SEBU6251-34 (en-us)
November 2025

# Operation and Maintenance Manual

## Cat Commercial Diesel Engine Fluids Recommendations

**Special Publication For All 3500 Series, C175, and smaller Commercial Diesel Engines**

**Scan to find and purchase genuine Cat® parts and related service information.**

# Important Safety Information

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

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

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

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

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

The meaning of this safety alert symbol is as follows:

**Attention! Become Alert! Your Safety is Involved.**

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

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

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

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

---

NOTICE

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

**Other parts may not meet certain original equipment specifications.**

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

---

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

# Table of Contents

Foreword ..... 4

**Distillate Fuel Section**

Diesel Fuel..... 5

**Alternative Fuels Section**

Biodiesel Fuel..... 26

Renewable Diesel ..... 39

Synthetic Fuels..... 41

Other Fuels..... 43

**Engine Oil Section**

Diesel Engine Oil (DEO)..... 44

**Other Lubricants Section**

Grease..... 60

Specialty Lubricants ..... 62

**Coolant Section**

Engine Coolant..... 64

**Exhaust Aftertreatment Section**

Diesel Exhaust Fluid (DEF)..... 84

**Additives Section**

Fuel Additives..... 90

Oil Additives ..... 92

**Maintenance Section**

Contamination Control Guidance..... 93

Fluid Sampling and Analysis ..... 99

**Reference Information Section**

Reference Materials ..... 105

**Index Section**

Index..... 106

# Foreword

## Fluids/Filters Recommendation

### Literature Information

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.

NOTICE
Many of the guidelines, recommendations, and requirements that are provided in this Special Publication are interrelated. Before using the provided information, it is the responsibility of the user of this Special Publication to read and understand the information provided in its entirety.

It is the responsibility of the user of this Special Publication to follow all safety guidelines found in this Special Publication and in engine and/or machine specific 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.

This manual should be stored in the literature holder or in the literature storage area on the machine. Immediately replace this manual if lost, damaged, or unreadable.

The information contained in this document is the most current information available for fluid maintenance and service products. Special maintenance and service products may be required for some machine compartments. Refer to the Operation and Maintenance Manual for your machine for the maintenance and service requirements. Read, study, and keep this manual with the product. This manual should be read carefully before using this product for the first time and before performing maintenance.

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

### Safety

Refer to the Operation and Maintenance Manual for your machine 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 warning signs used on the machine.

Read and understand the applicable precautions listed in the Maintenance and Operation Sections before operating or performing lubrication, maintenance, and repair on this machine.

### Maintenance

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

Proper maintenance and repair are essential to keep the equipment and systems operating correctly. As the owner, you are responsible for the performance of the required maintenance listed in the Owner Manual, Operation and Maintenance Manual, and Service Manual.

### Maintenance Interval Schedule

Use the Maintenance Interval Schedule in the Operation and Maintenance Manual for your machine to determine servicing intervals. Use the service hour meter to determine servicing intervals. Calendar intervals shown (daily, weekly, monthly, etc.) can be used instead of service hour meter intervals if calendar intervals provide more convenient servicing schedules and approximate the indicated service hour meter reading. Recommended service should always be performed at the interval that occurs first.

Under extremely severe, dusty, or wet operating conditions, more frequent lubrication and/or filter changes than is specified in the maintenance intervals chart might be necessary.

Following the recommended maintenance intervals reduces the risk of excessive wear and potential failures of components.

### Aftermarket Products and Warranty

NOTICE
When auxiliary devices, accessories or consumables (filters, oil, additives, catalysts, fuel, etc.) made by other manufacturers are used on Cat 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 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.

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.

# Distillate Fuel Section

# Diesel Fuel

i10746840

## Diesel Fuel General Information

**SMCS Code:** 1250; 1280

Table 1

| Diesel, Renewable, Synthetic, and Biodiesel Fuels Applicable in Cat Diesel Engines | | |
|---|---|---|
| **Fuel** | **Specification** | **Application** |
| Diesel | ASTM D975, EN 590, Others | Can be used in all Cat diesel engines. |
| Biodiesel | ASTM D6751 (B100), Others | Can be used at various blend levels.(1) |
| Renewable Diesel/HVO | EN15940, ASTM D975 | 100% or any blend level with diesel fuel. (2) |
| E-Diesel/Synthetic | EN 15940, ASTM D975, EN590, Others | 100% or any blend level with diesel fuel. (3) |
| Gas-to-Liquid (GTL) | EN 15940, ASTM D975, EN590, Others | 100% or any blend level with diesel fuel. (3) |

(1) Refer to this Special publication, “Biodiesel Fuel Applications” section for further information.
(2) Refer to this Special publication, “Renewable Diesel/HVO” section for further information.
(3) Refer to this Special publication, “Synthetic Diesel/E-Diesel” section for further information.

## Diesel Fuel Types

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 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 well 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 to help compensate for the fuel qualities that may interfere with cold-weather operation are the same.

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 after-treatment 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 is acceptable in all EPA certified engines. Sulfur free fuel is acceptable for use in all EPA and EU certified engines.

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 “Distillate Fuel” section and to the “Lubricant Specifications” section of this Special Publication.

**⚠ WARNING**

**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.**

**Note:** The removal of sulfur and other compounds in Ultra Low Sulfur Diesel (ULSD) fuel decreases the conductivity of ULSD and increases the ability of the fuel 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 the fuel is flowing through fuel delivery systems. Static electricity discharge when combustible vapors are present could result in a fire or explosion. Therefore, ensuring that the entire system used to refuel your machine (fuel supply tank, transfer pump, transfer hose, nozzle, and others) is properly grounded and bonded is important. Consult with your fuel or fuel system supplier to ensure that the delivery system is in compliance with fueling standards for proper grounding and bonding practices.

Diesel engines may burn a wide variety of fuels. Distillate fuels provide maximum engine service life and performance. Distillate fuels must meet the specifications that are found in this Special Publication, “Diesel Fuel Specifications” article.

Crude oils, blends of crude oil with distillate fuel, and marine diesel fuel are sometimes permissible. These fuels are not suitable for use in all engine applications, however. The acceptability of these fuels for use is determined on a case by case basis, and a complete fuel analysis is required. Understand that the use of these fuels can result in higher maintenance costs and reduced engine service life compared to distillate fuels. Consult you Cat dealer for further information.

**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.

## Cleanliness

Fuels of “ISO 18/16/13” cleanliness levels or cleaner as dispensed into the engine or machine fuel tank should be used. Reduced power, failures and related downtime can result if clean fuels are not used. Fuels of “ISO 18/16/13” are 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 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. Gels and other insoluble compounds can also form in biodiesel fuel at low temperatures or if biodiesel is stored for extended periods. An indication of microbial contamination, detrimental fuel additives interactions, or cold temperature gel is very rapid filter plugging of bulk fuel filters or machine fuel filters.

Clean fuels, as detailed below, are strongly recommended to allow optimal performance and durability of the fuel systems and to reduce power loss, failures, and related down time of engines.

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

To reduce downtime due to contamination, follow these fuel maintenance guidelines in addition to the recommendations given in the “Contamination Control” Chapter in this Special Publication:

- Use high-quality fuels per recommended and required specifications (refer to the “Diesel Fuel Specifications” chapter in this Special Publication).
- 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). Engine oils may raise the sulfur level of the fuel and may cause fouling of the fuel system and loss of performance. Engine oils in fuels can also reduce the maintenance intervals of aftertreatment devices in Tier 4 machines.
- Use recommended Cat filtration products, including Cat Advanced Efficiency Fuel Filters. Change your fuel filters per recommended service requirements or as needed. Never fill the new secondary and tertiary fuel filter with fuel before installation. Use the fuel priming pump to remove air from the system.
- Follow proper practices of fuel transport and filtration from storage tank to the machine to allow the delivery of clean fuel to machine tank. Keep the fuel storage tank clean of water, debris, and sediment.
- Filter the fuel coming into the bulk storage fuel tank and at every subsequent transfer into and out of any container and prior to adding to the engine fuel tank preferably through filters with a rating of 20 microns (c) absolute or less. The use of wire mesh media (strainer-type filters) is NOT recommended except when filters with standard media (cellulose or synthetic) are downstream of the wire mesh media filters. Wire mesh filters typically have poor filtration efficiency and can corrode with time, allowing the passing of large particles.
- Caterpillar recommends the use of properly designed and grounded bulk fuel filter / coalescer units which remove both particulate contamination and water in a single pass. These units can clean fuel to “ISO 16/13/ 11” or cleaner and can remove free water to 200 ppm (mg/kg) or less.
- Caterpillar 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. Refer to Special Publication, PEHJ0156, “Cat Bulk Fuel Filtration Systems”, and consult your Cat dealer for availability of bulk filtration products.

- 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 = 75 up to 200 at 4 microns) 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 that fuel is dispensed at 200 ppm water or less.
- Keep the area around the fuel tank filler neck clean of debris to prevent dirt entry and contamination of the fuel tank.
- Drain your water separators daily per the Operation and Maintenance Manual of your machine.
- Install desiccant type breathers of 4 µm or less absolute efficiency with the ability to remove water on bulk storage tanks.
- Drain your fuel tanks of sediment every 500 hours or 3 months per the Operation and Maintenance Manual of your machine.
- Centrifugal filters may need to be used as a prefilter 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 to achieve the recommended cleanliness level.
- Cover, protect, and ensure cleanliness of all connection hoses, fittings, and dispensing nozzles.
- Test for microbial contamination regularly and take proper corrective action if contamination is present. Properly dispose of cleanup waste according to all applicable local regulations and mandates.
- Every 3 months, or sooner if problems are suspected, analyze the fuel for acid number, density, particle content, water and microbial growth (tank bottom fuel sample). More tests can also be run per the “Caterpillar Specification for Distillate Diesel Fuel for Off-Highway Diesel Engines” table in this Special Publication. Refer to “Fluid Sampling and Analysis” section of this Special Publication. Take corrective action if necessary. Corrective actions may include, but are not limited to, treating the fuel, cleaning of the fuel storage tank/system, and replacing the problematic fuel with fresh fuel.

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 **and/or Ultra High Efficiency** filters 4 micron (c) absolute fuel filters.

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

**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.

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

## Injector Health

Fuel injectors are highly engineered components built with very tight clearances and designed to spray precise amounts of fuel into the combustion chamber. The accurate operation of the fuel injectors supports the performance and noise of the engine and impacts the emissions.

Fuels that are not per the characteristics described in this chapter and in the recommended specifications can lead to deposits in the injector, cold start issues, smoke, noise, low performance, increased emissions, and other issues.

Deposits in the injector can be external or internal:

- External deposits form on the tip of the injector. These deposits become carbonaceous (mainly composed of carbon) due to the high temperature of the combustion chamber. The deposits prevent the appropriate fine spray of the fuel and the proper atomization in the combustion chamber. These issues can significantly degrade the operation of the engine.
- Internal deposits form on the internal moving components of the injector. These deposits close the tight clearances in the injector and prevent the components from moving as designed. Some internal deposits can be "soaps" that form due to reaction of sodium contaminants in the fuel with certain fuel additives. Sometimes, these soaps cause injector sticking in the open or closed positions. The result is a malfunction of the injector.

Cleanliness of the injectors impact the performance, power, fuel consumption, and emissions throughout the life of modern diesel engines. To keep the injectors clean, avoid injector deposits and ensure appropriate operation and long life of the injectors:

- Ensure that the fuel has the proper chemistry. Fuels that are per the specifications given in this chapter have the appropriate cetane value, viscosity, density, distillation, stability, lubrication, and energy content.
- Ensure that the fuel has the proper quality. Fuel quality is determined by the lack of contamination and water. This quality is ensured through following the contamination control recommendations and filtering the fuel as recommended by the Operation and Maintenance Manual and as stated in this chapter.
- The use of fuel additives to improve detergency and overall quality of fuels may be needed sometimes. When needed, Caterpillar recommends the use of Cat Fuel System Cleaner. Caterpillar cannot validate or recommend other additives available in the market. The fuel supplier should be consulted when using additives to enhance other properties of the fuel.

Consult with the engine or machine Operation and Maintenance Manual for any special fuel requirements.

Consult with your fuel supplier to ensure that the fuel follows all the recommendations given in this chapter.

## Storage and Maintenance

When fuels are stored for extended periods, follow all the fuel supplier and tank maintenance procedures. Circulate the fuel regularly through a filter to remove sediments. Test the fuel regularly for acid number, density, particle content, water and microbial growth. Observe trends of these properties to ensure no detrimental changes. The fuel is not recommended for use when its properties change negatively. For fuels containing biodiesel, the storage duration may be significantly reduced. Observe all the guidelines given in this section and in "Guidelines and potential impacts associated with the use of biodiesel and biodiesel blends" Table in the "Biodiesel Fuel" section of this Special publication.

**Note:** Thorough cleaning of fuel storage tanks is strongly recommended 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 filtration unit and dispensing point filters, and onboard engine filters change intervals may need to be shortened for an extended period of time to allow for this cleaning effect.

**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 to follow all industry standard practices for fuel storage and for fuel handling.

## Seasonal Operation

Seasonally operated engines should 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. The use of biodiesel fuel of high oxidation stability can reduce the risks associated with prolonged storage. Follow the recommendations provided in this section and the guidelines given below to reduce the risk:

- Addition of a high-performance diesel fuel oxidation stabilizer 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 624-3389, 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 this Special Publication, “Biodiesel Fuel Specifications” section.
- 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 not in specification provided in this Special Publication, “Biodiesel Fuel Specifications” section, drain the tank, and flush the engine by running with high-quality fuel. **Repeat the process until the system is clean. Refill with high-quality fuel following the recommendations provided in this section. For standby generator sets and emergency vehicles that use biodiesel, use fuel with oxidation stability 6 hours or more per “EN 14112” test method.**

Consult your Cat dealer for the availability of Cat Diesel Fuel System Cleaner. In the case that a fuel conditioner is needed to improve certain fuel properties, consult with your fuel supplier or with a reputable provider

## Regulatory

**Recommendations for Europe Stage V Certified Nonroad Engines:**

All the fuel recommendations and requirements for US EPA Tier 4 Certified Nonroad Engines are applicable to the Europe Stage V type-approved Nonroad Engines. Additionally, for the correct operation of the engine in order to maintain the gaseous and particulate pollutant emissions of the engine within the limits of the type-approval, unless specified otherwise in the engine-specific Operation and Maintenance Manual, EU Stage V regulations REQUIRE the diesel fuels (also called nonroad gas oil) used in engines operated within the European Union (EU) to have the characteristics below:

- The sulfur content should be ≤ 10 mg/kg (20 mg/kg) at point of final distribution
- The Cetane number should be ≥ 45
- The biodiesel (also called Fatty Acid Methyl Ester (FAME)) content should be ≤ 7 % volume/volume

Refer to your engine Operation and Maintenance Manual for the allowed biodiesel blend in your engine model. Some Cat engines that are certified per EU Stage V can use up to B20 biodiesel blends.

Follow all the local regulations and fluids requirements in your area. Refer to your engine-specific Operation and Maintenance Manual, and refer to your aftertreatment device documentation, if available, for additional guidance.

Engine operating conditions play a key role in determining the effect that fuel sulfur will have on engine deposits and on engine wear.

i10421257

# Diesel Fuel Characteristics

**SMCS Code:** 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.

Fuels of improper viscosity result in poor atomization and spray pattern when injected, which cause poor combustion and loss of performance. If the kinematic viscosity of the fuel is lower than 1.4 cSt as supplied to the fuel injection pump or to the unit injectors, excessive scuffing and seizure can occur. If the fuel viscosity is too high, the fuel may cause high fuel pump resistance, negatively impact the injector spray pattern, and may cause filter damage.

For distillate fuel configured engines, Caterpillar 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. Fuels of high cetane rating are easier to ignite. 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 characteristics of fuels with natural cetane number can be different than those characteristics of a fuel addetized to reach the same cetane number. While both fuels may be rated as having the same cetane number, starting may be different.

## Cloud Point

The cloud point of a fuel is different from 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 very 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 cause filter plugging. Plugged filters cannot remove contaminants from the fuel and hence cannot protect the fuel injection systems. 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.

The common standard methods that are used to test the cloud point of diesel fuels are:

- “ASTM D2500” Test Method for Cloud Point of Petroleum Products
- “ASTM D5771” Test Method for Cloud Point of Petroleum Products (Optical Detection Stepped Cooling Method)

- “ASTM D5772” Test Method for Cloud Point of Petroleum Products (Linear Cooling Rate Method)
- “ASTM D5773” Test Method for Cloud Point of Petroleum Products (Constant Cooling Rate Method)

### 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, because 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 fuel supplier must be consulted to provide the proper mix of fuels that offers the appropriate cloud point.

Another approach to modify the cloud point is to use cold flow improvement additives. 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 of the fuel. 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”.

Generally, the most practical method that is used to prevent problems that are caused by fuel cloud point at low temperatures is the use of fuel heaters. In most applications, fuel heaters can be used at a lower cost than fuel mixtures.

## Pour Point

The fuel's pour point is a temperature below the cloud point of the fuel. Fuel stops flowing below the pour point. The pour point is the temperature which limits movement of the fuel inside 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. This temperature makes the fuel more solid than liquid. The pour point of the fuel can be improved. This improvement does not require 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 extremely cold weather, No. 1 fuel or No. 1-D fuel may be necessary because of these fuels' lower pour points.

