to this Special Publication, "Conventional Coolant/Antifreeze Cooling System Maintenance" article.

Table 1

Technical Requirements for Commercial Diesel Engine Antifreeze Coolants	
Specifications	ASTM D6210-08 or ASTM D4985-05
Additional Requirements	Silicon: 100 ppm minimum to 275 ppm maximum Nitrites: maintained at 1200ppm (70 grains/US gal) minimum to 2400 ppm (140 grains/US gal) maximum Cat SCA at 3 to 6 percent (if Cat SCA is added)
Maintenance	ASTM D4985-05: Add compatible SCA at initial fill ASTM D6210-08 and ASTM D4985-05: Add compatible SCA at maintenance intervals Clean and flush the cooling system at drain intervals

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i04332070

Water/SCA (Supplemental Coolant Additive)

SMCS - 1350; 1352; 1395

Cat SCA can be added to water of the recommended quality to form a Water/SCA finished coolant. SCA/Water finished coolant is glycol free. SCA/Water finished coolant is for engine applications that do not require freeze protection.

Exceptions are listed in this Special Publication, "Coolant Recommendations - Special Requirements". Failure to follow these recommendations can or will result in failures.

NOTICE

Never use water alone as a coolant. Water alone is corrosive at engine operating temperatures. In addition, water alone does not provide adequate protection against boiling or freezing.

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

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

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

The quality of the water is an important factor in this type of cooling system. Distilled water or deionized water is recommended for use in cooling systems. If distilled water or deionized water is not available, use water that meets or exceeds the minimum requirements that are listed in the table for recommended water properties in this Special Publication, "General Coolant Information" topic.

A cooling system that uses a mixture of SCA and water only needs more SCA. The SCA concentration in a cooling system that uses SCA and water should be 6 to 8 percent by volume.

Note: Do not exceed the 8 percent maximum concentration. Check the concentration of Cat SCA with a **298-5311** Coolant Nitrite Test Kit for SCA or perform an S·O·S coolant analysis. The test kit includes: testing tool, 30 nitrite test ampoules, instruction and hardcase. 294-7420 contains refill ampoules for the **298-5311** Coolant Nitrite Test Kit.

Note: The **298-5311** Coolant Nitrite Test Kit is NOT calibrated to test the nitrite levels of conventional coolants or extended life coolants.

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

Adding the Cat SCA to Water at the Initial Fill

Use the equation that is in this Special Publication, "Conventional Coolant/Antifreeze Cooling System Maintenance" to determine the amount of Cat SCA that is required at the initial fill. This equation is for a mixture of only Cat SCA and water.

Adding the Cat SCA to Water for Maintenance

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

Submit a coolant sample to your Cat dealer. See this Special Publication, "S·O·S Services Coolant Analysis" topic.

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

Use the equation that is in this Special Publication, "Conventional Coolant/Antifreeze Cooling System Maintenance" to determine the amount of Cat SCA that is required for maintenance, if necessary:

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

SCA and part numbers are available from your Cat dealer.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i04286217

S·O·S Services Coolant Analysis

SMCS - 1350; 1395; 7542

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

NOTICE

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

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

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

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

New Systems, Refilled Systems, and Converted Systems

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

- Every Year
- Initial 500 service hours

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

Recommended Sampling Interval for S·O·S Services Coolant Analysis

Table 1

Recommended Interval		
Type of Finished Coolant	Level 1	Level 2
Cat DEAC Cat SCA Conventional Heavy-Duty Coolants	Every 250 hours (1) (2)	Yearly (1) (2) (3)
Cat ELC Cat ELI Commercial EC-1 Coolants	Optional (3)	Yearly (3)

(1) The recommended sampling interval for all commercial coolants that meet Cat EC-1 (Engine Coolant specification - 1)

(2) The recommended sampling interval for all conventional heavy-duty coolant/antifreeze.

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

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

S·O·S Services Coolant Analysis (Level 1)

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

The following properties of the coolant are tested:

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

The results are reported, and appropriate recommendations are made.

S·O·S Services 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 cooling system.

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

- Full coolant analysis (Level 1)
- Identification of metal corrosion and of contaminants
- Identification of buildup of the impurities that cause corrosion
- Identification of buildup of the impurities that cause scaling

- Determination of the possibility of electrolysis within the cooling system of the engine

The results are reported, and appropriate recommendations are made.

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

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05424591

Diesel Exhaust Fluid (DEF) - For Use in SCR-equipped engines

SMCS - 108K

General Information

Diesel Exhaust Fluid (DEF) is a liquid that is injected into the exhaust system of engines equipped with Selective Catalytic Reduction (SCR) systems. SCR reduces emissions of nitrogen oxides (NOx) in diesel engine exhaust.