The standard methods to measure the pour point of the fuels are:

- “ASTM D4539” Test Method for Filterability of Diesel Fuels by Low-Temperature Flow Test (LTFT)
- “ASTM D6371” Test Method for Cold Filter Plugging Point of Diesel and Heating Fuels

### Modifying the Pour Point

You can lower the fuel's pour point by using additives. You can also lower the pour point of a diesel fuel by mixing the diesel fuel with a different 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. This table is true only if the fuels do not have additives which change the pour point. This table may not apply to Ultra Low Sulfur diesel fuels and should be used only as a general guide. To use the table, you must 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.

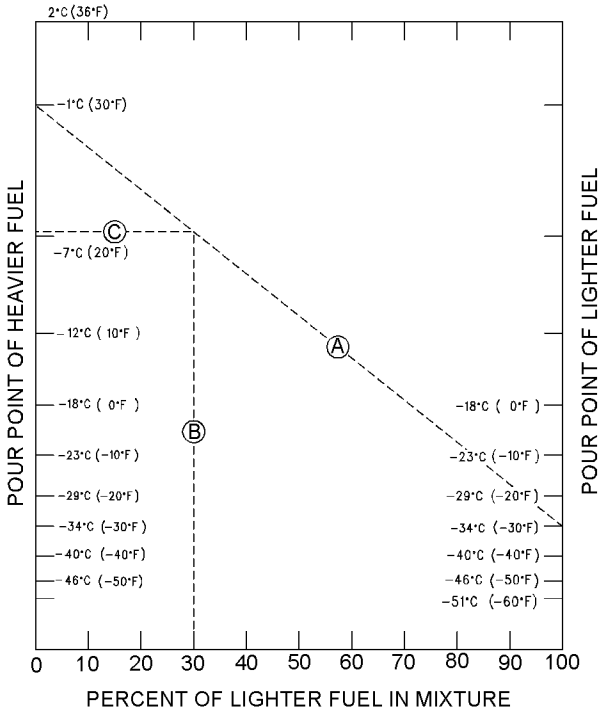


Illustration 1 g01180699

Pour point of fuel mixtures

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 that is 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 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 thoroughly mixed into the fuel at temperatures that are above the cloud point. The fuel supplier should be contacted to blend the fuel with the additives. The blended fuel can be delivered to your fuel tanks.

## Lubricity

The lubricity of the fluid 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.

**Note:** The fuel lubricity is important. The lubricity of the fuel should be considered whenever you operate the equipment in temperature extremes, whether extremely hot or extremely cold. Also, you should consider the fuel lubricity whenever you use fuels that are lower in viscosity or that have been hydro-treated. There are many aftermarket additives that are available to treat fuel. If the lubricity of the fuel 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 finished fuels as described by Caterpillar Diesel Fuel Specification, “ASTM D975” or “EN 590” are at the recommended lubricity levels. 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 sulfur and other components from the fuel. 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.

The finished fuels that are per the recommended specifications should have the correct lubricity. However, if required, the lubricity of the fuel 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 that are supplied by the aftermarket manufacturer 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 “Diesel Fuel Specifications” article in this Special Publication), using a reliable fuel supplier and performing proper maintenance of the fuel system. Caterpillar Advanced Efficiency fuel filters are required for diesel engines that run on diesel fuel 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 Caterpillar 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 the sulfur levels for these fuels typically far exceed 50 ppm, the EU low sulfur fuel.

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

## Sulfur Level

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 since December 2010for 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 the service interval. Failures that result form the use of fuels are not Cat factory defects. Therefore the cost of repairs would not be covered 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 ensure 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 the ability of the fuel 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 the fuel is flowing through fuel delivery systems. Static electricity discharge when combustible vapors are present could result in a fire or explosion. Therefore, ensuring that the entire system used to refuel your machine (fuel supply tank, transfer pump, transfer hose, nozzle, and others) is properly grounded and bonded is important. Consult with your fuel or fuel system supplier to ensure that the delivery system is in compliance with fueling standards for proper grounding and bonding practices.

The standard methods for testing conductivity of diesel fuel are:

- “ASTM D2624” Test Methods for Electrical Conductivity of Aviation and Distillate Fuels
- “ASTM D4308” Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter

## 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 Particulate 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 not 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 more 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).

## Volatility

Fuel volatility is measured and controlled by the fuel distillation curve. The optimal fuel volatility required for various engines depends on the engine application, design, loads, speeds, ambient temperatures, and other factors. Low volatility fuels may have a higher energy content (heating value). On the other hand, fuels of high initial volatility may improve the startability and warm up process and reduce smoke. High-performance fuels have the right balance of volatility.

The fuel distillation curve describes the amount of fuel that evaporates at various temperatures. Of these temperatures, the heavy end is characterized by the T90, the temperature where 90 percent of the fuel evaporates. If the T90 exceeds the maximum limits given in the "Caterpillar Specification for Distillate Fuel for Nonroad Diesel Engines" Table, in the “Diesel Fuel Specifications” section, the fuel may increase smoke, deposits, soot, and particulate matter emissions. The lower end or low distillation temperatures are not specified in the "Caterpillar Specification for Distillate Fuel for Nonroad Diesel Engines" Table, nor in “ASTM D975” or similar specifications. However, very low distillation temperatures may cause the fuel to become volatile at low temperatures and may cause cavitation of fuel pumps or fuel system components.

## Contamination

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 moisture 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 very 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 with the water. 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 to compensate for a loss of power with fuels that are lighter. The life of fuel system components can be decreased with fuels that are very light because lubrication will be less effective as a result of the lower viscosity. This issue is compounded if the fuel does not have sufficient lubricity. Refer to the “Lubricity and Low Sulfur Fuel Diesel (LSD) and Ultra Low Sulfur Diesel (ULSD) Fuel” topic in this Special Publication, “Diesel Fuel Characteristics” 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. This problem 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 the 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 more gums and resins will occur during fuel storage. The storage time for fuel needs to be minimized to help reduce the formation of gums and resins.

**Note:** Even when all fuel storage maintenance practices that are relevant to your application are followed, Caterpillar 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.

## Stability

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, which may include the formation of peroxides. 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. This process can stress the fuel in the fuel system. The thermal stress and an increase in recirculation fuel temperature is often responsible for fuel degradation and the formation of gums, resins, sediment, and deposits, which can cause fuel flow restriction through fuel filters and fuel injection systems.

When a fuel is left in a machine or engine fuel tank for a long time, the fuel is exposed to oxygen. This exposure leads to complex chemical reactions and degradation of the fuel. As a result, sludge and deposits are formed, which lead to poor performance, filter plugging, restriction of fuel lines, and deposits in the injector.

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.

Testing the fuels for thermal and oxidative stability as described in the "Caterpillar Specification for Distillate Fuel for Nonroad Diesel Engines" Table, in the “Diesel Fuel Specifications” section, ensures that the fuel meets the minimum requirements for stability. Fuels that pass these tests offer the desired performance and reduce the deposit formation.

i10643926

# Diesel Fuel Specifications

**SMCS Code:** 1250; 1280

## Cat Specifications

Using the Caterpillar distillate diesel fuel specification as the baseline, it is much easier to determine any potential economic and performance trade-offs, 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 be used, tested per the Caterpillar distillate diesel fuel specification.
- Use the Caterpillar distillate diesel fuel specification as a fuel quality baseline for comparison of distillate diesel fuel analysis results, and 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 (e.g. fuel can be cooled to address low viscosity; etc.).
- Some fuel parameters that are outside of specification limits may be able to be improved with the use of appropriate amounts of proven fuel additives. Refer to this Special Publication, “Fuel Additives” article 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 “Caterpillar Specification for Distillate Fuel for Nonroad Diesel Engines”, Table 2 .

**Note:** The diesel fuel must be bright and clear. The diesel fuel cannot have any visually apparent sediment, suspended matter, or undissolved water.

Diesel Fuels that meet the specifications in table 2 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 2 requirements.

In Europe, diesel fuels that are identified as meeting the latest version of “European Standard EN590” generally meet the table 2 requirements.

Table 2 is for diesel fuels that are distilled from conventional sources (crude oil, shale oil, oil sands, etc.). Diesel fuels from other sources could exhibit detrimental properties that are not defined or controlled by this specification.

Table 2

| **Caterpillar Specification for Distillate Fuel for Nonroad Diesel Engines** | | | |
|---|---|---|---|
| **Specifications** | **Requirements** | **ASTM Test** | **ISO Test** |
| Aromatics | 35% volume, maximum | “D1319” | “ISO 5186” |
| Ash | 0.01% maximum (weight) | “D482” | “ISO 6245” |
| Density at 15° C (59° F)[1][2] | 800 kg/m$^3$ minimum<br>860 kg/m$^3$ maximum | “D4052”, “D287” | “ISO 3675”, “ISO 12185” |
| Cetane Number | 40 minimum (DI engines) | “D613” | “ISO 5165” |
| | 35 minimum (PC engines) | | |
| Cetane Index | 40, minimum | “D976” | “ISO 4264” |
| Flash Point | legal limit | “D93” | “ISO 2719” |
| Carbon Residue on 10% distillation residue - Ramsbottom, % mass | 0.30% mass, maximum | “D524” | “ISO 10370” |
| Oxidation Stability | 25 g/m$^3$, maximum | “D2274” | “ISO 12205” |

(continued)

(Table 2, contd)

| Caterpillar Specification for Distillate Fuel for Nonroad Diesel Engines | | | |
|---|---|---|---|
| **Specifications** | **Requirements** | **ASTM Test** | **ISO Test** |
| Thermal Stability | Minimum of 80% reflectance after aging for 180 minutes at 150° C (302° F) | “D6468”, “D3241” | No equivalent test |
| Copper Strip Corrosion (Control temperature 50° C (122° F) minimum) | No. 3 maximum | “D130” | “ISO 2160” |
| Distillation, vol recovered | 10%, Record | “D86” | “ISO 3405” |
| | 90% at 360° C (680° F) maximum (3) | | |
| | 90% at 350° C (662° F) maximum (3) | | |
| Lubricity (HFRR Wear Scar) | 0.52 mm (0.0205 inch) maximum at 60° C (140° F) | “D6079”/“D7688” | “ISO 12156–1.3” |
| Pour Point | 6°C (10°F) minimum below ambient temperature | “D97” | |
| Cloud Point | The cloud point must not exceed the lowest expected ambient temperature. | “D2500” | “ISO 3015” |
| Low Temperature Flow Test/Cold Filter Plugging Point Test (LTFT/CFPP) | Must not exceed the lowest expected ambient temperature. | “D4539”/“D6371” | No equivalent test |
| Sulfur by weight | (4) | “D5453”, “D2622”, “D129” (based on the sulfur level) | “ISO 20846”, “ISO 20884” |
| KInematic Viscosity at 40° C (104° F) for No. 1 diesel | 1.3 cSt minimum and 2.4 cSt maximum (5) | “D445” | “ISO 3104” |
| KInematic Viscosity at 40° C (104° F) for No. 2 diesel | 1.9 cSt minimum and 4.5 cSt maximum | “D445” | “ISO 3104” |
| **Contaminants** | | | |
| Solids | 10 mg/l | “D6217” | “ISO 12662” |
| Sediment | 0.05% maximum (weight) | “D473” | No Equivalent Test |
| Water/Sediment | 0.05% maximum | “D2709” | “ISO 3734” |
| Water | 0.02% maximum | “D1744” | “ISO 12937” |
| Cleanliness | (6) | “D7619” | “ISO 4406” |
| Appearance | Clear and Bright | “D4176” | No equivalent test |

(1) The equivalent API gravity of 875.7 kg/m$^3$ is 30 and for 801.3 kg/m$^3$ is 45 (per “ASTM D287” test method temperature of 15.56° C (60° F)).

(2) The density range allowed included # 1 and # 2 diesel fuel grades. Fuel density varies depending on sulfur levels, where high sulfur fuels have higher densities. Some unblended (neat) alternative fuels have lower densities than diesel fuel. This density is acceptable if the other properties of the alternative fuel fall within this specification.

(3) 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 360° C (680° F). Distillation of 90% at 360° C (680° F) maximum is acceptable for Pre-Tier 4 engines.

(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 strongly 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

(continued)

(Table 2, contd)

(5) The recommended fuel viscosity as delivered to fuel injection pump should be a minimum of 1.4 cSt at 40° C(104° F). For low viscosity fuels, cooling of the fuel may be required. Refer to this Special Publication, “Diesel Fuel Application” section for additional information.

(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 “Cleanliness” topic in the “Diesel Fuel General Information” section for more information.

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

## Warnings and Notices

**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.

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

The “Caterpillar Specification for Distillate Fuel for Off-Highway 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, etc.) when used in Cat diesel engines.

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 is 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 the “Diesel Fuel Characteristics” section and to the “Lubricants Specifications” section of this Special Publication.

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.

ULSD and any other fuel used in Cat engines must be properly formulated and addetized by the fuel supplier and 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, “Diesel Fuel Characteristics” article for additional pertinent information concerning fuel lubricity, fuel oxidative stability, fuel sulfur, and aftertreatment devices. Also refer to the latest version of “ASTM D975”, the latest version of “EN 590”, the specific engine Operation and Maintenance Manual, and to aftertreatment device documentation for guidance.

**Note:** Caterpillar strongly recommends the filtration of distillate fuel and biodiesel/biodiesel blends through a fuel filter with a rating of four microns(c) absolute or less. This filtration should be 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. Caterpillar recommends that the fuel dispensed into the machine tank meets “ISO 18/16/13” cleanliness level.

**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 “Caterpillar Specification for Distillate Fuel for Off-Highway Diesel Engines”, table 2 .**

The values of the fuel viscosity given in table 2 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 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.

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.

To obtain additional information on Cat designed and produced filtration products, refer to this Special Publication, “Reference Material” article, “Filters” and “Miscellaneous” topics. Additionally 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.**

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

i10746541

# Diesel Fuel Application

**SMCS Code:** 1250; 1280

## Heavy Fuel Oil

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.

## Cold-Weather Applications

In extreme cold ambient conditions, you may choose to use the distillate fuels that are specified in table 3 . However, the fuel that is selected must meet the requirements that are specified in the “Caterpillar Specification for Distillate Diesel Fuel for Off-Highway Diesel Engines”, table 3 . These fuels are intended to be used in operating temperatures that are down to −54 °C (−65 °F).

**Note:** The fuels that are listed in table 3 may have higher sulfur levels than the 15 ppm maximum sulfur allowed for ULSD. The sulfur levels for these fuels may exceed 50 ppm maximum sulfur allowed in “EN590:2004”. These fuels may not be acceptable for use in areas that restrict maximum fuel sulfur levels to 15 ppm maximum or to 50 ppm maximum.

The jet fuels described in table 3 are of lower viscosity than #2 diesel. To meet the viscosity requirements given in table 3 , cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Ensure that the lubricity of these fuels is per the requirements given in table 3 . Consult the supplier for the recommended additives to maintain the proper fuel lubricity.

The fuel specifications listed in this table allow and/or recommend the use of fuel additives that have not been tested by Caterpillar 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, 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 3

| 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 3 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 to maintain the minimum viscosity of 1.4 cSt at the fuel injection pump.

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

## 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 “Aftermarket Products and Warranty” article in the Warranty Information section of this special publication.

### 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. This is especially true for fuel filters that 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. This 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, Caterpillar 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.

**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 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.

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 Caterpillar dealer.

### De-icers

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

## Diesel Fuels for Marine Engines

The information and guidelines given in the “Diesel Fuel” article of this Special Publication 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 Manual for 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 Manual for 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 they 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.

# Alternative Fuels Section

# Biodiesel Fuel

i10575234

## Biodiesel Fuel General Information

**SMCS Code:** 1250; 1280

### Biodiesel Blends

Table 4

| Biodiesel Fuel Application in Diesel Engines | | | | | |
|---|---|---|---|---|---|
| **Fuel** | **Source** | **Processing** | **Chemistry** | **Specification** | **Application** |
| **Biodiesel** | Vegetable oils, animal fats and used cooking oil | Esterfication | Ester, oxygenated | ASTM D6751 (B100), others | Various blend levels (1) |

(1) Refer to thisSpecial Publication, Biodiesel Fuel Application section

Biodiesel is a renewable fuel that can be made from vegetable oils, animal fat, and waste cooking oil. Soybean oil, rapeseed oil, and palm oil are some of the common 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. 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. Blends of biodiesel are represented as BXX, where XX represents the volume percent of biodiesel that is blended with diesel fuel.

Example:

- To blend 100 gallons of B5 biodiesel fuel: mix 5 gallons of B100 biodiesel fuel with 95 gallons of diesel fuel
- To blend 100 gallons of B20 biodiesel fuel: mix 20 gallons of B100 biodiesel fuel with 80 gallons of diesel fuel

The quality of biodiesel fuel is critical to its successful use. Biodiesel fuel that is not per the specification given in this Special Publication , “Biodiesel Fuel Specifications" section may result in performance issues and engine downtime.

Alternative fuels such as biodiesel fuels are typically of lower carbon intensity than diesel fuel and have the potential to reduce carbon dioxide emissions.

Biodiesel fuels covered in this section are acceptable for use in Cat engines per the guidance and recommendations given. Applicable specifications, blend levels, and guidance for biodiesel fuels are detailed in this Special Publication.