Diesel Exhaust Fluid (DEF) is available in many brands, including those brands that carry the AdBlue or API certification. DEF is also generically referred to as urea.

In engines equipped with SCR emissions reduction system, DEF is injected in controlled amounts into the engine exhaust stream. At the elevated exhaust temperature, urea in DEF is converted to ammonia. The ammonia chemically reacts with NOx in diesel exhaust in the presence of the SCR catalyst. The reaction converts NOx into harmless nitrogen (N_2) and water (H_2O).

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

Note: These general recommendations and guidelines concerning maintenance and care of DEF and DEF storage systems are not intended to be all inclusive. Discuss proper DEF safety, health, handling, and maintenance practices with your DEF supplier. Use of these general recommendations and guidelines does not lessen the responsibility of the engine owner and/or DEF supplier to follow all industry standard practices for DEF storage and for DEF handling.

Characteristics of DEF and Urea Fluids

DEF solutions are typically of 32.5 percent concentration urea. However, some marine engines may use DEF (32.5 percent urea concentration) or urea solutions of 40 percent concentration. All DEF solutions that are of 32.5 percent urea must meet all the requirements defined by the "ISO 22241-1" standard.

The caps of DEF tanks are blue, as required by emissions regulations. Fill DEF only in clearly marked DEF tanks that have the blue cap.

Caterpillar recommends the use of DEF available through the Cat parts ordering system for use in Cat engines equipped with SCR systems. Refer to Table 1 for part number information:

Table 1

Cat Part Number (32.5% Urea)	Container Size
350-8733	2.5 gal bottle

350-8734	1000-L tote

In North America, commercial DEF of 32.5 percent urea concentration that is API approved and meets all the requirements defined in "ISO 22241-1" may be used in Cat engines that are equipped with SCR systems.

Outside of North America, commercial DEF of 32.5 percent urea concentration that meets all requirements defined in "ISO 22241-1" may be used in Cat engines that are equipped with SCR systems.

The supplier should provide documentation to prove the DEF is compliant with the requirements of "ISO 22241-1".

NOTICE

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

NOTICE

Do not use agriculture grade urea solutions. Do not use any DEF 32.5 percent fluid that does not meet "ISO 22241-1" Requirements in SCR emissions reduction systems. Use of these fluids can result in numerous problems including damage to SCR equipment and a reduction in NOx conversion efficiency.

DEF is a solution of solid urea that is dissolved in demineralized water to produce a final concentration of 32.5 percent urea. Most SCR systems are designed to operate only on DEF concentration of 32.5 percent. DEF solution of 32.5% urea has the lowest attainable freeze point of −11.5° C (11.3° F). DEF concentrations that are higher or lower than 32.5 percent have higher freeze points. DEF dosing systems and "ISO 22241-1" specifications are designed for a solution that is approximately 32.5 percent.

Marine engines and other specific applications may use urea solutions of 32.5 percent or 40 percent concentrations in engines equipped with SCR systems. Refer to the information given specifically for marine engines in this DEF article and to your engine Operation and Maintenance Manual.

Cat offers refractometers that can be used to measure DEF concentration. Refer to Table 2 for the part numbers. Follow the instructions provided with the instruments.

Table 2

Cat DEF Refractometers		
Refractometer Part Numbers	360-0774	Digital display, easy to use, and multifunctional (DEF, coolant, battery fluid, and more)
	431-7087	Analog, specific to DEF, and requires a multi-step test procedure

Urea Solution Recommendations for Marine Engines

US waters are an International Maritime Organization (IMO) NOx Emissions Control Area (NECA). Low NOx engines are required in these areas. These engines may require the use of Diesel Exhaust Fluid (DEF) and other urea solutions for engines equipped with Selective Catalytic Reduction (SCR) systems. If required, Cat marine engines are designed to operate on DEF of urea concentrations of 32.5 percent (by weight) or 40 percent (by weight). The crystallization temperature of 40 percent urea solution is 0° C (32° F). If urea solution ambient temperatures are routinely below 5° C (41° F) and supplemental heat is not applied to urea storage, then 32.5 percent solution should be used and maintained at a temperature above −10° C (14° F). Urea solutions should be maintained above the specified freezing temperature. Consult the urea supplier and follow the guidelines provided in this article for solution handling and recommendations

Vessels that are traveling internationally and that have on/off NOx controls must enable these controls prior to entering a NECA. For US flagged vessels, on/off controls are not allowed without an exemption during international travel. The controls must always be on. Foreign destinations should be reviewed for supply of ULSD fuel and DEF prior to departure. Exemptions for ULSD or DEF use by US flagged vessels may be requested from the US Environmental Protection Agency (EPA). The EPA can be contacted at the following address:

complianceinfo@epa.gov

When used in marine engines, DEF of 32.5 percent urea concentration must meet all the guidelines and quality recommendations given in this Chapter.

When used in marine engines, urea solutions of 40 percent concentration must follow all the DEF guidelines and quality recommendations given in this chapter and must meet the characteristics listed in Table 4 for 40 percent concentration. The supplier should provide documentation to prove that the urea solution is compliant with the characteristics published in Table 4.

Refer to your engine Operation and Maintenance Manual to determine the concentration of urea solution allowed in your engine.

NOTICE

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

DEF Guidelines

DEF solution is typically colorless and clear. Changes to color or clarity are indicators of quality issues. Quality of DEF can degrade when stored and handled inappropriately or if DEF is not protected from contamination. Details are provided below.

If quality issues are suspected, testing of DEF should focus on urea percentage, alkalinity as NH3 and biuret content. DEF that does not pass all these tests or that is no longer clear should not be used.

Note: Caterpillar strongly recommends that customers purchase the pre-mixed DEF urea solution from a reputable supplier. The DEF must satisfy all the specifications of quality given in this chapter of this

Special Publication. Urea solutions that are not made of urea and water of the appropriate quality and cleanliness may damage the SCR system. Poor or questionable quality DEF can lead to additional repair and maintenance costs to the customer. Cat warranties do not cover failures caused by or related to use of out of specification urea solutions in Tier 4 Stage IIIB MLIT Step 4 products equipped with SCR systems.

Materials compatibility

DEF is corrosive. Due to the corrosion caused, DEF must be stored in tanks constructed of approved materials. Recommended storage materials:

Stainless Steels:

- 304 (S30400)
- 304L (S30403)
- 316 (S31600)
- 316L (S31603)

Alloys and metals:

- Chromium Nickel (CrNi)
- Chromium Nickel Molybdenum (CrNiMo)
- Titanium

Non-metallic materials:

- Polyethylene
- Polypropylene
- Polyisobutylene
- Teflon (PFA)
- Polyfluoroethylene (PFE)
- Polyvinylidene fluoride (PVDF)
- Polytetrafluoroethylene (PTFE)

Materials NOT compatible with DEF solutions include aluminum, copper, copper alloys, magnesium, zinc, nickel coatings, silver and carbon steel and solders containing any of the above. Unexpected reactions may occur if DEF solutions come in contact with any non-compatible material or unknown materials.

Bulk storage

Follow all local regulations covering bulk storage tanks. Follow proper tank construction guidelines. Tank volume typically should be 110% of planned capacity. Appropriately vent indoor tanks. Plan for control of overflow of the tank. Heat tanks that dispense DEF in cold climates.

Bulk tank breathers should be fitted with filtration to keep airborne debris from entering the tank. Desiccant breathers should not be used because water will be absorbed, which potentially can alter DEF concentration.

Handling

Follow all local regulations covering transport and handling. DEF transport temperature is recommended to be −5° C (23° F) to 25° C (77° F). All transfer equipment and intermediate containers should be used exclusively for DEF. Containers should not be reused for any other fluids. Ensure that transfer equipment is made from DEF-compatible materials. Recommended material for hoses and other non-metallic transfer equipment include:

- Nitrile Rubber (NBR)
- Fluoroelastomer (FKM)
- Ethylene Propylene Diane Ionomer (EPDM)

The condition of hoses and other nonmetallic items that are used with DEF should be monitored for signs of degradation. DEF leaks are easily recognizable by white urea crystals that accumulate at the site of the leak. Solid urea can be corrosive to galvanized or unalloyed steel, aluminum, copper, and brass. Leaks should be repaired immediately to avoid damage to surrounding hardware.

Cleanliness

Contaminants can degrade the quality and life of DEF. Filtering DEF is recommended when dispensed into the DEF tank. Filters should be compatible with DEF and should be used exclusively with DEF. Check with the filter supplier to confirm compatibility with DEF before using. Mesh-type filters using compatible metals, such as stainless steel, are recommended. Paper (cellulose) media and some synthetic filter media are not recommended because of degradation during use.

Care should be taken when dispensing DEF. Spills should be cleaned immediately. Machine or engine surfaces should be wiped clean and rinsed with water. Caution should be used when dispensing DEF near an engine that has recently been running.

Note: Spilling DEF onto hot components may cause the release of ammonia vapors. Do not breathe ammonia vapors. Do not clean up any spills with bleach.