Table 5

| Biodiesel Fuel Quality Recommendations for Cat Engines | | |
|---|---|---|
| **Fuel** | **Specification(1)** | **Details** |
| B5(2) | Cat Distillate Diesel Fuel Specification or "ASTM D975" or "EN 590" | A blend of 5 percent by volume of B100 and 95 percent by volume of diesel fuel. |
| B20 | "ASTM D7467" or "EN 16709" and "API" gravity 30–45 | A blend of 20 percent by volume of B100 and 80 percent by volume of diesel fuel. |
| B30 | "EN 16709" and "API" gravity 30–45 | A blend of 30 percent by volume of B100 and 70 percent by volume of diesel fuel. |
| B100 | Cat Biodiesel Fuel Specification(3) or "ASTM D6751" or "EN 14214" | Neat biodiesel fuel (100 percent) used for blending with diesel fuel to get the desired blend level. |
| Distillate Diesel Fuel | Cat Distillate Diesel Fuel Specification (4) | Diesel fuel used for blending with biodiesel fuel to get the desired blend level. |

(1) Some regions or countries may have their own fuel specifications. Follow the local requirements and regulations and use the fuel of highest quality.
(2) The same specifications also apply to B7 and B8, which are common blend levels in some regions.
(3) Cat Biodiesel Fuel Specification (B100) is given in this Special Publication “Biodiesel Fuel Specifications” section.
(4) Cat Distillate Diesel Fuel Specification is given in the “Diesel Fuel Specifications” section of this Special Publication.

**Note:** Do not change any engine settings when using biodiesel fuel. When the use of biodiesel fuel is planned, simply convert to this fuel. Follow the guidelines, recommendations, and quality specifications given in this Chapter to avoid any performance issues or downtime.

Two methods can be used for determining the volume percent biodiesel in a biodiesel blend:

- “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)”
- “EN 14078” - “Liquid Petroleum Products - Determination of fatty acid methyl esters (FAME) in middle distillates -Infrared spectroscopy method”

For applications running biodiesel or biodiesel blends, if fuel treatments are needed, consult with your fuel supplier or with a reputable provider.

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

U.S. distillate diesel fuel specification “ASTM D975” includes up to B5 (5 percent) biodiesel. Any diesel fuel in the U.S. may contain up to B5 biodiesel fuel without labeling that indicates biodiesel content in the finished fuel.

European distillate diesel fuel specification “EN 590” includes up to B5 (5 percent) biodiesel and in some regions up to B7 or B8 (7 or 8 percent by volume) biodiesel. Any diesel fuel in EU may contain up to these blend levels of biodiesel fuel without labeling that indicates biodiesel content in the finished fuel.

Certain regions or countries around the world may mandate blend levels of B20 or higher. Refer to the local regulations and mandates and to local biodiesel specifications for fuel quality.

Biodiesel fuel that is per Caterpillar and Industry recommended specifications (Refer to Special Publication , “Biodiesel Fuel Specifications") offers the following advantages:

- Renewable fuel, nontoxic, and biodegradable
- Reduces tailpipe particulate matter (PM), hydrocarbon (HC), and carbon monoxide (CO) emissions from most modern diesel engines
- High lubricity, hence reduces friction
- High cetane number

Biodiesel at B5 blend level has the same attributes as diesel fuel. At blend levels over B5, biodiesel has the following attributes that are different than diesel fuel and require management:

- Energy density is lower than diesel fuel. At B100, biodiesel has about 8% lower energy density than diesel fuel. At B20 or lower blend levels, the energy density difference from diesel fuel is not significant.
- Oxidation stability and storage stability are lower than diesel fuel.

- Cold temperature operability is different than diesel fuel. Cloud point, pour point, and CFPP are typically higher than diesel fuel.
- Materials compatibility is more restricted than diesel fuel.
- A higher tendency to dissolve and absorb water than diesel fuel.
- Metal content is higher than diesel fuel. Biodiesel can contain certain materials naturally or due to processing (phosphorus, sodium, calcium, potassium, and magnesium). The maximum levels of these materials are controlled by the appropriate specifications.
- Contaminants content due to incomplete esterification or purifying process can be present. These contaminants may include glycerides, mono and diesters, sterol glucosides, and others.
- Higher propensity for microbial growth due to the biodegradable nature of biodiesel and to the tendency of higher water absorption.

Meeting specifications as detailed in this Chapter is paramount for biodiesel fuel used in engines, to avoid performance issues and engine downtime.

Refer to guidelines given in this Chapter and to Special Publication , “Biodiesel Fuel Specifications" for the biodiesel fuel requirements, specifications and risks associated with biodiesel.

**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.

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.

## Cleanliness

Biodiesel fuels key difference from diesel fuel is the ester chemical group (contains two oxygen atoms) in every biodiesel molecule. Biodiesel may also have double bonds (unsaturation) in the carbon chain that can vary based on the feedstock. Due to the ester chemical group and the unsaturation, the oxidation stability of biodiesel fuels is typically lower than that of diesel fuel. The oxidation stability of biodiesel and biodiesel blends is controlled in specifications as given in the Special Publication , “Biodiesel Fuel Specifications" section. Biodiesel fuels that do not conform to these specifications can oxidize quickly during use due to the high temperature and pressure conditions in the engine or during storage and handling practices. Oxidized biodiesel forms acids, gums, high viscosity and deposits, which can reduce storage stability, plug filters, form deposits, particularly in the fuel injector, and reduce the performance of fuel systems. Use of **biodiesel fuels meeting or exceeding the oxidation stability limits is critical** to avoid poor performance and downtime of engines.

To avoid the issues associated with oxidized biodiesel fuel, always purchase fuels that conform to or exceed the specifications (refer to Special Publication , “Biodiesel Fuel Specifications"). Also, follow all the guidelines for appropriate storage and handling of this fuel such as avoiding excessive heat and sunlight during storage, exposure to oxygen (air), contact with metals such as copper, lead, tin, zinc, and others. The use of antioxidants can improve the oxidation stability of biodiesel fuel. The antioxidants are most effective when added to new fuels. Consult with your fuel supplier to ensure the quality of the fuel and refer to the details given in this chapter for guidance.

Cat Diesel Fuel System Cleaner (Part number 624-3389), used as needed or on an on-going basis, is most effective at cleaning and preventing the formation of fuel-related deposits.

Refer to the “Fuels Additives” section in this Special Publication for additional information. Consult your Caterpillar dealer for availability of Cat Diesel Fuel System Cleaner. In case a fuel conditioner is needed to improve certain fuel properties, consult with your fuel supplier or with a reputable provider.

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

http://www.BQ-9000.org

**Note:** Additional filtration may be necessary with the use of biodiesel prior to dispensing fuel into a machine or engine fuel tank. Use of biodiesel that meets the specifications defined within this Special Publication, “Biodiesel Fuel Specifications” section reduces the need for additional filtration.

## Storage and Maintenance

Storage tanks used for storing diesel fuel are appropriate for storing biodiesel fuels. 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. Loosened deposits result in filter plugging with the loosened deposits. For this reason, the change intervals of bulk tank continuous filtration unit, dispensing point filters, and onboard engine filters should be shortened for an extended period to allow for this cleaning effect. Once the systems are cleaned, the typical filter service intervals can be resumed.

Biodiesel fuel is hygroscopic, which implies that biodiesel tends to absorb and dissolve water at a higher concentration than diesel. All precautions and measures must be taken to ensure that storage tanks are protected from water ingress. Follow all the contamination control measures provided in the “Contamination Control” section of this Special Publication.

Biodiesel storage duration is shorter than diesel due to the chemical nature of biodiesel. Storage duration is dependent on the blend level. Blends up to B30 can be stored up to 8 months. Testing of biodiesel at 4 months and monthly thereafter is recommended. Blends up to B50 can be stored for 6 months. Testing at 3 months and every 3 weeks thereafter is recommended. B100 can be stored for 4 months. Testing at 2 months and every 2 weeks thereafter is recommended. Tests should include oxidation stability, acid number, viscosity and sediments. Refer to Special Publication, “Diesel Fuel Cleanliness” section for related guidelines and further details.

**Note:** If switching from biodiesel to distillate fuel, it is recommended to change all fuel filters to avoid filter plugging. Failure to do so can create low fuel pressure.

## Impact on Engine Oil

Biodiesel fuel has higher density and lower volatility than diesel fuels. As a result, during engine operation, biodiesel fuel that dilutes the crankcase oil may not evaporate as effectively as diesel fuels. For this reason, fuel dilution of crankcase oils may be higher when biodiesel blends are used.

Also, biodiesel contains oxygen molecules. These oxygen molecules cannot be differentiated from oil oxidation when using current oil analysis techniques. As a result, biodiesel fuel dilution of the crankcase oil can appear to be higher oxidation of the oil.

When using biodiesel fuel and higher fuel dilution and/or apparent oil oxidation are detected in the crankcase engine oil, consider all the other characteristics of the used oil If these characteristics, such as wear metals, soot, viscosity or others, are per Caterpillar guidelines and have not reached condemnation limits, then the oil drain intervals should not be impacted.

To reduce any potential impact of biodiesel fuel dilution on crankcase oil, **the use of Cat S·O·S Services oil analysis is strongly recommended when up to B20 (20 percent) and lower biodiesel blends are used, and 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).

## Aftertreatment

Biodiesel fuels as defined in the current ASTM specifications, may contain phosphorous, alkali and alkaline metals (sodium, potassium, calcium, and magnesium) due to processing techniques or due to the natural contents of the biodiesel feedstock. When present in biodiesel, these metals form ash upon combustion in the engine. The ash accumulates in the aftertreatment systems such as Diesel Particulate Filters (DPF), DOC or other systems. The ash can affect the life and performance of aftertreatment emissions control devices and may cause the need for more frequent ash service intervals. For these reasons, acceptable biodiesel blend levels for engines with aftertreatment devices are limited, even at the concentration levels defined by current specifications for those ash-forming metals.

Local and regional regulations may also restrict the blend levels that are allowed in engines of certain emissions levels. **EU Stage V** regulations REQUIRE the biodiesel blends used in engines operated within the European Union (EU) to be ≤ 8 % volume/volume unless specified otherwise in the engine-specific Operation and Maintenance Manual.

**Note:** Note that some Cat engines that are certified per EU Stage V can use up to B20 or B30 biodiesel blends. Refer to the engine or machine Operation and Maintenance Manual, Special Publication, “Biodiesel Fuel Application" and Special Publication , “Biodiesel Fuel Specifications".

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 maximum of 15 ppm sulfur.

**Note:** Do not change any engine settings when using biodiesel fuel. When the use of biodiesel fuel is planned, simply convert to this fuel. Follow the guidelines, recommendations, and quality specifications given in this Chapter to avoid any performance issues or downtime.

## Additives

The biodiesel blend levels acceptable for use in Cat engines in various machines, marine, and locomotive commercial applications are given in Special Publication, “Additives” section. For general biodiesel specifications refer to Special Publication , “Biodiesel Fuel Specifications". Consult your Caterpillar dealer for further information on compatibility of non-metallic materials such as fuel lines, and other connections to the engine.

Biodiesel fuel must be per the quality recommendations given in Special Publication , “Biodiesel Fuel Specifications". Otherwise, the fuel may result in performance issues and engine downtime.

Caterpillar 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 or biodiesel blends that meet Cat biodiesel recommendations and requirements. Refer to Special Publication, “Additives” section for further information on Cat additive recommendations.

**Note:** Not all fuel cleaners are suitable for use with biodiesel or biodiesel blends. Follow all applicable label usage instructions.

i10644150

# Biodiesel Fuel Characteristics

**SMCS Code:** 1250; 1280

## Stability

Biodiesel fuels key difference from diesel fuel is the ester chemical group (contains two oxygen atoms) in every biodiesel molecule. Biodiesel may also have double bonds (unsaturation) in the carbon chain that can vary based on the feedstock. Due to the ester chemical group and the unsaturation, the oxidation stability of biodiesel fuels is typically lower than that of diesel fuel. The oxidation stability of biodiesel and biodiesel blends is controlled in specifications as given in the tables listed within Special Publication, “Biodiesel Fuel Specifications". Biodiesel fuels that do not conform to these specifications can oxidize quickly during use due to the high temperature and pressure conditions in the engine or during storage and handling practices. Oxidized biodiesel forms acids, gums, high viscosity and deposits, which can reduce storage stability, plug filters, form deposits, particularly in the fuel injector, and reduce the performance of fuel systems. Use of **biodiesel fuels meeting or exceeding the oxidation stability limits is critical** to avoid poor performance and downtime of engines.

To avoid the issues associated with oxidized biodiesel fuel, always purchase fuels that conform to or exceed the specifications (refer to Tables within Special Publication, “Biodiesel Fuel Specifications" for further specification information). Also, follow all the guidelines for appropriate storage and handling of this fuel such as avoiding excessive heat and sunlight during storage, exposure to oxygen (air), contact with metals such as copper, lead, tin, zinc, and others. The use of antioxidants can improve the oxidation stability of biodiesel fuel. The antioxidants are most effective when added to new fuels. Consult with your fuel supplier to ensure the quality of the fuel and refer to the details given in this chapter for guidance.

Cat Diesel Fuel System Cleaner (Part number 624-3389), used as needed or on an on-going basis, is most effective at cleaning and preventing the formation of fuel-related deposits.

Refer to the “Cat Diesel Fuel Systems Cleaner” topics in the “Additives” section in this Special Publication for additional information. Consult your Cat dealer for availability of Cat Diesel Fuel System Cleaner. If a fuel conditioner is needed to improve certain fuel properties, consult with your fuel supplier or with a reputable provider.

If additional information is needed on diesel fuel characteristics refer to Special Publication, “Diesel Fuel Characteristics".

# Equipment Impact

## Guidelines

Information provided in Table 6 refers to biodiesel and biodiesel blends that fully comply with the appropriate specifications as described in the “Biodiesel Fuel” section of this Special Publication and to handling and maintenance procedures that follow recommended guidelines.

Table 6

| Guidelines and Potential Impacts Associated with the Use of Biodiesel and Biodiesel Blends In Cat Engines[1] | | | | | |
|---|---|---|---|---|---|
| | **Impact** | **B8-B20** | **B21-B30** | **B31-B50** | **B51-B100** |
| 1 | Reduction of oil change interval | No risk | Not noted in Cat engines | Medium | High |
| 2 | Fuel filters compatibility risk | No risk | Not noted in Cat engines | Medium risk | Medium risk |
| 3 | Loosening of fuel systems deposits upon conversion to biodiesel | More than ULSD | Medium | High | High |
| 4 | Bulk filtration of biodiesel | ≤4 microns absolute, required | ≤4 microns absolute required | ≤4 microns absolute required | ≤4 microns absolute required |
| 5 | Energy content of biodiesel | Minor loss of 1-2 percent | Minor loss of 1-2 percent | Potentially detectable loss of 2-4 percent | Detectable loss of 5-8 percent |
| 6 | Seals and O-Ring (Elastomer) compatibility | Not noted in Cat engines with required material | Not noted in Cat engines with required material | Not noted in Cat engines with required material | Not noted in Cat engines with required material |
| 7 | Hose compatibility | Low risk of softening | Softening may occur | Softening is likely | Softening is likely |
| 8 | Low ambient temperature issues for both storage and operation | Gelling can start higher than 0 °C(32 °F) | Gelling at increasing temperatures compared to diesel fuel | Gelling at increasing temperatures compared to diesel fuel | Gelling at increasing Temperature,−2 °C (28 °F)to 18 °C (64 °F) |
| 9 | Oxidation stability-Injector deposits | Not noted in Cat engines | Not noted in Cat engines | Increasing risk | Increasing risk |
| 10 | Oxidation stability-Duration of storage[2] | 8 months - start testing at 4 months[3] | 8 months - start testing at 4 months[3] | 6 months - start testing at 3 months [3] [4] | 4 months - start testing at 2 months[3][4] |
| 11 | Use in engines with limited operational time | Unacceptable[5] | Unacceptable[5] | Unacceptable[5] | Unacceptable |
| 12 | Microbial contamination and growth | Increasing. Testing required - treat at trace levels | Increasing. Testing required - treat at trace levels | High. Testing required - treat at trace levels | High. Testing required - treat at trace levels |
| 13 | Need for water removal | Increasing | Increasing | High | High |
| 14 | Metal incompatibility | Incompatible with certain materials | Incompatible with certain materials | Incompatible with certain materials | Incompatible with certain materials |
| 15 | Glycerides, total, free, mono, di (if not per spec) | Detectable impact | Detectable impact | Medium impact | High impact |

(continued)

(Table 6, contd)

(1) Information provided in this Table refers to biodiesel and biodiesel blends that fully comply with the appropriate specifications as described in Special Publication, “Biodiesel Fuel Specifications" and per following recommended maintenance procedures.

(2) Testing of biodiesel or biodiesel blend during storage is strongly recommended. Tests should include oxidation, acid number, viscosity and sediments. Tests should be conducted periodically to ensure biodiesel is per specification. Antioxidants are allowed to improve stability. Consult with your fuel supplier for more information.

(3) Testing is recommended at the indicated duration of storage and on a monthly basis thereafter. Tests should include oxidation, acid number, viscosity and sediments.

(4) 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.

(5) If B30, B40, or B50 are used in engines of limited operational time, it is recommended that a stabilizer additive is added at the beginning of the storage period. Follow all storage recommendations.