Stability

DEF fluid is stable when stored and handled properly. The quality of DEF rapidly degrades when stored at high temperatures. The ideal storage temperature for DEF is between −9° C (15.8° F) and 25° C (77° F). DEF that is stored above 35° C (95° F) for longer than 1 month must be tested before use. Testing should evaluate Urea Percentage, Alkalinity as NH3 and Biuret content.

The length of storage of DEF is listed in the following table:

Table 3

Storage Temperature	Expected DEF Life
Below 25° C (77° F)	18 months

25° C (77° F) to 30° C (86° F)	12 months
30° C (86° F) to 35° C (95° F)	6 months
Above 35° C (95° F)	test quality before use

Refer to "ISO 22241" document series for more information about DEF quality control.

Note: Dispose of all fluids according to applicable regulations and mandates.

General Characteristics of DEF

For detailed information on the requirements and characteristics of DEF, refer "ISO 22241". For a quick reference, typical characteristics of DEF are given in Table 4.

Table 4

Characteristics for Urea Solutions			
Property	Unit	DEF 32.5 percent	Urea Solution 40 percent
Urea content		32.5 percent (1)	40 percent (2)
Alkalinity as NH_3	Percent	0.2	0.2
Density at 20° C (68° F)	g/L	1.087 - 1.093 (3)	1.108 - 1.114 (4)
Refractive Index at 25° C (77° F)		1.381 - 1.384 (5)	1.394-1.397 (6)
Biuret	Percent	0.3 max	
Aldehydes	mg/kg	5 max	
Insoluble Matter	mg/kg	20 max	
Aluminum	mg/kg	0.5 max	
Calcium	mg/kg	0.5 max	
Chromium	mg/kg	0.2 max	
Copper	mg/kg	0.2 max	
Iron	mg/kg	0.5 max	
Magnesium	mg/kg	0.5 max	
Nickel	mg/kg	0.2 max	

Phosphate (PO_4)	mg/kg	0.5 max
Potassium	mg/kg	0.5 max
Sodium	mg/kg	0.5 max
Zinc	mg/kg	0.2 max

(1) Acceptable range is 31.8 - 33.2 percent

(2) Acceptable range is 39-41 percent

(3) Target value is 1.090 g/L

(4) Target value is 1.112

(5) Target value is 1.382

(6) Target value is 1.3956

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05472409

Contamination Control

SMCS - 1280; 1348; 3080; 5095; 7581

Defining Contamination

Contamination is defined as the presence of unwanted foreign substances in fluid systems or fluid wetted parts. Contamination alters the properties of fluids, causes damage of fluid 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, oil, and fuel
- 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 be drawn into the system from the outside environment or contaminated fill fluids or improper maintenance and repair practices.

Particle contaminants 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. The critical particle size for wear particles in a modern diesel engine fuel system is 4 µm.

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

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

Measuring Cleanliness

Fluid cleanliness can be measured by taking fluid samples from various machine compartments. Your Cat

dealer can analyze the samples. Particle contaminants are typically measured by particle counters. Chemical contaminants can be measured by specific analysis techniques such as oxidation, water, or soot tests. Some chemical contaminants, such as water in fuel, can interfere with the particle counters and can be counted as particles. Refer to your Cat S·O·S lab or to your Cat dealer for more information.

The number of particles in fluids is expressed in "ISO (International Organization for Standardization)" ratings. "ISO 4406" Standard classifies fluid cleanliness by the number and size of particles in 1 milliliter of fluid. "ISO 4406" Standard measures particle size in µm (microns) and reports the resulting count in three code ranges X, Y & Z. The three code range defines the size and distribution of particles in 1 milliliter of fluid:

- The first code range, X represents the number of particles equal to or larger than 4 µm per milliliter of fluid.
- The second code range, Y represents the number of particles equal to or larger than 6 µm per milliliter of fluid.
- The third code range, Z represents the number of particles equal to or larger than 14 µm per milliliter of fluid.

An example of an "ISO 4406" particle count is 18/16/13. Cat "ISO" cleanliness recommendations are expressed as two or three codes, depending on the machine system. The three code range follows "ISO 4406" definitions and is used for liquid fuels such as diesel and gasoline. The two code system, example "ISO -/16/13", is used for certain lubricant systems. In the two code system, the first number is the number of particles equal to or larger than 4 µm per milliliter of fluid. This number is not required and may be represented by a dash (-). The second number (Y) and the third number (Z) follow "ISO 4406" definitions. Cat reports the Y and Z codes for lubricating oils to keep consistency with older data and reports.

An example of the particle size and distribution of the "ISO 4406" codes is given in Table 1.

Table 1

ISO 4406 Code	**Number of particles in 1 milliliter of fluid**		
	4µm and up	**6µm and up**	**14µm and up**
"ISO 18/16/13"	1300 - 2500	320 - 640	40 - 80
"ISO 21/19/17"	10000 - 20000	2500 - 5000	80 - 160

Note: Several factors affect the results of particle counts. The factors include the cleanliness of the equipment used to obtain the sample, sample 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.

Note: American Society for Testing and Measurement has developed "ASTM D7619" "Standard Test Method for Sizing and Counting Particles in Light and Middle Distillate Fuels, by Automatic Particle Counter". This test procedure was developed in 2010 to count and measure the size of dispersed dirt particles, water droplets, and other particles in 1-D and 2-D diesel fuels when the specified particle

counter is used. "ASTM D7619" is also applicable to biodiesel fuels.

Cleanliness Standards for Fill Fluids

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

Cat has established minimum fluid cleanliness targets for fuels and fill oils and for engines before they return to work after maintenance. Fluids filled into engine fill tanks are recommended to be at the target levels provided in Table 2 or cleaner. When system fill fluids are maintained at or cleaner than the "ISO" cleanliness targets, contamination-related effects will be reduced.

Table 2

Cat Recommended Fluid Cleanliness Targets [1]		
Cat Recommended Cleanliness Targets for Fluids Dispensed into Engine Fill tanks	Fill oils	[2]
	Dispensed fuels	"ISO 18/16/13"

[1] The fluids should meet or exceed the cleanliness requirements of the listed ISO levels.

[2] For engine oils, when filtering the oil prior to dispensing into the engine tank, use engine oil filters of 12 micron absolute efficiency and ensure that the oil temperature is 20° C (68° F) or higher. Refer to the details given in this article.

The "fill" fluids cleanliness target is not a fluid "delivery" target. The level of cleanliness for delivered fluids is not specified by Cat. Customers can work with the distributors or carriers to determine the cleanliness level of delivered fluids. However, a more effective and economic means to achieve the fill cleanliness targets is to filter the fluids prior to filling into engine tanks as compared with specifying delivery fluid cleanliness level. Follow the guidelines provided in this Contamination Control article.

Although older technology machines may not be able to maintain the recommended cleanliness targets of advanced models, the same contamination control intervention measures such as filtration and subsequent service procedures should be used on all Cat products.

Note: When particle counting new multi-viscosity engine oils, there may be difficulties achieving cleanliness targets. Optical particle counters cannot distinguish between particulate contaminants and additives. 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. 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 Fuel Systems in this chapter for recommended fuel cleanliness levels and guidelines.
- Refer to the engine Operation and Maintenance Manual for the required maintenance for all engine fluids.
- When you add oil to an engine, use engine oil filters of 12 microns absolute efficiency. Ensure that the oil temperature is 20° C (68° F) or higher.
- Perform scheduled S·O·S Services Oil Analysis for contamination in order to maintain the recommended ISO cleanliness level of fill and machine fluids. Refer to the S·O·S Oil Analysis section in this Special Publication. The particle count analysis can be performed by your Cat dealer. Particle count can be conducted during the scheduled S·O·S Services Oil Analysis for the compartment. Extra oil samples are not required for the particle count sampling.
- 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 ingression.
- Follow contamination control practices for the shop area, component/machine disassembly areas, parts, shop tools, test setups, test areas, storage areas and waste collection areas. Keep components clean during inspection, assembly, testing, and filling engines 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 of debris and water.
- Drain the storage tanks from 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. Based on the contamination control program followed, and/or on the fuel supplier recommendations, the storage tank draining schedule may be as frequent as daily until no water is present, and then can be extended to longer periods.
- Install and maintain a properly designed and grounded filtration system. Filtration should include 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.

Note: Bulk fuel filtration units are available through your Cat dealer. Proper maintenance practices of the

bulk filtration systems are available through your Cat dealer.

Contamination Control Recommendations for Fuels

Fuels of "ISO 18/16/13" cleanliness level or cleaner as dispensed into the engine or machine fuel tank should be used. Reduce power loss, failures, and related down time of engines will result. This cleanliness level is important for new fuel system designs such as Common Rail injection systems and unit injection systems. Injection system designs utilize higher fuel pressures and tight clearances between moving parts in order to meet required stringent emissions regulations. Peak injection pressures in current fuel injection systems may exceed 30,000 psi. Clearances in these systems are less than 5 µm. As a result, particle contaminants as small as 4 µm can cause scoring and scratching of internal pump and injector surfaces and of injector nozzles.