The following are details of the Risks and Guidelines listed in Table 6 . Refer to the paragraph reference numbers:

**1.** When using biodiesel fuel, dilution of oil by the fuel may increase as detailed in this Chapter. Use S·O·S Services oil analysis 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. Use of S·O·S is strongly recommended for up to B20 biodiesel blends and required for blends >B20.

**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 tanks and fuel system deposits. During the conversion period fuel filter change intervals should be shortened to allow for this cleaning effect. Once the deposits are removed, convert back to the regular filter service intervals. Filter change interval of 50 hours or less should be used during initial conversion to B20 or higher biodiesel blends.

**4.** Filter biodiesel and biodiesel blends through a fuel filter with a rating of 4 microns (c) absolute or less. Filters should be on the device that dispenses the fuel from the bulk storage tank to the fuel tank for the engine. Bulk filtration with fuel water separators is recommended. Series filtration is recommended.

**5.** Neat biodiesel (B100) typically provides less energy per gallon compared to diesel fuels. The energy content of B100 is 5 percent to 8 percent lower than No. 2 diesel fuel. The energy content of B20 is 1 percent to 2 percent lower than No. 2 diesel fuel, which is not significant. Do NOT attempt to change the engine rating to compensate for the power loss. Any adjustments to the engine in service may result in violation of emissions regulations such as the U.S. EPA anti-tampering provisions. Also, if any tempering with the engine ratings occurs, problems may occur when the engine is converted back to 100 percent distillate diesel fuel.

**6.** Compatibility of the elastomers with biodiesel can be different than compatibility with diesel fuel. Prolonged exposure of certain elastomers, hoses, seals, and gaskets to B100 may cause some degradation and softening of these materials. The condition of gaskets, seals, and hoses should be monitored regularly. The risk of degradation increases with the increase of biodiesel blend level.

a. In general, Cat engines built early to mid-90s and beyond use Viton seals and Viton O-rings in the fuel system. Viton is compatible with biodiesel and degradation upon exposure to this fuel is not expected.

**7.** Nitrile hoses typically used in some fuel transfer lines are not compatible with biodiesel. Hoses exposed to biodiesel and biodiesel blends may soften and may show some beading of fluid on the outside of the hose. 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. Consult with Cat dealers for appropriate hose materials.

**8.** Biodiesel fuels may gel or freeze at high temperatures due to the nature of this fuel. Ensure that the biodiesel pour point is appropriate for the climate of the application. In general, the risk of low temperature gelling of biodiesel increases with the increase of blend levels and may depend on the biodiesel feedstock (soy, used cooking oil, animal fats, palm and others). If the pour point of the biodiesel is not appropriate for the climate of the application, the fuel can gel and plug filters, hoses and transfer lines. At low ambient temperatures, biodiesel fuel may need to be stored in a heated building or a heated storage tank. Consult your biodiesel supplier for assistance in the blending and attaining of the proper cloud point for the fuel. Refer to the “Cloud Point” section in the “Diesel Fuel Characteristics”Section of this Special Publication.

**Note:** The performance of cold flow improvers may be less effective in biodiesel fuel compared to diesel fuel. Consult the fuel supplier for appropriate cold flow improvers if needed.

**9.** Biodiesel oxidation stability is in general lower than that of diesel fuel, as detailed earlier in this Chapter. The use of biodiesel fuels that are not per specifications can accelerate fuel oxidation in the fuel system. Also, engines with an electronic fuel system operate at higher temperatures and pressures that can also accelerate fuel oxidation. Oxidized fuel can form deposits in fuel injection systems and in fuel systems in general. Always use biodiesel fuel that meets or exceeds the stability limits defined in Special Publication, “Biodiesel Fuel Specifications" to avoid fuel oxidation and degradation. The use of appropriate antioxidants can enhance oxidation stability of biodiesel. Refer to the “Stability” portion of the Alternative Fuels section in this Special Publication for details and guidelines.

**Note:** Cat Diesel Fuel System Cleaner is highly recommended for use with biodiesel. Cat Diesel Fuel System Cleaner is effective at cleaning and preventing the formulation of fuel related deposits. Refer to this Special Publication, “Cat Diesel Fuel System Cleaner” section for additional information.

**10.** Due to the chemical nature of biodiesel fuel, biodiesel can age and degrade during long-term storage. Fuel aging and fuel oxidation upon long-term storage may cause the formation of gels, acids and/or deposits. For these reasons, biodiesel should be used within a limited time from production. 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 at the durations given in Special Publication, “Biodiesel Fuel Specifications" to ensure that biodiesel is per specification. Antioxidants are recommended to improve stability of biodiesel and increase the storage time limits. Consult with your fuel supplier or with a reputable provider to select appropriate additives.

a. Up to B30 biodiesel blends can generally be stored up to 8 months. Testing blends is recommended at 4 months of storage and on a monthly basis thereafter to ensure that the fuel has not degraded.

b. Up to B50 can generally be stored up to 6 months. Testing is recommended at 3 months of storage and every 3 weeks thereafter to ensure the fuel has not degraded.

c. 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 for more than 4 months. Consult your fuel supplier for more information.

d. B100 should be stored at temperatures of 3° C to 6° C (5° F to 10° F) above the cloud point. Other storage conditions such as avoiding direct sunlight or heat should be followed.

**11.** Due to limited oxidation stability and other potential issues, engines with limited operational time and seasonal use should 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, school buses, farm machinery, etc. For more information, refer to the “Seasonal Operation” section.

a. 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 not in specification (provided in Special Publication, “Biodiesel Fuel Specifications" in this “Alternative Fuels” section), drain the tank, and flush the engine by running with high-quality fuel.

Repeat the process until the system is clean. Refill with high-quality fuel following the recommendations provided in this “Fuel” section. For standby generator sets and emergency vehicles that use biodiesel, use fuel with oxidation stability 6 hours or more per “EN 14112” test method.

**12.** Biodiesel is prone to microbial contamination and growth due to the chemical nature. 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. Use anti-microbial additives at the first sign of detection. The cleaning process will be more effective if the biocide is used before extensive growth of microorganisms.

**Note:** Additional fuel filtration may be necessary after anti-microbial additive treatment.

**13.** Biodiesel can absorb and dissolve more water than diesel due to its chemical nature. Care must be taken to prevent water from contaminating the fuel and to remove water from fuel tanks. Water accelerates microbial contamination and growth and can cause system corrosion.

**14.** Biodiesel is not compatible with some metals. Biodiesel, in particular at blends of B20 and higher, will oxidize and form sediments upon long-term contact with lead, zinc, tin, copper, and copper alloys such as brass and bronze. These materials are typically avoided in the fuels systems. Consult your Cat dealer for more information.

**15.** During the esterification and cleaning process of the biodiesel production, glycerol and unreacted oils (mono, diand tri glycerides) may remain in the biodiesel. If these undesirable components are above the allowed specification levels, they can cause issues such as filter plugging and injector deposits. It is critical that the biodiesel fuel is per the recommended specifications.

**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.

**Note:** Use of biodiesel that is per or preferably exceeds the specifications can avoid the issues listed above and reduce the risks listed above.

i10695162

# Biodiesel Fuel Specifications

**SMCS Code:** 1250; 1280

## Caterpillar Specifications

Biodiesel fuel used for blending must meet the requirements in the following table, the requirements of ASTM “D6751” and/or “EN14214”.

The final blend of biodiesel as used in the engine must meet the requirements that are stated in Table 7 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 “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 gel and plug fuel filters when fuel temperatures are below −12° C (10.4° F).

Table 7

| Caterpillar Specification for Neat (B100) Biodiesel Blending Fuel | | | | |
|---|---|---|---|---|
| **Property** | **Test Method, United States** | **Test Method, International** | **Units** | **Limits, B100 Blending Fuel** |
| Density at 15°C | “ASTM D1298” | “ISO 3675” | g/cm3 | 0.86-0.90 |
| Viscosity at 40°C | “ASTM D445” | “ISO 3104” | mm2/s (cSt) | 1.9-6.0 |
| Flash Point | “ASTM D93” | “ISO 3679” | °C | 93 minimum |
| Pour Point | - | - | - | 6 °C (10 °F) minimum below ambient temperature |
| - Summer | “ASTM D97” | “ISO 3016” | °C | |
| - Winter | | | | |
| Cloud Point | “ASTM D2500” | | °C | Report |
| Sulfur Content(1) | “ASTM D5453” | “ISO 20846” “ISO 20884” | percent weight | 0.0015(2) maximum |
| Distillation | - | - | - | - |
| T90 | “ASTM D86” | “ISO 3924” | °C | 360 |
| Cetane Number | “ASTM D613” | “ISO 5165” | % evaporation | 45 minimum |
| Sulfated Ash | “ASTM D874” | “ISO 3987” or "ISO 6245" | percent weight | 0.02 maximum |
| Water and Sediment | “ASTM D2709” | “ISO 12937” | percent volume | 0.050 maximum |
| Water | "ASTM D1796" | "EN ISO 12937" | % m/m | 0.050 maximum |
| Copper Corrosion, 3 hours at 50°C | “ASTM D130” | “ISO 2160” | - | No. 1 |
| Oxidation Stability | “EN 14112” or "EN 15751" | “EN 14112” or "EN 15751" | hours | 3 minimum |
| Ramsbottom Carbon Residue on 10% bottoms | "ASTM D524" | “ISO 10370” | %-m/m | 0.30 maximum |
| Carbon Residue, Conradson (CCR) | “ASTM D4530” | - | percent weight | 0.05 maximum |
| Esterification | "ASTM D 7806" or "ASTM D 7371" | “EN 14103” | percent volume | 97.5 minimum |
| Total Acid Number | “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 maximum |
| Calcium plus Magnesium | “EN 14538” | “EN 14538” | ppm | 5 maximum |
| Sodium plus Potassium | “EN 14538” | “EN 14538” | ppm | 5 maximum |
| Cold Soak Filterability | “ASTM D7501” | – | seconds | 360 maximum |
| Cleanliness | “ASTM D7619” | “ISO 4406” | – | (3) |

(continued)

(Table 7, contd)

| Caterpillar Specification for Neat (B100) Biodiesel Blending Fuel | | | | |
|---|---|---|---|---|
| **Property** | **Test Method, United States** | **Test Method, International** | **Units** | **Limits, B100 Blending Fuel** |
| Total contamination | "EN 12662" | "EN 12662" | mg/kg | 24 maximum |
| Appearance | "ASTM D4176" | - | - | Clear and Bright |

(1) Methods for testing S are based on the sulfur content in diesel fuel used for blending. Consult with the fuel supplier and ensure the correct method has been used
(2) Sulfur level must be per local regulations. Higher S levels may be used where allowed.
(3) Recommended cleanliness level for fuel as dispensed into the engine fuel tank is “ISO 18/16/13” or cleaner per the test methods listed. Refer to the contamination control Chapter for more details.

**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.

NOTICE
In North America, the use of biodiesel from “BQ-9000” accredited producers and “BQ-9000” certified marketers is required. Refer to the “Recommendations” section for details.

i10575242

# Biodiesel Fuel Application

**SMCS Code:** 1250; 1280

Use of biodiesel blends above the maximum B7 for those engine models specified to that limit may cause premature wear of the fuel pump and damage to the low-pressure fuel system components, as both may contain material incompatible with higher biodiesel blends.

Local and regional regulations may also restrict the blend levels that are allowed in engines of certain emissions levels. EU Stage V regulations **REQUIRE** the biodiesel blends used in engines operated within the European Union (EU) to be less than or equal to 8% volume/volume unless specified otherwise in the engine-specific Operation and Maintenance Manual.

Understand that some Caterpillar engines that are certified per EU Stage V can use up to B20 or B30 biodiesel blends. Refer to the engine or product specific Operation and Maintenance Manual and to the information specified within this Special Publication.

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 the 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 meet maximum of 15 ppm sulfur.

**Note:** Except for testing and research purposes, fuel used in engines operated within Japan cannot be more than 5% volume/volume biodiesel for normal use.

**Note:** Do not change any engine settings when using biodiesel fuel. When the use of biodiesel fuel is planned, simply convert to this fuel. Follow the guidelines, recommendations and quality specifications given in this Special Publication to avoid any performance issues or downtime.

Biodiesel fuel must be per the quality recommendations given in this Special Publication, “Biodiesel Fuel Specifications”. Otherwise, the fuel may result in performance issues and engine downtime.

Consult your Cat dealer for further information on compatibility of non-metallic materials such as fuel lines, and other connections to the engine.

## Nonroad Engine Applications

The biodiesel blend levels acceptable for use in Caterpillar engines in various nonroad applications are given in Table 8 and Table 9 .

### U.S. EPA Tier 4 / EU Stage IIIB / China NR IV or Later Emissions Regulations

Table 8 details biodiesel blend levels acceptable for use in Caterpillar engines for U.S. EPA Tier 4, EU Stage IIIB, China NR IV or later emissions regulations. This information includes the regional equivalencies to these advanced emissions regulations.

Table 8

| Biodiesel Acceptability in Cat Nonroad Engines for U.S. EPA Tier 4 / EU Stage IIIB / China NR IV or Later Emissions Regulations[1] | | |
|---|---|---|
| **Engine Model(s)** | **Model Specific** | **Biodiesel Acceptable Blend Levels[2]** |
| C9.3 through C32<br>CM20, CM25 and CM32<br>3500 Series<br>C175 and C280 Series | Engine models with aftertreatment devices | Up to B20 |
| C0.5 through C7.1 | C0.5, C0.7, C1.1, C1.3, C1.7, C1.8, C2.4 Engine models without aftertreatment devices | Up to B20 |
| | C1.7, C2.2, C2.8, C3.3B, C3.4B, C3.6, C3.8, C4.4, C6.6, C7.1 Engine models with aftertreatment devices | |

(1) Includes the regional equivalencies to Nonroad U.S. Tier 4, EU Stage IIIB, China NR IV or later emissions regulations.
(2) EU regulations require the biodiesel blends used in Stage V engines and Special-Purpose Engines (SPE) operated within the European Union (EU) to contain no more than 8% v/v FAME unless specified otherwise in the engine-specific Operation and Maintenance Manual. B8 can be used where B7 is specified.

## U.S. EPA Tier 3 / EU Stage IIIA / China NR III or Earlier Emissions

Table 9 details biodiesel blend levels acceptable for use in Caterpillar engines for U.S. EPA Tier 3, EU Stage IIIA, China NR III, or earlier emissions regulations. This information includes the regional equivalencies to these emissions regulations.

Table 9

| Biodiesel Acceptability in Cat Nonroad Engines for U.S. EPA Tier 3 / EU Stage IIIA / China NR III or Earlier Emissions Regulations[1] | | |
|---|---|---|
| **Engine Model(s)** | **Model Specific** | **Biodiesel Acceptable Blend Levels** |
| C7 through C32<br>CM20, CM25 and CM32<br>3100 through 3400<br>3500 and 3600 Series<br>C175 and C280 Series | Engine models without aftertreatment devices | Up to B100<br>(For use of blends higher than B20, ensure the fuel is per specification and consult with your Cat dealer.) |
| 3003 through 3066 | All engine models | Up to B8 |
| C0.5 through C7.1 | C0.5, C0.7, C1.1, C1.5, C1.6, C2.2, C3.3, C4.4 engine models U.S. EPA Tier 2 / EU Stage II / China NR II or earlier emissions regulation | Up to B8 |
| | C0.5, C0.7, C1.1, C1.5, C2.2, C2.8, C3.3, C3.4, C3.6, C4.4, C6.6, C7.1 engine models U.S. EPA Tier 3 / EU stage IIIA / China NR III emissions regulation | Up to B20 [2] |
| | C1.7 (S/N D68, G34, J3C, J3N, J4N, J7J, J7L, J33, J35, Z29) | Up to B20 [2] |
| | C1.7, C1.8, C2.4, C2.6, and C3.3B engines | Up to B20[3] |
| C4.2, C4.4, C6.4 & C6.6<br>Engine Serial Prefixes 444, C4E, 666 and C6E | C4.4 engines (S/N 44400001-04303)<br>C6.6 engines (S/N C6E00001-14623 and S/N 66600001-09015) | Up to B8 |

(continued)

(Table 9, contd)

| | | |
|---|---|---|
| | C4.2 and certain C4.4 engines (S/N: C4E05524-Up and 44404304 - Up) C6.4 and certain C6.6 engines (S/N C6E14624 - Up and 66609016 - Up) | Up to B20 (2) |

(1) Includes the regional equivalencies to Nonroad U.S. EPA Tier 3, EU Stage IIIA, China NR III or earlier emissions regulations.
(2) Higher blends, up to B50, where mandated can be used in these engines.
(3) Higher blends, up to B40, where mandated can be used in these engines.

# Marine Engine Applications

The biodiesel blend levels acceptable for use in Caterpillar marine engines can be found in Table 10 .

Table 10

| Biodiesel Acceptability in Cat Marine Engines | | |
|---|---|---|
| **Engine Model(s)** | **Model Specific** | **Biodiesel Acceptable Blend Levels**(1) |
| 3034 and 3056 C1.5 through C4.4 | Marine models with mechanical fuel systems | Up to B8 |
| C4.4 through C7.1 | Marine models with a high pressure common rail fuel system | Up to B20(2) |
| C9.3 through C32 C175 through C280 | Marine models without aftertreatment devices | Up to B100 (For use of blends higher than B20, ensure fuel is per specification and consult with your Cat dealer.) |
| | Marine models with aftertreatment devices certified to Marine U.S. EPA Tier 4 or IMO III emissions regulations | Up to B20 |
| | Marine models with aftertreatment devices certified to EU Stage V emissions regulations | Up to B8 |
| 3500 Series | Marine models without aftertreatment devices | Up to B100 (For use of blends higher than B20, ensure fuel is per specification and consult with your Cat dealer.) |
| | Marine models with aftertreatment devices certified to Marine I.S. EPA Tier 4, IMO III, or EU Stage V emissions regulations | Up to 30 |

(1) EU regulations require the biodiesel blends that are used in stage V engines and Special-Purpose Engines (SPE) operated within the European Union (EU) to contain no more than 8% v/v FAME unless specified otherwise in the Operation and Maintenance Manual. B8 can be used where B7 is Specified.
(2) Higher blends, up to B50, where mandated can be used within these engines.

# Renewable Diesel

i09968185

## Renewable Diesel/Hydrotreated Vegetable Oil (HVO)

**SMCS Code:** 1250; 1280

Table 11

| Renewable Diesel Fuel Application in Diesel Engines | | | | | |
|---|---|---|---|---|---|
| **Fuel** | **Source** | **Processing** | **Chemistry** | **Specification** | **Application** |
| Renewable Diesel/ HVO | Vegetable oils, animal fats, and used cooking oil | Hydrotreating | Paraffin | EN 15940, ASTM D975 | 100% or any blend |

Renewable diesel fuels covered in this section are typically hydrocarbons (composed of 99% hydrogen and carbon) and that are known as a drop-in replacement for diesel fuel (refer to potential impacts detailed in this section). These fuels must be per the specifications and characteristics described below, and in all the relevant sections in this publication in order to be used in the engines, and to reduce the risk of downtime.

Renewable diesel fuels are derived from renewable resources such as planted crops (soy, palm, rapeseed, etc.), used cooking oil, animal fat, biomass, algae, and others. Renewable diesel fuels reduce the carbon footprint of the fuels on a Life Cycle Analysis basis.

Renewable diesel can be derived from fats and oils through a hydrotreating process. These fuels are then called HVO (hydrotreated vegetable oils). Renewable diesel can also be referred to as renewable paraffinic diesel, HDRD (hydrogenation-derived renewable diesel), or HEFA (hydroprocessed esters and fatty acids).

Biomass can be converted to renewable fuel through various processes and is typically called BTL (Biomass-to-Liquid).

Note that renewable diesel covered in this section is different than biodiesel fuel. The latter is covered in a separate section in this Special Publication.

In order to be applicable in the engine, Caterpillar recommends that renewable diesel must be per the latest version of any of the following specification:

- “EN 15940”, which defines quality requirements for Gas to Liquids (GTL), Biomass to Liquids (BTL) and hydrotreated vegetable oil (HVO). This is the preferred specification for renewable and synthetic fuels covered in this section.
- “ASTM D975”, which is the specification for diesel fuel in the United States.
- Cat  Diesel Fuel Specification, except for density. Renewable diesel fuels that are per the requirements listed above can be used as:
- 100 percent (may be called RD100, HVO100, R100 or other)
- Any blend level with diesel fuel

**Note:** Biodiesel (FAME) can be blended with renewable and synthetic fuels to the same equivalent blend level of standard diesel. Refer to the “Biodiesel Fuel” section for acceptable levels of the specific product.

Renewable diesel fuels are typically paraffinic hydrocarbons, which are a subset of diesel fuel composition. Hence these fuels, whether at 100% or blended, can be used as a drop-in replacement for diesel fuel. Benefits of these fuels include:

- (RD or HVO) fuels are renewable and can reduce the carbon footprint of the engine
- High cetane number
- Can be designed to provide low temperature capability. Consult with your supplier to ensure that the fuel is per the ambient temperature of the application.
- Can reduce emissions of certain products of incomplete combustion, such as unburned hydrocarbons (UHC), soot, and carbon monoxide (CO). May reduce $NO_x$ emissions under certain engine loads and cycles

Guidance and potential impacts for the use of renewable diesel fuels that are per the specifications detailed above:

- No specific conversion process is needed when these fuels are used for the first time of thereafter

- May reduce the power output of engines due to their low density. Up to 5% reduction may be noted at 100%
- Compatible with aftertreatment technologies such as DPF, DOC, and SCR, and can be used on engines that are per Tier 4, Stage V, and/or similar advanced emissions regulations
- Compatible with filters and engine oils used with typical diesel fuels. No impact on maintenance intervals is expected. In general, it is recommended that oil drain intervals are based on oil analysis.
- Compatible with elastomeric materials and hoses use on most modern engines. Certain elastomers used in older engines (such as engines manufactured prior to the early 1990s) may not be compatible with the new synthetic fuels. Refer to your Cat dealer for guidance.
- Can be stored in the same tanks used for diesel fuel, and are of similar aging life as diesel fuel.

As with all fuels, renewable diesel fuels have to be managed to reduce contamination and water ingress. Refer to this Special Publication, “Diesel Fuel” section for more contamination control information.

Caterpillar is following the development of renewable fuels, and is involved in the development of appropriate specifications to ensure successful application of these fuels in the engines. Use of fuels of low carbon footprint supports Caterpillar's sustainability initiatives.

# Synthetic Fuels

i09968177

## Synthetic Diesel/E-Diesel/Gas-to-Liquid (GTL)

**SMCS Code:** 1250; 1280

Table 12

| Synthetic Diesel Fuel Application in Diesel Engines | | | | | |
|---|---|---|---|---|---|
| **Fuel** | **Source** | **Processing** | **Chemistry** | **Specification** | **Application** |
| E-Diesel/Synthetic Diesel | Carbon dioxide, hydrogen, other | Fischer Tropsch, other | Paraffin | EN 15940, ASTM D975, EN 590, other | 100% or any blend |
| Gas-to-Liquid | Natural gas, synthetic, other | Fischer Tropsch, other | Paraffin | EN 15940, ASTM D975, EN 590, other | 100% or any blend |

Synthetic fuels may be made from various non-renewable resources such as natural gas (GTL: Gas-to-Liquid) through Fischer Tropsch process, or through other pathways.

Synthetic liquid fuels covered in this section are typically hydrocarbons (composed of 99% hydrogen and carbon) and are known as a drop-in replacement for diesel fuel and the potential impacts can be found within this section. These fuels must be per the specification and characteristics described below, and within the relevant sections within this Special Publication in order to be used in Cat engines, and to reduce the risk of potential downtime.

Synthetic fuels may be made from various non-renewable resources such as natural gas or Gas to liquid (GTL) through Fischer Tropsch process, or through other pathways.

**Note:** Synthetic fuels covered in this section are different than biodiesel fuel. Biodiesel fuel information is covered in this Special Publication, “Biodiesel Fuel” section.

In order to be applicable in the engine, Caterpillar recommends that synthetic fuels must be per the following specification:

- "EN 15940", which defines quality requirements for Gas to Liquids (GTL), Biomass to Liquids (BTL) and Hydrotreated Vegetable Oil (HVO). This is the preferred specification for synthetic fuels covered in this section.
- "ASTM D975", which is the specification for diesel fuel in the United States.
- Caterpillar Diesel Fuel Specification, except for density.

Synthetic fuels that are per the requirements listed in this section can be used as:

- 100% (may be called GTL100 or other)
- Any blend level with diesel fuel

**Note:** Biodiesel (FAME) can be blended with renewable and synthetic fuels to the same equivalent blend level of standard diesel. Refer to the “Biodiesel” section within this Special Publication for acceptable levels of a specific product.

Synthetic fuels are typically paraffinic hydrocarbons, which are a subset of diesel fuel composition. Hence these fuels whether at 100% or blended, can be used as a drop-in replacement for diesel fuel. Benefits of these fuels include:

- Potentially lower carbon footprint, depending on the source of the fuel.
- High cetane number
- Can be designed to provide low temperature capability. Consult with your supplier to ensure that the fuel is per the ambient temperature of the application.
- Can potentially reduce emissions of certain products of incomplete combustion, such as unburned hydrocarbons (UHC), soot, and carbon monoxide (CO). Also may reduce $NO_x$ emissions under certain engine loads and cycles.

Guidance and potential impacts for the usage of synthetic fuels that are per specifications listed within this section are as follows:

- No specific conversion process is needed when these fuels are used for the first time or thereafter.
- May reduce the power output of engines due to their low density. up to 5% reduction can be expected at 100%.

- Compatible with aftertreatment technologies such as DPF, DOC, and SCR.
- Can be used on engines that are per Tier 4, Stage V and similar configurations.
- Compatible with filters and engine oils used with typical diesel fuels. No impact on maintenance intervals is expected. in general, it is recommended that the oil drain intervals are based on oil analysis.
- Compatible with elastomeric materials and hoses used on most modern engines. Certain elastomers used in older engines (such as engines manufactured prior to the 1990's) may not be compatible with the new synthetic fuels. Refer to your Cat dealer for further guidance.
- Can be stored in the same tanks used for diesel fuel, and are of similar aging life as diesel fuel. As with all fuels, renewable and synthetic fuels have to be managed to reduce contamination and water ingress. Refer to Special Publication, “Diesel Fuel General Information” section for general fuel cleanliness information.

Caterpillar is following the development of synthetic fuels, and is involved in the development of appropriate specifications to ensure successful application of these fuels in the engines. Use of fuels of low carbon footprint supports the Caterpillar sustainability initiatives.

i09967897

# Pyrolysis

**SMCS Code:** 1250; 1280

## Pyrolysis Fuels

A particular family of synthetic fuels, known as pyrolysis fuels, are typically NOT suitable for use in modern diesel engines. Pyrolysis fuels can be obtained from various resources including wood, used tires, plastic, etc. Pyrolysis fuels in their raw form do not meet all the requirements listed in Operation and Maintenance Manual, “Biodiesel Fuel Specifications", "ASTM D975" and/or "EN 590" specifications. These fuels have to be upgraded in order to produce a hydrocarbon product that meets all requirements defined in these specifications. Upgrading can include fractionation to remove volatiles, hydro-desulfurization, hydrotreating, etc.

Where the pyrolysis fuel is obtained from wood, our experience has been that the liquid obtained contains high oxygen content (>10%), has high acidity (ph~1), and does not meet distillation, lubricity, and cetane requirements. Use of this fuel is likely to lead to severe impairment and wear in the fuel system. Suitable upgrading would likely involve, at a minimum, hydro-deoxygenation, fractionation and other hydrotreating.

Where the pyrolysis fuel is obtained from used tires, our experience has been that the distillation and sulfur requirements are not met. Use of this fuel is likely to lead to impaired function of the fuel and aftertreatment systems. Suitable upgrading would likely involve, at a minimum, fractionation and desulfurization.

Where the pyrolysis fuel is obtained from waste plastic, our experience has been that the distillation, lubricity, and cetane requirements are not met. Use of this fuel is likely to lead to impaired function of the fuel system. Suitable upgrading would likely involve, at a minimum, fractionation and other hydrotreating.

Upgraded pyrolysis fuels that meet Cat Diesel Fuel specification listed in Operation and Maintenance Manual, “Biodiesel Fuel Specifications", "ASTM D975" and/or "EN 590" specifications can be considered for use in Cat engines. Refer to your Cat dealer for questions.

# Other Fuels

i10422094

## Heavy Fuel Oil/Residual Fuel/ Blended Fuel

**SMCS Code:** 1250; 1280

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.

# Engine Oil Section

# Diesel Engine Oil (DEO)

i10210802

## Diesel Engine Oil (DEO) General Information

**SMCS Code:** 1348

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.

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 and pressures
- 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 older formulations. Current lubricants are developed to support advanced engine technologies as well as those with lower emissions while supporting the performance and durability of these engines. At the same time, these oils are backwards compatible and protect older engines.

Cat high-performance oils are produced and validated using industry standard tests, internal proprietary tests, field tests, and often prior experience with similar formulations. The American Petroleum Institute (API) categories describe the key industry standards that set the minimum acceptable performance for engine oils. Other global standard setting organizations may also develop common standards, for example the European ACEA oil specs. Cat high quality and high-performance lubricants are validated based on these factors.

Use the recommended engine oils as provided in this special publication to provide optimal engine performance and life and comply with regulated emission reductions. Due to the significant variations in the quality and performance of commercially available oils on a global basis, Caterpillar recommends the use of Cat oils as detailed in this article.

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 Special Publication, SEBU9208, “Caterpillar Filters Recommendations”. Also 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.

**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.

## Caterpillar Fluids

In order to avoid potential damage to your 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.

Cat fluids have been developed and tested by Caterpillar in order to increase the performance and the life of Cat components. The quality of finished oil is dependent on the quality of the base stock, the quality of the additives and the compatibility of the base stock and additives. Cat fluids are formulated of high-quality refined oil base stocks and additives of optimal chemistry and quantity in order to provide high performance in engines and 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 with your Cat dealer for more information on these Cat fluids.

Caterpillar recommends the use of the following Cat fluids. The fluids listed below are approved by Cat, but may not be suited best for every machine application. For information on what fluids best suit a given application, refer to this Special Publication, "Lubricant Viscosities" section for more information.

Table 13

| Cat Lubricants | | Viscosity Grade |
|---|---|---|
| Diesel Engine Oil-Ultra Low Sulfur [1] (API CK-4) | Cat DEO-ULS | SAE 15W-40 |
| | | SAE 10W-30 |
| | Cat DEO-ULS SYN | SAE 5W-40 |
| | Cat DEO Cold Weather | SAE 0W-40 |
| Diesel Engine Oil [1] (API CI-4/API CI-4PLUS) | Cat DEO | SAE 15W-40 |
| | | SAE 10W-30 |
| Multi Application Engine Oil | Cat MAEO Plus (Non-Cat mixed fleets) | SAE 10W-40 |
| Diesel Engine Oil (API CF) | Cat DEO (3600 engines only) | SAE 40 |
| Pre Combustion Oil | Cat PCO | SAE 40 |

[1] Cat engine oils exceed the performance requirements of the respective API categories

**Note:** Additional Cat fluids may be available.

**Note:** Cat offers Special Application Engine Oil (SAEO), API CF-4 oil of SAE 30 and SAE 40 viscosity grades. These oils are recommended for use in 3116 and 3126 marine engines.

**Note: Cat fluids availability will vary by region.**

This information applies to Cat commercial diesel engines. For more lubricant recommendations see the following Special Publications:

- Special Publication, SEBU6250, “Caterpillar Machine Fluid Recommendations”
- Special Publication, SEBU6385, “Caterpillar On-Highway Diesel Engine Fluids Recommendations”
- Special Publication, SEBU6400, “Caterpillar Gas Engine Fluids Recommendations”
- Special Publication, SEBU7003, “Caterpillar 3600 Series and C280 Series Diesel Engine Fluids Recommendations”

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

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

## Determining Optimum Oil Change Intervals

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

- Use recommended oils, as described in this document or the Operation and Maintenance Manual
- Use of recommended fuels, as described in this document or the Operation and Maintenance Manual
- Use of Cat  oil filters
- Use of Caterpillar recommended maintenance

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

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

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

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

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

The process for extending engine oil drains is available in the brochure “Optimizing Oil Change Intervals”PEHJ0192. This process is basically the same for all lubricated compartments on a Cat machine. Work with your Cat dealer to select the proper high-performance Cat lubricant for your extended oil drain program. Your Cat dealer has additional resources to guide you in the extended oil drain process.

## Cat Lubricants for Extended Oil Drains

All Cat lubricants are high performance products, and are recommended for extended oil drains. Within each group of Cat lubricants, there are products available at different performance levels. Your Cat dealer has the list of Cat lubricants that are available in your region of the world. Work with your Cat dealer to select the best Cat lubricant for your extended oil drain program.

i10211051

# Diesel Engine Oil (DEO) Characteristics

**SMCS Code:** 1348

## Selecting the Viscosity

Ambient temperature is the temperature of the air in the immediate vicinity of the engine. This temperature may differ due to the engine application from the generic ambient temperature for a geographic region. When selecting the proper oil viscosity for use, review both the regional ambient temperature and the potential ambient temperature for a given engine application. Generally, use the highest oil viscosity that is allowed for the ambient temperature when you start the engine. Refer to the “Lubricant Viscosities for Ambient Temperatures” tables for guidance. In cold weather applications, the preferred method is to use properly sized engine compartment heaters and a higher viscosity grade oil. Thermostatically controlled heaters that circulate the oil are preferred.

The proper oil viscosity grade is determined by the minimum ambient temperature (the air in the immediate vicinity of the engine). In order to determine the proper oil viscosity grade, refer to the “Min” column in table 14 . This information reflects the coldest ambient temperature condition for starting a cold engine and for operating a cold engine. Refer to the “Max” column in table 14 in order to select the oil viscosity grade for operating the engine at the highest temperature that is anticipated. Unless specified otherwise in the tables, use the highest oil viscosity that is allowed for the ambient temperature when you start the engine.

Engines that are operated continuously should use oils that have the highest recommended viscosity. The oils that have the higher oil viscosity will maintain the highest possible oil film thickness. Refer to this Special Publication, “Diesel Engine Oil General Information” article, Special Publication, “Diesel Engine Oil Specifications”, Lubricant Viscosities tables, and any associated footnotes. Consult your Cat dealer if additional information is needed.