Water in the fuel causes cavitation, corrosion of fuel system parts, and provides an environment where microbial growth in the fuel can flourish. Other sources of fuel contamination are soaps, gels, or other compounds that may result from undesirable chemical interactions in the fuels, particularly in Ultra Low Sulfur Diesel (ULSD). Gels and other compounds can also form in biodiesel fuel at low temperatures or if biodiesel is stored for extended periods. The best indication of microbial contamination, fuel additives, or cold temperature gel is rapid filter plugging of bulk fuel filters or machine fuel filters.

In order to reduce downtime due to contamination, follow these fuel maintenance guidelines. Also, follow the General Contamination Control Recommendations or Practices given above in this Chapter:

- Use high-quality fuels per recommended and required specifications (refer to the Fuel Chapter in this Special Publication)
- Fill machine fuel tanks with fuels of "ISO 18/16/13" cleanliness level or cleaner, in particular for engines with common rail and unit injection systems. When you refuel the machine, filter the fuel through a 4 µm absolute filter (Beta 4 = 75 up to 200) in order to reach the recommended cleanliness level. This filtration should be located at the device that dispenses the fuel to the engine or machine fuel tank. In addition, filtration at the dispensing point should remove water to ensure that fuel is dispensed at 500 ppm water or less.
- Cat recommends the use of bulk fuel filter / coalescer units which clean the fuel of both particulate contamination and water in a single pass. Cat offers heavy-duty filter / coalescer units to accommodate fueling rates from 50 to 300 gpm (gallons per minute).
- Ensure that you use Cat Advanced Efficiency Fuel Filters. Change your fuel filters per recommended service requirements or as needed.
- Drain your water separators daily per the Operation and Maintenance Manual of your machine.
- Drain your fuel tanks of sediment and water per the Operation and Maintenance Manual of your machine or sooner as fuel condition indicates.
- Install and maintain a properly designed bulk filter / coalescer filtration system. Continuous bulk filtration systems may be required to ensure that dispensed fuel meets the cleanliness target. Consult your Cat dealer for availability of bulk filtration products.
- Centrifugal filters may need to be used as a pre-filter with fuel that is severely contaminated with gross amounts of water and/or large particulate contaminants. Centrifugal filters can effectively remove large contaminants, but may not be able to remove the small abrasive particles required to

achieve the recommended "ISO" cleanliness level. Bulk filter / coalescers are necessary as a final filter in order to achieve the recommended cleanliness level.

- Install desiccant type breathers of 4 µm or less absolute efficiency with the ability to remove water on bulk storage tanks.
- Follow proper practices of fuel transportation. Filtration from the storage tank to the machine promotes the delivery of clean fuel to machine tank. Fuel filtration can be installed at each transport stage in order to keep the fuel clean.
- Cover, protect, and ensure cleanliness of all connection hoses, fittings, and dispensing nozzles.

NOTICE

In order to meet expected fuel system component life, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with common-rail fuel systems. Also, 4 micron(c) absolute or less secondary fuel filtration is required for all Cat diesel engines that are equipped with unit injected fuel systems. For all other Cat diesel engines (mostly older engines with pump, line and nozzle type fuel systems), the use of 4 micron(c) absolute or less secondary fuel filtration is strongly recommended. Note that all current Cat diesel engines are factory equipped with Cat Advanced Efficiency 4 micron(c) absolute fuel filters.

Consult your local Cat dealer for additional information on Cat designed and produced filtration products.

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i05423675

Reference Material

SMCS - 1000; 7000

The following publications are available for order through your Caterpillar dealer.

Note: The information that is contained in the listed publications is subject to change without notice. Consult your local Caterpillar dealer for the most current recommendations.

Note: Refer to this Special Publication, the respective product data sheet, and to the appropriate Operation and Maintenance Manual for product application recommendations.

Lubricants, Coolants, and Greases

- Data sheets, specifications, and recommendations for Cat lubricants, coolants, and greases are available through your Cat dealer and at the following website:

http://parts.cat.com/parts/machine-fluids

- Special Publication, PEWJ0074, "Filters and Fluids Application Guide"
- Special Publication, PEHJ0149, "Cat Filters and Fluids Toolbox Update - Datasheet Set"
- Special Publication, REHS1063, "Know Your Track-Type Tractor Cooling System"
- Special Publication, SEBD0518, "Know Your Cooling System"
- Special Publication, SEBD0970, "Coolant and Your Engine"
- Special Publication, PEGJ0035, "Grease Selection Guide"
- Datasheet, PEHJ0093, "Cat DEO Monograde - Monograde Diesel Engine Oil for Cat 3600 series diesel engines"