**Note:** SAE 0W and SAE 5W oils, are not recommended for use in engines that are operated continuously and/or are heavily loaded. Refer to table 14 for guidance. The oils that have the higher oil viscosity will maintain the highest possible oil film thickness. Consult your Cat dealer if additional information is needed.

**Note:** Generally, use the highest oil viscosity that is available to meet the requirement for the temperature at start-up.

Proper oil viscosity AND oil type/specification are required to maximize engine performance and life. Do NOT use only oil viscosity, or only oil type to determine the engine oil selection. Using only the oil viscosity or only the oil type to determine the engine oil selection can lead to reduced performance and engine failure. Refer to the applicable “Lubricant Viscosities for Ambient Temperatures” tables and to ALL of the associated footnotes.

In colder ambient conditions an engine warm-up procedure and/or supplemental engine fluid compartment heat may be required. Engine warm-up procedures can typically be found in the Operation and Maintenance Manual for the engine. The “Lubricant Viscosities for Ambient Temperatures” tables in this Special Publication include footnotes that address engine warm-up.

## Lubricant Viscosity Recommendations for Direct Injection (DI) and Precombustion Chamber (PC) engines

Refer to the minimum temperature in table 14 in order to determine the required oil viscosity for starting a cold engine. Refer to the maximum temperature in order to select the oil viscosity for engine operation at the highest ambient temperature that is anticipated.

Table 14

| Lubricant Viscosities for Ambient Temperatures for Cat Diesel Engines[1] | | | | | | |
|---|---|---|---|---|---|---|
| Engine Type | Oil Type and Performance Requirements | Viscosity Grade | °C | | °F | |
| | | | Min | Max | Min | Max |
| Direct Injection (DI) and Pre Combustion (PC) | Cat Cold-Weather DEO-ULS (API CK-4) | SAE 0W-40 | −40 | 40 | −40 | 104 |
| | Cat DEO-ULS SYN (API CK-4) | SAE 5W-40 | −30 | 50 | −22 | 122 |
| | Cat DEO-ULS (API CK-4) Cat DEO (API CPI-4/CPI-4 PLUS) | SAE 10W-30 | −18 | 40 | 0 | 104 |
| | | SAE 15W-40 | −10 | 50 | 14 | 122 |
| Pre Combustion (PC) only | Cat PCO | SAE 40 | 5 | 50 | 41 | 122 |

(1) Refer to Special Publication, SEBU6251, “Engine Oil”, for information on the recommended and required engine oils for Tier 4 emissions certified engines.

Supplemental heat is recommended for cold-soaked starts below the minimum ambient temperature. 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. Cold-soaked starts occur when the engine has not been operated for a time, allowing the oil to become more viscous in cooler ambient temperatures.

**Note:** Use the highest oil viscosity that is available to meet the requirement for the temperature at start-up.

If ambient temperature conditions at engine start-up require the use of multigrade SAE 0W oil, SAE 0W-40 viscosity grade is preferred over SAE 0W-30.

**Note:** C175 Series diesel engines require the use of multigrade SAE 40 oil: SAE 0W-40, SAE 5W-40, SAE 10W-40, or SAE 15W-40. In ambient temperatures of −10° C (14° F) or above, SAE 15W-40 is the preferred oil viscosity grade.

If ambient temperature conditions at engine start-up require the use of multigrade SAE 0W oil, SAE 0W-40 viscosity grade is preferred over SAE 0W-30.

Refer to this Special Publication, “Lubricant Viscosities” and “Cold-Weather Lubricants” for additional information.

## Lubricant Viscosity Recommendations (3116 and 3126 Marine Engines)

Table 15

| Lubricant Viscosities for Ambient Temperatures for Cat 3116 and 3126 Marine Engines | | | | | | |
|---|---|---|---|---|---|---|
| Engine Model | Oil Type and Performance Requirements | Viscosity Grade | °C | | °F | |
| | | | Min | Max | Min | Max |
| 3116 and 3126 Marine Diesel Engines | Cat SAEO API CF or equivalent | SAE 30 | 0 | 40 | 32 | 104 |
| | | SAE 40 | 5 | 50 | 41 | 122 |

The information provided in the “Lubricant Viscosities, Selecting the Viscosity” article in the “DI and PC Engines” section is applicable to 3116 and 3126 Marine Engines.

Use the highest oil viscosity that is allowed for the ambient temperature at start-up.

**Note:** 10W-30 is the preferred viscosity grade for the 3116, 3126, C7, C-9, and C9 diesel engines when the ambient temperature is above −18° C (0° F) and below 40° C (104° F).

**Note:** Cat offers Special Application Engine Oil (SAEO), API CF oil of SAE 30 and SAE 40 viscosity grades. These oils are recommended for use in 3116 and 3126 marine engines.

Cat does not recommend the use of multigrade oils in the 3116 and 3126 Marine Diesel Engines that use mechanical unit injection (MUI).

Multigrade oils use high molecular weight polymers as viscosity index improvers. When the crankcase blowby flows through the turbocharger and the aftercooler, the viscosity index improvers can adhere to the turbocharger compressor and aftercooler core.

The fouling of the turbocharger and aftercooler can cause reduced air flow, loss of power, and increased black smoke. The emission of black smoke results in buildup of soot on the transom of the boat.

**Note:** Caterpillar recommends the use of single grade oils that pass all API CF-4 category requirements unless crankcase blowby has been routed away from the air cleaner inlet.

## Cat SAEO (Special Application Engine Oil)

**Note:** Cat SAEO is recommended for use in Cat 3116 and 3126 Marine Diesel Engines with mechanical unit injection. 3116 and 3126 Marine Diesel Engines that begin with the following serial number prefixes are included:

- **S/N:** 6SR
- **S/N:** 8NM
- **S/N:** 4KG
- **S/N:** 1SK
- **S/N:** 1ZJ
- **S/N:** 6MK
- **S/N:** 4EZ

The factory-fill for 3116 and 3126 Marine Engines is Cat SAEO with the following properties:

- Meets all requirements of API CF-4 category
- Viscosity grade of SAE 30

For maximum performance in 3116 and 3126 Marine Diesel Engines with mechanical unit injection, Caterpillar recommends the following engine oil:

- Cat SAEO (SAE 30)
- Cat SAEO (SAE 40)

## Commercial Oils (3116 and 3126 Marine Engines)

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

When Cat SAEO is not used, use the following commercial oils:

- Single grade oil with a viscosity of SAE 30 or SAE 40 that meets all API CF category requirements is preferred.
- Single grade oil with a viscosity of SAE 30 or SAE 40 with an API CF additive package and no viscosity improvers is acceptable oil.

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.

Oil products that used to be licensed as API CF oil performance category and have not changed formulation are acceptable for use in Cat 3116 and 3126 marine engines.

For an acceptable commercial single grade oil, consult your Cat dealer.

Some commercial oils that meet the requirements API CF-4 category may require reduced oil change intervals. To determine the oil change interval, closely monitor the condition of the oil and perform a wear metal analysis. Cat S·O·S Services oil analysis program is the preferred method.

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

## Synthetic Basestock Oils

Synthetic base oils are acceptable for use in Cat engines and in Cat machines **IF these oils meet the performance requirements that are specified by Caterpillar for a particular compartment**. Each compartment has specific lubrication specifications to ensure proper lubrication and life of the system.

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

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

Some synthetic base oils have performance characteristics that enhance the service life of the oil. However, Caterpillar does not recommend automatically extending the oil drain interval for any machine compartment for any type of oil, whether synthetic or non-synthetic.

Oil drain intervals for Cat diesel engines can only be adjusted 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 “ Warranty Information” section of this special publication.

## Refined Basestock Oils

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.

i10746629

# Diesel Engine Oil (DEO) Specifications

**SMCS Code:** 1348

## Cat Diesel Engine Oils Recommendations

Cat DEO-ULS and Cat DEO multigrade oils are the preferred and recommended oils for use in ALL Cat diesel engines that are covered by this Special Publication. Commercial alternative diesel engine oils are, as a group, second choice oils. Refer to Table 16 for further information.

Table 16

| Cat Engine Lubricants Recommendations | |
|---|---|
| Engines with aftertreatment devices(1) | Recommended: Cat DEO-ULS (API CK-4) |
| | Commercial, second-class oils: API CK-4; Cat ECF-3/API CJ-4 |
| Engines without aftertreatment devices | Recommended: Cat DEO-ULS (API CK-4); Cat DEO (API CI-4/API CI-4 PLUS) |
| | Commercial, second-class oils: API CK-4; Cat ECF-3/API CJ-4, Cat ECF-2; Cat ECF-1-a |

(1) For details, refer to Recommendations for US EPA Tier 4 Certified Nonroad Engines and Recommendations for Europe Stage V Certified Nonroad Engines.

**Note:** Cat DEO-ULS (API CK-4) oil is backwards compatible and can be used in all engines with some restrictions related to fuel sulfur level, refer to Table 16 . Cat DEO (API CI-4/API CI-4 PLUS) can be used in engines that are Tier 3 emissions certified and prior, and in engines that do not use aftertreatment devices.

Cat DEO-ULS is per the latest API CK-4 heavy duty engine oil category. Cat DEO-ULS has the following characteristics compared to the prior API CJ-4 category:

- Improved oxidation stability (per ASTM D8048).
- Improved air release (Per ASTM D8047).
- Improved used oil shear stability per tighter specification limits.
- Preserved the same level of phosphorous, 1000 ppm (parts per million) (mg/kg), to ensure achieving long hour engine durability goals
- Same chemical limits as API CJ-4 oil category, designed for use in engines with aftertreatment devices.

**Note:** The new API FA-4 Heavy Duty Engine Oil Category is NOT allowed in Cat engines. API FA-4 is a special low High Temperature High Shear (HTHS) viscosity oil that is designed for certain 2017 and later On-Highway engine models.

**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 17 for details.

The engine oils recommended/required for Tier 4 certified engines are formulated with limited ash and chemical limits:

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

These chemical limits were developed to support the expected aftertreatment devices life, performance, and service intervals. Use of oils other than those listed in this section of this special publication in aftertreatment equipped engines can negatively impact performance of the aftertreatment devices, can contribute to Diesel Particulate Filter (DPF) plugging and/or can cause the need for more frequent DPF ash service intervals.

Cat diesel engine oils, 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.

NOTICE
Do not use single grade API CF oils or multigrade API CF oils in Cat Series 3500, Series C175 and smaller Direct Injection (DI) diesel engines. Single grade API CF oils (or oils that meet all the performance requirements of API CF category) may only be used in Cat Series 3600 and Series C280 diesel engines, and older Cat engines that have precombustion chamber (PC) fuel systems. Oils that are used in Cat Series 3600 and Series C280 diesel engines must also pass a 7000 hour field performance evaluation. Consult your Cat dealer for details.

Cat diesel engine oils are formulated with the optimal amounts and chemistry of various additives including detergents, dispersants, antioxidants, alkalinity, antifoam, viscosity modifiers, and others. These oils have been proven in internal tests and in the field to provide superior performance in Cat diesel engines where recommended for use.

Cat DEO-ULS and Cat DEO are multigrade oils. Refer to Table 16 in this article for details. Multigrade oils provide the correct viscosity for a broad range of operating temperatures. Multigrade oils provide the appropriate oil film thickness for moving engine components such as piston, ring and liners, bearings, valve train and others.

Mixed fleets: Cat diesel engine oils exceed many of the performance requirements of the corresponding API categories and of other manufacturers of diesel engines. Therefore these oils are excellent choices for many mixed fleets. Refer to the 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 for technical details.

Non-EPA certified engines: Cat DEO-ULS and Cat DEO are recommended for all pre-Tier 4 engines that use Ultra Low Sulfur Diesel (ULSD) or Low Sulfur Diesel (LSD) fuels. Cat DEO is recommended for engines using fuels of sulfur levels that exceed 0.2 percent (2000 ppm). Cat DEO-ULS may be used in these applications if an oil analysis program is followed. The oil change interval may be affected by the fuel sulfur level. Refer to the “S·O·S Analysis” topic in this section of this Special Publication.

Tier-4 certified engines: 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 certified engines in this Chapter, to “Diesel Fuel Sulfur Impacts” article of the “Fuels Specifications” section and to “Lubricants Specifications” section of this Special Publication.

Consult your Cat dealer for part numbers and for available sizes of containers.

**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. Oils that claim the requirements of API CF can be used ONLY in Cat Series 3112 and Cat Series 3126 Marine Engines and in 3600 engine models per the OMM of these engines. Refer to the details given in the Marine engine section in this Special Publication.

## Commercial Engine Oil

Caterpillar strongly recommends the use of Cat engine oils in Cat engines since these oils are developed and optimized for use in these engines.

**Note:** Cat diesel engine oils are required to pass proprietary full-scale diesel engine testing. The testing is above and beyond the testing required by the various Cat ECF specifications and by the various API oil categories that are also met. This additional proprietary testing helps ensure that Cat multigrade diesel engine oils, when used as recommended, provide superior performance in Cat diesel engines.

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

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

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.

There are significant variations in the quality and performance of commercially available oils. For this reason, Cat recommends the Cat oils listed within this Special Publication, “Diesel Engine Oil (DEO) General Information” section.

When the recommended Cat diesel engine oils are not used, commercial oils that are API CK-4 licensed and/or meet the requirements of the Cat ECF-1-a, Cat ECF-2, and/or the Cat ECF-3 specification are acceptable, but second choice, for use in Cat diesel engine.

Oils that are API CJ-4, API CI-4/CI-4 PLUS and API CH-4 licensed, and do not meet any Cat ECF specification are, as a group, third choice.

Oils that meet only API CI-4/CI-4 PLUS and/or API CH-4 categories and that have not met the requirements of at least one Cat ECF specification may cause reduced engine life.

**Note:** API FA-4 oils are NOT allowed for use in Cat engines. These oils are designed for use in certain 2017 On-Highway engine models.

API CK-4 oils exceed the performance requirements of prior API categories. Cat developed the Engine Crankcase Fluid (ECF) specifications to ensure the availability of minimum acceptable performance commercial diesel engine oils. The three Cat ECF specifications: Cat ECF-1-a, Cat ECF-2 and Cat ECF-3 are described in Table 17 . These specifications require more engine tests than the corresponding API categories.

Each higher Cat ECF specification 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 17 for details

Table 17 below provides details of Cat ECF specifications.

Table 17

| Cat Engine Crankcase Fluids (ECF) Definitions | |
|---|---|
| **Cat Minimum Performance Requirements for Commercial Oils** | **Cat ECF Specifications Requirements** |
| (1) | API CK-4 Oil Category performance 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 sulfated ash ≤ 1.50 percent |
| 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 sulfated ash ≤ 1.50 percent |

(1) Caterpillar did not develop an ECF external specification for API CK-4. Cat DEO-ULS API CK-4 oil is specifically developed and validated for Cat engines. The API categories define the minimum common OEM requirements for engine oils

**Note:** For engines that are Tier 4 EPA certified, refer to the Recommendations for Tier 4 Engines article in this Engine Oil section. Tier 4 EPA certified engines require specifically formulated oils.

The fuel sulfur level impacts oil drain intervals and hence the choice of oils. Fuels of sulfur level of >0.2 percent (2000 ppm) require the use of oils of adequate ash content such as Cat DEO oils. Cat DEO-ULS is of limited ash content and can be used if an oil analysis program is followed.

In selecting oil for any engine application, both the oil viscosity and oil performance category/specification as specified by the engine manufacturer must be defined and satisfied. Using only one of these parameters will not sufficiently define oil for an engine application.

In order to make the proper diesel engine oil viscosity grade choice, refer to “Lubricant Viscosities for Ambient Temperatures” table in the “Diesel Engine Oil Specifications” section of this Special Publication.

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

The current API categories represent the minimum requirements for diesel engine oils. These categories are developed in collaboration of OEMs and the Oil and Chemical industries.

The current licensed oils are:

- API CK-4, released 2016
- API CJ-4, released 2006
- API CI-4, API CI-4PLUS released 2002
- API CH-4, released 1998

Each API category is technically more advanced and of higher performance than the prior one.

Refer to API 1509 document and/or ASTM D4485 for details of the API tests requirements and limits.

**Note:** Obsolete API oil categories are not licensed by the API and hence are of uncontrolled quality. These oils are technically inferior to current oils and can result in reduced engine performance and life. These obsolete oil categories are not allowed in Cat engines.

API FA-4 is **NOT** recommended for Cat engines. API FA oil is designed with low High Temperature High Shear (HTHS) viscosity oil for use in certain 2017 On-Highway truck engines that must meet certain on-road emissions regulations. This category is not backwards compatible.

In order to help protect your engine, and in order to help optimize oil drain intervals for engine applications and duty cycles, use Cat S·O·S Services oil analysis. Refer to the section below and to the section on Cat S·O·S Services given later in the Special Publication.

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.

i10746635

# Diesel Engine Oil (DEO) Applications

**SMCS Code:** 1348

## Recommendation for US EPA Tier 4 Certified Nonroad Engines

All diesel engines with aftertreatment devices are REQUIRED to use specially formulated engine oils and specific diesel fuels. The engine categories that are certified per the emissions regulations listed below commonly have aftertreatment devices:

- United States Environmental Protection Agency (EPA) Tier 4 Nonroad
- European Union Stage IIIB, IV, and V, Nonroad
- Japan 2014 (Tier 4) Nonroad
- Korea Tier 4 Nonroad
- India Bharat Stage IV for Construction Equipment Vehicles
- China Nonroad Stage IV

The REQUIRED engine oils are listed below. These oils are developed with restricted ash level and chemical limits that are suitable for use in engines with aftertreatment.