Fuel

- Special Publication, PEHP7046, "Fuel Contamination Control Data Sheet"
- Special Publication, SENR9620, "Improving Fuel System Durability"
- Special Publication, SEBD0717, "Diesel Fuels and Your Engine"
- "ASTM D6751 Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels"

- "EN 14214 Automotive fuels - Fatty acid methyl esters (FAME) for diesel engines - Requirements and test methods"
- "ASTM D7467 Standard Specification for Diesel Fuel Oil, Biodiesel Blend (B6 to B20)"
- "ASTM D975 Standard Specification for Diesel Fuel Oils" (includes requirements for B5 and lower biodiesel blends)
- "EN 590 Automotive fuels - Diesel - Requirements and test methods" (includes requirements for B5 and lower biodiesel blends)
- "EN 14078 Liquid petroleum products - Determination of fatty acid methyl esters (FAME) in middle distillates - Infrared spectroscopy method"
- "EN 14104 Fat and oil derivatives - Fatty Acid Methyl Esters (FAME) - Determination of Acid Value"
- "ASTM D664 Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration"
- "ASTM D6469 Standard Guide for Microbial Contamination in Fuels and Fuel Systems"
- "Facts You Should Know About Renewable Fuels, EMA (Engine Manufacturer Association)"
- "EMA Technical Position on Use of Biodiesel Position Statement, EMA (Engine Manufacturer Association)"
- "ISO 8217 Petroleum products Fuels (class F) Specifications of marine fuels"
- Special Instruction, REHS0104, "Guidelines for 3600 Heavy Fuel Oil Engine"

http://www.truckandenginemanufacturers.org/articles

Filters

- For general Cat filtration products, refer to the following website:

https://commerce.cat.com/en/catcorp/filters

- Special Publication, PEWJ0074, "Filters and Fluids Application Guide"
- Special Publication, PEHP7046, "Fuel Contamination Control"

S·O·S Services

- Special Publication, PEHJ0191, "S·O·S Services Data Sheet"
- Special Publication, PEHP7052, "Making the Most of S·O·S Services"
- Special Publication, PEGJ0046, "Understanding S·O·S Reports"
- Special Publication, PEGJ0047, "How to Take a Good S·O·S Sample"
- Special Publication, PEGJ0045, "Reporting Particle Count by ISO Code"

- Special Publication, PEDJ0129, "Fuel Sampling Guide"
- Special Publication, PEDP7036, "S·O·S Fluids Analysis Cornerstone"
- Special Publication, PEHP7076, "Understanding S·O·S Service Tests"

Miscellaneous

- Special Publication, PEBJ0002, "Caterpillar Dealer Contamination Control Compliance Guide"
- Special Publication, PEBJ0007, "Caterpillar Customer Contamination Control Compliance Guide"
- Special Publication, SEBU5898, "Cold Weather Recommendations"
- Special Publication, PEDP9131, "Fluid Contamination - The Silent Thief"
- Special Publication, AECQ1043, "Caterpillar Product Line Brochure"
- Special Publication, PEWJ0074, "Cat Filter and Fluid Application Guide"
- Special Publication, PECP9067, "One Safe Source"
- Special Publication, NENG2500, "Caterpillar Dealer Service Tool Catalog"
- Special Publication, PECJ0003, "Cat Shop Supplies and Tools" catalog
- Special Publication, SENR3130, "Torque Specifications"
- Special Publication, SENR9620, "Improving Component Durability - Fuel Systems" (Package of 10)
- Special Publication, SEBF1018, "Improving Component Durability - Engines" (Package of 10)
- Special Publication, SEBF1020, "Improving Component Durability - Managing Fluid Cleanliness" (Package of 10)
- Special Publication, SEBF1015, "Improving Component Durability - Final Drives and Differentials" (Package of 10)
- Special Publication, SEBF1016, "Improving Component Durability - Powershift Transmissions" (Package of 10)
- Special Publication, SEBF1017, "Improving Component Durability - Component Removal and Installation" (Package of 10)
- Special Publication, SEBF1019, "Improving Component Durability - Hydraulics" (Package of 10)
- Special Publication, SEBF1021, "Improving Component Durability" Boxed set (Includes one each of the 7 "Improving Component Durability" series.)
- Special Publication, SEBD0348, "Caterpillar Performance Handbook"
- ASTM D6469"Standard Guide for Microbial Contamination in Fuels and Fuel Systems"

Additional Reference Material

SAE J183"Classification" This document can normally be found in the SAE handbook.

SAE J313"Diesel Fuels" This document can be found in the SAE handbook. Also, this publication can be obtained from your local technological society, from your local library, or from your local college.

SAE J754"Nomenclature" This document can normally be found in the SAE handbook.