- Cat DEO-ULS (preferred)
- API CK-4 engine oil category
- Oils meeting the Cat ECF-3 specification
- API CJ-4 engine oil category
- ACEA E11

**Note:** Note that ACEA E11 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 API CK-4, Cat ECF-3 or API CJ-4 qualified.

The chemical limits are detailed in the “Diesel Engine Oil Specifications” section of this Special Publication.

### Diesel Fuels

The diesel fuels REQUIRED by regulations for use in engines that are certified to nonroad emissions standards listed above and in engines equipped with exhaust aftertreatment systems are.

- United States Ultra Low Sulfur Diesel (ULSD) fuel ≤15 ppm (mg/kg) (0.0015 percent) sulfur
- European ULSD ≤ 10ppm (mg/kg) (0.0010 percent) sulfur fuel. This fuel is also called “sulfur free”
- Other fuels available around the world that are ≤15 ppm (mg/kg) (0.0015 percent) sulfur

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.

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

The fuels listed above must meet the performance levels detailed in the Fuel Information for Diesel Engines chapter in this Publication. The Fuel Information for Diesel Engines Chapter also includes the pertinent recommendations for biodiesel fuels in the engines that are certified to nonroad emissions standards listed above.

### Recommendation for Europe Stage V Certified Nonroad Engines

All the recommendations and requirements given in “Recommendation for US EPA Tier 4 Certified Nonroad Engines” section are applicable to the Europe Stage V type-approved Nonroad Engines

Additionally, for the correct operation of the engine in order to maintain the gaseous and particulate pollutant emissions of the engine within the limits of the type-approval, unless specified otherwise in the engine-specific Operation and Maintenance Manual, **EU Stage V** regulations REQUIRE the diesel fuels (also called nonroad gas oil) used in engines operated within the European Union (EU) to have the characteristics below

- The sulfur content should not be greater than 10 mg/kg (10 ppm) at point of final distribution
- The Cetane number should not be less than 45
- The biodiesel (also called Fatty Acid Methyl Ester (FAME)) content should not be greater than 8 % volume/volume

**Note:** Certain Cat engines that are certified per EU Stage V can use up to B20 or B30 biodiesel blends. Refer to your engine-specific Operation and Maintenance Manual.

Follow all the local regulations and fluids requirements in your area. Refer to your engine-specific Operation and Maintenance Manual, and refer to your aftertreatment device documentation, if available, for additional guidance.

## Fuel Sulfur Impact on Engine Oil

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

For Cat machines operating under emissions regulations such as US EPA Tier4, EU Stage V or other emission regulations controls, the maximum fuel sulfur level permitted by regulations in the US is 0.0015% or 15 ppm. Maximum permitted fuel sulfur levels in other emissions regulated countries may vary from .0015% or 15 ppm slightly and must be followed.

In order to help protect your engine and optimize oil drain intervals for engine applications and duty cycles, it is important to use S·O·S Services oil analysis to determine if the sulfur has degraded the oil. **Use Cat S·O·S Services oil analysis per the following general guidelines:**

- Recommended normally
- For fuel sulfur level up to 0.05 percent (500 ppm), no additional sampling is required. Follow the recommended oil sampling in the machine OMM
- For fuel sulfur level of > 0.05 percent to 0.5 percent (500 ppm to 5000 ppm), S·O·S services oil analysis is strongly recommended to determine oil drain intervals. Sample the oil every 250 hours until a trend is established, then sample as needed.
- For fuel sulfur level of > 0.50 percent (>5000 ppm), S·O·S services oil analysis is required to determine oil drain intervals. Sample oil every 125 hours until a trend is established, then sample as needed.

These recommendations apply for Cat DEO-ULS and DEO oils.

**Note:** Engine operating conditions play a key role in determining the effect that fuel sulfur will have on engine deposits and on engine wear. Refer to the “Distillate Fuel” section in this Special Publication for the impacts of high sulfur in the fuel on engine performance and oil service interval and consult your Cat dealer for guidance when fuel sulfur levels are above 0.2% (2000 ppm).

The engine oil Total Base Number (TBN) and ash content can impact the oil performance and the oil service interval. 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. The engine oil TBN can be measured by S·O·S Services upon special request. However, analysis of used oil for parameters such as oxidation, wear metals and other typical S·O·S Services analyses are strong indicators of the condition of the oil and impacts of fuel sulfur level on its degradation.

Refer to Severe Operation Conditions in this Section of this Special Publication.

Consult a trained S·O·S Services analyst when making oil drain decisions based on oil sample results.

**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.

**Note:** The use of Cat S·O·S Services oil analysis helps environmental sustainability as the best way to optimize oil life, and help engines reach expected life.

Consult your Cat dealer regarding the testing required to establish a safe, optimized oil drain interval.

# 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 result in reduction of maintenance intervals. For the maximum expected engine compartment performance and life and where LSD or ULSD fuels are available, Cat DEO-ULS should be used.

The vast number of varying applications of Cat machines and engines makes it impossible to identify all 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, SEBU6250, “Caterpillar Machine Fluids Recommendations” “Distillate Diesel Fuel”
- Operating with a blend of distillate fuel which contains more than 20 percent biodiesel

## Engine Oil for Precombustion Chamber (PC) Diesel Engines

**(Engine Crankcase Fluid Recommendations for All 3500 Series and Smaller PC Diesel Engines)**

Most Cat medium and heavy-duty PC diesel engines were produced before 1991.

Cat Precombustion Chamber Oil (Cat PCO) is acceptable for use in Cat PC diesel engines. Cat PCO is available in SAE 40 grade. In addition, PC diesel engines can use the multigrade oils that are recommended for DI diesel engines.

For additional lubricant information, refer to the “Other Lubricants” section of this Special Publication for engine oils.

NOTICE
Do not use single grade API CF oils or multigrade API CF oils in Cat 3500 Series, C175 Series, and smaller Direct Injection (DI) diesel engines.

API CF oils are only recommended for Cat 3600 Series and C280 Series diesel engines, and Cat engines that have precombustion chamber (PC) fuel systems. Oils that are used in Cat 3600 Series and C280 Series diesel engines must also pass a 7000 hour field performance evaluation. Contact your Cat dealer for details.

**Fuel Sulfur Impact on Engine Oil**

Follow the recommendations given in the "Fuel Sulfur Impact on Engine Oil" section given earlier in this Special Publication in the Engine Oil chapter.

Use the oils recommended for the precombustion chamber engines in order to ensure the protection of the engines and follow the recommendations in your Operation and Maintenance Manual for oil drain intervals.

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 shortened oil change intervals to help maintain adequate wear protection. Refer to this Special Publication, “Diesel Fuel Specifications” section for additional information.

**Note:** For PC (Precombustion Chamber) diesel engines, which are mainly 1990 and older engines, the minimum new oil TBN must be 20 times the fuel sulfur level. The diesel engine oil types, specifications, and viscosity grades recommendations provided for DI diesel engines in this Special Publication are also applicable to PC diesel engines.

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

## 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, SEBU6250, “Caterpillar Machine 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” and/or Special Publication, SEBU9208, “Caterpillar Filter Recommendations”
- 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”)

For fuel and coolant analysis and use of S·O·S services, refer to the “Distillate Fuel” and “Coolant” section in this Special Publication.

## Cold-Weather Applications

NOTICE
Recommended compartment warm-up procedure must be followed. Refer to the machine Operation and Maintenance Manual. Also refer to the relevant “Lubricant Viscosities for Ambient Temperatures” tables footnotes in this Special Publication and to the “Warm-up Procedures for Machines that are used in Cold Weather - (Generic)” topic in this Special Publication.

NOTICE
Excessive engine idling time can contribute to excessive water in the crankcase oil, causing corrosion, sludge, and other problems. Excessive engine idling time can also lead to injector fouling, piston and combustion chamber deposits, corrosive damage, and increased oil consumption.

For the proper selection of oil viscosity grade, refer to the relevant “Lubricant Viscosities for Ambient Temperatures” table in this Special Publication. Also, refer to this Special Publication, “Diesel Engine Oil Specifications” article.

NOTICE
Not following the recommendations found in the “Lubricant Viscosities for Ambient Temperatures” tables and associated footnotes can lead to reduced performance and engine failure.

NOTICE
Do NOT use only the oil viscosities when determining the recommended oil for an engine compartment. The oil type (performance requirements) MUST also be used.

For easier cold weather starting, make sure that all 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 need to be the proper size for the application.

Various starting aids are available 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 “Aftermarket Products and Warranty” article in the “ Warranty Information” section of this Special Publication.

Additional information on cold-weather operation is available in Special Publication, SEBU5898, “Cold Weather Recommendations For All Caterpillar Equipment”. This publication is available from your Cat dealer.

Additionally, for more information on cold-weather operation, refer to this Special Publication, “Diesel Fuel Specifications” section. Also refer to this Special Publication, “Coolant Specifications”.

Before attempting to start the engine, make sure that the oil in the engine is fluid enough to flow. Check the oil by removing the oil level gauge. If the oil will drip from the oil level gauge, 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. Evaporation will 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 oil performance, and reduce the engine protection that the additives provide. If your machine is equipped with a gasoline starting engine (earlier machine), make sure that the oil is fluid enough to flow.

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 to circulate the thinner oil.

When you start a cold-soaked engine or when you operate an engine in ambient temperatures that are below −18°C (0°F), use base oils that can flow in low temperatures. These multigrade oils have lubricant viscosity grade of SAE 0W or of SAE 5W. An example of viscosity grade is SAE 5W-40.

When you start a cold-soaked engine or when you operate an engine in ambient temperatures that are below −30°C (−22°F), use a synthetic basestock multigrade oil. The oil should have a lubricant viscosity grade of SAE 0W or SAE 5W. Use an oil with a pour point that is lower than −40°C (−40°F).

**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 “Lubricant Viscosities for Ambient Temperatures”, use the viscosity grade that is specified in the table. **In arctic applications, a properly sized engine compartment heater is recommended, and use a higher viscosity grade oil.** Refer to the “Diesel Engine Oil Specifications” 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 becomes 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 at startup. **BUT, under continuous usage (multiple shifts per day),** and/or when using **fluid or pan heaters**, use a higher viscosity oil than 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.

**Example:** The oil viscosity recommended for use in Cat diesel engines for cold-soaked starts at −40 °C (−40 °F) is multigrade oil of the SAE 0W viscosity grade (SAE 0W-30). If the diesel engine is run continuously, SAE 15W-40 viscosity grade diesel engine oil can be used and is generally the preferred oil viscosity in this situation.

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.

## Warm-Up Procedures for Machines that are used in Cold Weather (Generic)

**Note:** For recommendations that are specific to your machine, refer to the Operation and Maintenance Manual for your machine.

After the engine is warm, warm up the other systems. Start with the hydraulic system. Run the engine at less than one-third throttle and slowly move the control lever to lift the attachment. Initially, lift the control lever for a few centimeters (inches). Lower the attachment slowly. Continue the following sequence: raising, lowering, extending, and retracting. Extend the travel during each cycle. This operation must be performed for all hydraulic circuits. Alternate between all the attachments.

Exercise the transmission and the power train. If you cannot move the control for the transmission, perform the following steps:

- Engage the parking brake or apply the parking brake.
- Run the engine slightly above LOW IDLE.
- Shift the transmission several times from FIRST GEAR FORWARD to FIRST REVERSE.

Release the brake. Move the equipment forward and backward for several meters (yards). Exercise the machine for several minutes.

To reduce the total warm-up time, start exercising the entire machine before you complete the hydraulic warm-up time.

Operate under a light load until the systems reach normal operating temperatures.

If the engine temperature is not high enough, enclose the engine and block the radiator. A thermostat that opens at a higher temperature will not increase the engine temperature if the engine is not under load.

To prevent seal damage and gasket damage, keep the pipe for the engine crankcase breather clear of blockage.

In extreme conditions, use a canvas over the engine compartment. Heat the engine area with a space heater. Heating will aid in starting the engine. Extending the canvas over the hydraulic components will provide initial warming of the components. **Follow all applicable safety guidelines.**

Running the engine at low idle will not keep the hydraulic systems warm.

Cold-weather operations require more time for completion than other operations. The extra time that is spent in properly caring for the equipment can prolong the life of the equipment. Extra care is especially helpful in extreme conditions. Longer equipment life will decrease overall cost.

# Other Lubricants Section

# Grease

i10210983

## Grease General Information

**SMCS Code:** 0645

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.

Table 18

| Cat Grease products | |
|---|---|
| Grease | Cat Utility Grease |
| | Cat Ball Bearing Grease |
| | Cat White Assembly Grease |

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.**

i10217359

# Grease Applications

**SMCS Code:** 0645

## 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.

# Specialty Lubricants

i10211126

## Special-Purpose Cat Lubricants

**SMCS Code:** 0645

Table 19

| 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) |

(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.

i10217352

## Leak Detection

**SMCS Code:** 0645

Table 20

| 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 (1 ounce) 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 (1 ounce) per 151.5 L (40 US gal) of water |
| 1U-5577 | Water Glo 23 Additive | 0.47 L (1 pint) bottle | 28.4 gram (1 ounce) per 151.5 L (40 US gal) of water |

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

i10746645

# Marine Transmission Oil

**SMCS Code:** 0645

## Cat Transmission/Drive Train Oils

Table 21

| Lubricant Viscosities for Ambient Temperatures for Cat Marine Transmissions | | | | | | |
|---|---|---|---|---|---|---|
| **Oil Type and Performance Requirements** | **Cooling of transmission** | **Viscosity Grade** | **°C** | | **°F** | |
| | | | **Min** | **Max** | **Min** | **Max** |
| Cat TDTO | Raw/Sea Water | SAE 30 | −15 | 80 | 5 | 176 |
| | | SAE 50 | −5 | 95 | 23 | 203 |
| | Jacket Water | SAE 50 | −5 | 95 | 23 | 203 |

Cat TDTO (Transmission/Drive Train Oil) is balanced in order to give maximum frictional material service life and performance in Cat transmissions. Cat TDTO is offered in different lubricant viscosity grades for maximum service life of components at high ambient temperatures and heavy-duty cycles.

For optimum transmission service life and performance, Cat TDTO is recommended. Refer to Table 21 for Cat Marine Transmissions recommendations.

Consult your Cat dealer for part numbers and for sizes of available containers.

Cat TDTO oil is formulated for transmissions and drive trains only, and should not be used in engines. Shortened engine life will result.

NOTICE
Cat GO is not the same as Cat TDTO, and does not meet marine transmission oil performance requirements. Cat GO or commercial gear oils should not be used in compartments that specify Cat TDTO.

## Commercial Marine Transmissions

For marine transmissions which are not manufactured by Cat, refer to the lubrication recommendation of the Original Equipment Manufacturer (OEM).

# Coolant Section

# Engine Coolant

i10737509

## Coolant General Information

**SMCS Code:** 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.

Table 22

| Cat Engine Coolant Products | |
|---|---|
| Cat Extend Life Coolants and Extenders | Cat Extended Life Coolant (Cat ELC) |
| | Cat Extended Life Coolant Advanced (Cat ELC Advanced) |
| | Cat Extended Life Inhibitor (Cat ELI) |
| | Cat Extended Life Extender (Cat ELC Extender) |
| Cat Conventional Coolants and Supplemental Coolant Additives | Cat Diesel Engine Antifreeze Coolant |
| | Cat Supplemental Coolant Additive (SCA) |

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.

## 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, Cat ELC Advanced 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 D6210-06” may be used at the recommended maximum coolant service life intervals that are 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 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.

i10704693

# Coolant Characteristics

**SMCS Code:** 1395

## 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:** With glycol-based coolants, Caterpillar strongly recommends 50 percent glycol for optimal freeze protection, with a minimum 30 percent to be maintained in diesel engine cooling systems. 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.

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.

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 23 .

Table 23

| Cat Minimum Acceptable Water Requirements | | |
|---|---|---|
| **Property** | **Maximum Limit** | **ASTM Test** |
| Chloride (Cl) | 40 mg/L (2.4 grains/US gal) | “D4327” |
| Sulfate ($SO_4$) | 100 mg/L (5.9 grains/US gal) | “D4327” |
| Total Hardness | 170 mg/L (10 grains/US gal) | “D1126” |
| Total Solids | 340 mg/L (20 grains/US gal) | “Federal Method 2540B”(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 ELC Advanced
- 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 24 and 25 .

Table 24

| 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 25

| 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.

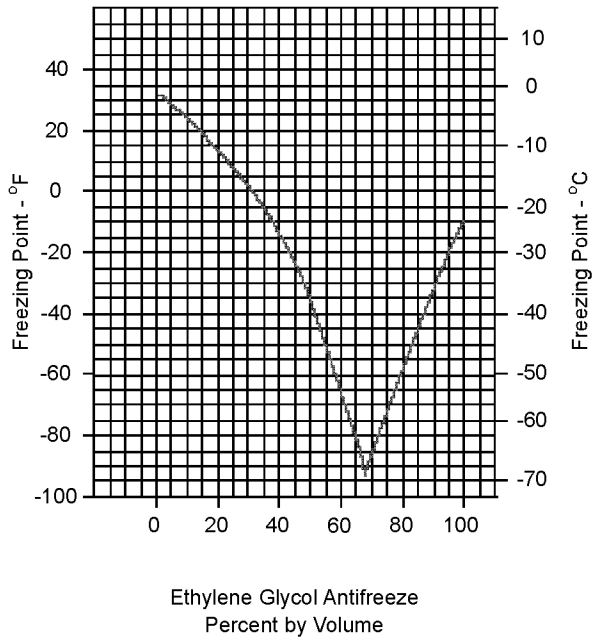


Illustration 2 g01189253

Approximate curve of the freezing point for a typical ethylene glycol solution.