Engine Manufacturers Association" Engine Fluids Data Book"

Engine Manufacturers Association
Two North LaSalle Street, Suite 2200
Chicago, Illinois USA 60602
http://www.truckandenginemanufacturers.org/articles

For information on the American Petroleum Institute (API) engine oil categories, contact the API at:

1220 L Street, NW
Washington, DC USA 20005-4070
http://www.api.org

Operation and Maintenance Manual
Cat 3600 Series and C280 Series Diesel Engine Fluids Recommendations
Media Number -SEBU7003-05 **Publication Date -01/11/2013** **Date Updated -18/11/2013**

i02780825

Additional Reference Material

SMCS - 1000; 7000

The "Society of Automotive Engineers (SAE) Specifications" can be found in your SAE handbook. This publication can also be obtained from the following locations: local technological society, local library and local college. If necessary, consult SAE at the following address:

SAE International
400 Commonwealth Drive
Warrendale, PA, USA 15096-0001
Telephone (724) 776-4841

The "American Petroleum Institute Publication No. 1509" can be obtained from the following locations: local technological society, local library and local college. If necessary, consult API at the following address:

American Petroleum Institute
1220 L St. N.W.
Washington, DC, USA 20005
Telephone (202) 682-8000

The International Organization for Standardization (ISO) offers information and customer service regarding international standards and standardizing activities. ISO can also supply information on the following subjects that are not controlled by ISO: national standards, regional standards, regulations, certification and related activities. Consult the member of ISO in your country.

International Organization for Standardization (ISO)
1, rue de Varembé
Case postale 56
CH-1211 Genève 20
Switzerland
Telephone +41 22 749 01 11
Facsimile +41 22 733 34 30
E-mail central@iso.ch
Web site http://www.iso.ch

European classifications are established by the Counseil International Des Machines a Combustion (CIMAC) (International Council on Combustion Engines).

CIMAC Central Secretariat
Lyoner Strasse 18
60528 Frankfurt
Germany

Telephone +49 69 6603 1567
Facsimile +49 69 6603 1566

Diesel Engines

ABS	Agco-Sisu
Akasaka	Baudouin
BMW	Bukh
Caterpillar	CHN 25/34
Cummins	Daihatsu
Detroit	Deutz
Doosan-Daewoo	Fiat
Ford	GE
Grenaa	Guascor
Hanshin	Hatz
Hino	Honda
Hyundai	Isotta
Isuzu	Iveco
John-Deere	Kelvin
Kioti	Komatsu
Kubota	Liebherr
Lister	Lombardini
MAK	MAN B&W
Mercedes	Mercruiser
Mirrlees BS	Mitsubishi
MTU	MWM
Niigata	Paxman
Perkins	Pielstick
Rolls / Bergen	Ruggerini
Ruston	Scania
Shibaura	Sisu-Valmet
SKL	Smit-Bolnes
Sole	Stork
VM-Motori	Volvo
Volvo Penta	Westerbeke
Wichmann	Yanmar

Machinery

ABG	Airman
Akerman	Ammann
Astra	Atlas Copco
Atlas Weyha.	Atlet
Bell	Bendi
Bigjoe	Bobcat
Bomag	BT
Carelift	Case
Caterpillar	Cesab
Challenger	Champion
Claas	Clark
Combilift	Crown
Daewoo-Doosan	Demag
Deutz-Fahr	Dressta

Machinery

Drott	Dynapack
Extec	Faun
Fendt	Fiat
Fiatallis	Flexicoil
Furukawa	Gehl
Genie	Grove-gmk
Halla	Hamm
Hangcha	Hanix
Hanomag	Hartl
Haulpack	Hiab
Hidromek	Hino truck
Hitachi	Hyster
Hyundai	IHI
Ingersoll-rand	JCB
JLG	John-Deere
Jungheinrich	Kalmar
Kato	Kioti
Kleeman	Kobelco
Komatsu	Kramer
Kubota	Lamborghini
Landini	Liebherr
Linde	Link-belt
Manitou	Massey-Ferg.
Mccormick	MDI-Yutani
Mitsubishi	Moxy
Mustang	Neusson
New-Holland	Nichiyu
Nissan	OK
OM-Pimespo	others-tech
Pel-Job	PH-mining
Poclain	Powerscreen
Same	Samsung
Sandvik	Scania
Schaefer	Schramm
Sennebogen	Shangli
Shibaura	Steiger
Steinbock	Steyr
Still	Sumitomo
Super-pac	Tadano
Takeuchi	TCM
Terex	Toyota
Valpadana	Venieri
Versatile	Vogele
Volvo	Weidemann
Wirtgen	Yale
YAM	Yanmar