Table 26

| Freeze Protection for Antifreeze Concentrations(1) | |
|---|---|
| **Protection to:** | **Concentration** |
| −8° C (18° F) | 20% glycol<br>80% water |
| −15 °C (5 °F) | 30% glycol<br>70% water |
| −24 °C (−12 °F) | 40% glycol<br>60% water |
| −37 °C (−34 °F) | 50% glycol<br>50% water |
| −52 °C (−62 °F) | 60% glycol<br>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 ELC Advanced, Cat DEAC, and Cat NGEC) are embittered. Embittering agents have no beneficial or detrimental effect on coolant performance or characteristics.

i10743129

# Coolant Specifications

**SMCS Code:** 1395

The finished coolants that are recommended or acceptable for use in Cat diesel engines are given in Table 27 below:

Table 27

| Recommendations for Finished Coolants for use in Cat engines | | | | |
|---|---|---|---|---|
| **Coolant Type** | **Recommendations** | **Product** | **Service hours (1)(2)** | **Required Maintenance(3)** |
| **Cat ELC, Cat ELC Advanced, Cat ELI, or commercial coolant that meets Cat EC-1** | Preferred | Cat ELC Advanced(4) | 20 000 or 6 years (4) | Add Cat ELC Extender every 6 000 service hours |
| | | Cat ELC(5) | 12 000 hours or 6 years | Add Cat ELC Extender at 6000 service hours or one half of service life |
| | | Cat ELI (water based) (6) | 12 000 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. Free of phosphate, borate and silicate. Tolyltriazole: minimum typical concentration of 900 ppm Nitrite: minimum typical concentration of 500 ppm in new coolants | 6 000 hours or 6 years | Add Extender at 3 000 service hours or one half of service life |
| **Cat DEAC, Cat SCA, conventional coolants, and commercial extended life coolants that do not meet EC-1** | Acceptable | Cat DEAC | 3 000 hours or 3 years | SCA at maintenance intervals |
| | | Cat SCA (water based) (6) | 3 000 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 | 3 000 hours or 2 years | SCA at maintenance intervals |
| | Min requirements for Commercial coolants requiring SCA precharge. | ASTM D4985 and Nitrate (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 | 3 000 hours or 1 year | SCA at initial fill and SCA at maintenance intervals |

(continued)

(Table 27, contd)

| Recommendations for Finished Coolants for use in Cat engines | | | | |
|---|---|---|---|---|
| | Min requirements for SCA and water (7) | 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 concentration: minimum of 100 ppm and maximum of 275 ppm | 3 000 hours or 1 year | Per manufacturer recommendations |

(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) Consult the product specific Operation and Maintenance Manual for service interval guidance.
(5) When an Organic Acid Technology (OAT) Extended Life Coolant (ELC) that contains nitrites (e.g. Cat ELC and Cat ELI) is used in aluminum core radiators, reference REHS7296. It is highly important the material of the radiator be identified prior to use of such coolant.
(6) Water-based coolants are not allowed for use in machines that has NOx reduction aftertreatment devices, in engines that has AATAC and in Marine engines that have SWAC
(7) There are currently no industry standards to define the quality of water-based conventional coolants. To control the quality of SCA and water coolants, the commercial SCA additive package should pass ASTM D6210 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 28

| Special Requirements(1) | |
|---|---|
| Cat diesel engines equipped with air-to-air aftercooling (ATAAC) | Minimum of 30% glycol is required. 50% Glycol is recommended. Water alone or water with SCA or with ELI is NOT allowed. |
| Cat C7-C32 marine engines with engine mounted heat exchangers and raw water aftercoolers (SWAC(2)) | |
| Cat 3618 engine model | Water based ELI is recommended. Water based SCA is acceptable. Glycol-based coolants are NOT allowed. |
| Cat C18 SCAC(3), Cat C32 SCAC, and Cat 3500C Tier 3 and Cat 3500E Tier 4(4) certified marine engines | Maximum of 20% glycol is allowed in the aftercooler circuit.(5) (not applicable to the jacket water circuit, which is capable of 50% glycol mixture) |

(1) Water based ELI and SCA are not recommended for use in applications that require freeze protection.
(2) SWAC: seawater aftercoolers
(3) SCAC: Separate Circuit Aftercooler
(4) 43° C SCAC inlet temperature is allowed when using treated water only.
(5) For freezing protection of −5° C (23° F) temperatures and lower, consult your Cat dealer for guidance.

In the New Systems, Refilled Systems, and converted systems

Every year: add to it hours: ever year or every 2000 hours, whichever comes first.

When referring to the Service Life in table 27 , 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 29 .

Table 29

| 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 a SCA unless approved by the coolant supplier for use with the coolant. The coolant manufacturer is responsible to ensure compatibility and acceptable performance.

“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 2 years. **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 is fully formulated and does not require a treatment with a SCA at the initial fill.

A commercial heavy-duty coolant/antifreeze that meets the “ASTM D6210”specification does not require a treatment with a SCA at the initial fill.

Commercial Heavy Duty coolants that meet only "ASTM D4985" specification are not recommended for Caterpillar applications. These coolants may not provide the performance characteristics needed for heavy duty applications. Cat coolants and the coolants detailed in Table 27 and in this Chapter are formulated to offer the required performance in Cat engines. Refer to Table 27 for Cat coolants recommendations.

Cat ELC, Cat ELC Advanced, 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 28 , 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.

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

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, Cat ELC Advanced 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 and 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.

i10704695

# Coolant Applications

**SMCS Code:** 1395

## Cat ELC and Cat ELC Advanced

Caterpillar provides Cat ELC (Extended Life Coolant) and Cat ELC (Extended Life Coolant) Advanced for use in the following applications:

- Heavy-duty diesel engines
- Automotive applications

When Cat ELC and Cat ELC Advanced are compared to conventional coolants, the Cat ELC and Cat ELC Advanced anti-corrosion packages are based on a different additive system. Cat ELC and Cat ELC Advanced have 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 12 000 service hours or 6 years. Cat ELC Advanced can extend the service life of the coolant to 20 000 service hours or 6 years. Consult the product specific Operation and Maintenance Manual for service interval guidance. A maintenance dose of Cat ELC Extender additive should be added to Cat ELC and Cat ELC Advanced every 6 000 service hours.

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

Cat ELC Concentrate and Cat ELC Advanced Concentrate are also available. Cat ELC Concentrate and Cat ELC Advanced 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” section for available quantities and part numbers.

**Note:** Cat ELC and Cat ELC Advanced can be used in most diesel and gasoline OEM engines. Cat ELC and Cat ELC Advanced meet the performance requirements of “ASTM D6210” for heavy-duty low silicate antifreeze/coolants. Cat ELC and Cat ELC Advanced also meet the performance requirements of “ASTM D3306” for automotive applications.

**Note:** When an Organic Acid Technology (OAT) that contains nitrites (e.g. Cat ELC, Cat ELC Advanced and Cat ELI) is used in aluminum core radiators, Reference REHS7296. It is highly important the material of the radiator be identified prior to use of such coolant.

### Commercial Extended Life Coolant

NOTICE
Caterpillar 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 30 in this Special Publication.

Table 30

| 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 that are 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 30 . 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 Caterpillar 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

## Proper Additions to Cat ELC (Extended Life Coolant) and Cat ELC (Extended Life Coolant) Advanced

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 or Cat ELC Advanced.

Do NOT use conventional SCA with Cat ELC or Cat ELC Advanced. Mixing Cat ELC or Cat ELC Advanced 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.

In order to maintain the correct balance between the antifreeze and the additives, maintain the recommended concentration of Cat ELC or Cat ELC Advanced. Lowering the proportion of antifreeze lowers the proportion of additive. The coolant will not be able to protect the system from pitting, cavitation, erosion, and deposits.

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

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

Do not use conventional SCA. Only use Cat ELC Extender in cooling systems that are filled with Cat ELC or Cat ELC Advanced.

## Cat ELC Extender

Cat ELC Extender should be added to the cooling system every 6 000 hours of service life. Treat the cooling system with Cat ELC Extender at 6000 hours or one half of the coolant service life, whichever the lesser. Refer to your machines Operation and Maintenance Manual for any exceptions. Contact your Cat dealer for further information on quantities and part numbers.

Use the formula in Table 32 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 31

| Formula For Adding Cat ELC Extender To Cat ELC and Cat ELC Advanced |
|---|
| **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 32 is an example for using the formula that is in Table 31 . This example is based on the typical capacity of a D8R Track-Type Tractor.

Table 32

| Example Of The Equation For Adding Cat ELC Extender To Cat ELC and Cat ELC Advanced | | |
|---|---|---|
| **Total Volume of the Cooling System (V)** | **Multiplication Factor** | **Amount of Cat ELC Extender that is Required (X)** |
| 94.6 L (25.0 US gal) | × 0.02 | 1.9 L (0.5 US gal) |

NOTICE
When using Cat ELC or Cat ELC Advanced, do not use conventional SCA, 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 and Cat ELC Advanced Cooling System Maintenance

**Note:** If the cooling system is already using Cat ELC or Cat ELC Advanced, 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 or Cat ELC Advanced is drained from a properly maintained cooling system.

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

## Recycling Cat ELC and Cat ELC Advanced

Cat ELC and Cat ELC Advanced 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 classified as either Cat ELC, Cat ELC Advanced 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 and Cat ELC Advanced

To change from heavy-duty coolant/antifreeze to the Cat ELC and Cat ELC Advanced, 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 or Cat ELC Advanced.

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

Remove the SCA element base and plug off or bypass 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 and Cat ELC Advanced.

**7.** In systems with heavy deposits, disconnect the hoses. Clean the deposits and debris from the hoses and the fittings. Install the hoses and tighten the hose fittings. Refer to Specifications, SENR3130, “Torque Specifications” for the proper torques. Pipe threads may also need to be cleaned and sealed. Seal the threads with 5P-3413 Pipe Sealant.

**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 Cat ELC or Cat ELC Advanced.

**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 or Cat ELC Advanced.

**Note:** Clean water is the only flushing agent that is required when Cat ELC or Cat ELC Advanced is drained from a properly maintained cooling system.

### Cat ELC and Cat ELC Advanced Cooling System Contamination

NOTICE
Mixing Cat ELC or Cat ELC Advanced 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 and Cat ELC Advanced. Do NOT mix brands or types of coolants. Failure to follow these recommendations can result in shortened cooling system component life.

**Note:** Cat ELC and Cat ELC Advanced can be mixed with one another.

Cat ELC and Cat ELC Advanced 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 and Cat ELC Advanced are reduced above 10 percent. 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 and Cat ELC Advanced” heading. Also, follow the procedures under the “Changing to Cat ELC and Cat ELC Advanced” heading 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 Cat ELC or Cat ELC Advanced.
- 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.

## Extended Life Inhibitor (ELI)

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) and Cat Extended Life Coolant (ELC) Advanced.
- 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 when 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 33 for information about Cat ELI.

Table 33

| 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 33 .

After the addition of water and proper mixing, the concentration of Cat ELI can be determined using the 360-0774 Digital Brix Refractometer.

### Changing to Cat ELI

For cooling systems previously running Cat ELC, Cat ELC Advanced 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 or Cat ELC Advanced”. 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 and Cat ELC Advanced. 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 and Cat ELC Advanced. 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 360-0774 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 With Cat ELC and Cat ELC Advanced

Since Cat ELI, Cat ELC and Cat ELC Advanced are based on the same corrosion inhibitor technology, Cat ELI can be mixed with Cat ELC and Cat ELC Advanced. 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.

## Diesel Engine Antifreeze/Coolant (DEAC)

Follow the maintenance information provided in this Special Publication, “Coolant and General Maintenance Recommendations”section.

Caterpillar 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.

## Supplemental Coolant Additive (SCA)

**Supplemental Coolant Additive (SCA)** – SCA is a general term for an inhibitor package that is added to a cooling system. SCA is added for one of three reasons:

- to precharge a new coolant that is not fully formulated
- 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 (supplemental coolant additive) helps to prevent the following conditions from occurring:

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

Cat DEAC (Diesel Engine Antifreeze/Coolant) is formulated with the correct level of Cat SCA. When the cooling system is initially filled with Cat DEAC, adding more Cat SCA is not necessary. To ensure that the correct amount of Cat SCA is in the cooling system, test the concentration on a scheduled basis. Testing the concentration of nitrites and silicates through the S·O·S analysis is the best indicator of the amount of SCA in the coolant.

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

For the maintenance schedule, refer to the Operation and Maintenance Manual, “Maintenance Interval Schedule” (Maintenance Section) of the specific engine.

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.

## Conventional Coolant/Antifreeze Cooling System Maintenance

NOTICE
Caterpillar 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 34 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 34

| Equation For Adding The Cat SCA To Water At The Initial Fill |
|---|
| **V × 0.07 = X** |
| V is the total volume of the cooling system. |
| X is the amount of Cat SCA that is required. |

Table 35 is an example for using the equation that is in Table 34 .

Table 35

| 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 36

| 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 37 is an example for using the equation that is in Table 36 .

Table 37

| 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 for extremely 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” article in this Special Publication.

3. Start the engine and run the engine until the thermostat opens.
4. Add a non-foaming detergent containing tripolypentasodium phosphate (TSP) 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 38

| Cat Cooling System Cleaner for use with Quick Flush Method | |
|---|---|
| Cleaner part number | Size of Container |
| 619-8710 | 1 L (0.25 US gal) |
| 619-8712 | 3.8 L (1 US gal) |
| 619-8713 | 19 L (5 US gal) |
| 619-8714 | 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” section 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.

## 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, Cat ELC Advanced 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”.

# Commercial Heavy-Duty Coolant/ Antifreeze and SCA (Supplemental Coolant Additive)

NOTICE
Caterpillar 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 39 . 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 39

| Technical Requirements for Commercial Diesel Engine Antifreeze Coolants | |
|---|---|
| Specifications | ASTM D6210-08 |
| Additional Requirements | Silicon: 100 ppm minimum to 275 ppm maximum<br>Nitrites: maintained at 1200ppm (70 grains/US gal) minimum to 2400 ppm (140 grains/US gal) maximum<br>Cat SCA at 3 to 6 percent (if Cat SCA is added) |
| Maintenance | ASTM D6210-08 Add compatible SCA at maintenance intervals<br>Clean and flush the cooling system at drain intervals |

## Water/Supplemental Coolant Additive (SCA)

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.

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 ofCat 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.

# Exhaust Aftertreatment Section

# Diesel Exhaust Fluid (DEF)

i10704706

## DEF General Information

**SMCS Code:** 108K

### General Information

This fluid MUST be used in engines that are equipped with Selective Catalytic Reduction (SCR) systems. DEF must meet all the requirements detailed in the Exhaust Aftertreatment Fluids Specification chapter in this Special Publication.

Aftertreatment systems may include the following:

- Diesel Particulate Filters (DPF)
- Diesel Oxidation Catalysts (DOC)
- Selective Catalytic Reduction (SCR)
- Lean NOx Traps (LNT)

Other systems may apply.

Regulations may vary around the world. Follow all the local regulations and fluids requirements in your area. Refer to your engine-specific Operation and Maintenance Manual, and refer to your aftertreatment device documentation, if available, for additional guidance.

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.

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 (N2) gas and water vapor (H2O).

**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.

### DEF Recommendations for SCR Aftertreatment Systems

For use in Cat engines, DEF must meet all the requirements defined by the “ISO 22241-1” standard.

The caps of DEF tanks are typically blue as recommended by the “ISO 22241-4” Standard. 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 40 for part number information:

Table 40

| Cat Part Number (32.5% Urea) | Container Size |
|---|---|
| 625-1658 | 2.5 gal bottle |
| 652-3018 | 275-gal tote |

In North America, commercial DEF 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 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 that the DEF is compliant with the requirements of “ISO 22241-1”.

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

NOTICE
**Do not use agriculture grade urea solutions.** Do not use any fluids that do 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 deionized water to produce a final concentration of 32.5% 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% have higher freeze points. DEF dosing systems and “ISO 22241-1” specifications are designed for a solution that is approximately 32.5%.

Caterpillar offers refractometers that can be used to measure DEF concentration. Refer to Table 41 for the part numbers. Follow the instructions provided with the instruments.

Table 41

| 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 |

# 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 that are 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.

i10223304

# DEF Specifications

**SMCS Code:** 108K

## General Characteristics of DEF

For detailed information on the requirements and characteristics of DEF, refer “ISO 22241”. For a quick reference, typical specifications of DEF are given in Table 42 .

Table 42

| Characteristics for Urea Solutions | | | |
|---|---|---|---|
| Property | Unit | DEF 32.5 percent | Urea Solution 40 percent (1) |
| Urea content | | 32.5 percent (2) | 40 percent (3) |
| Alkalinity as $NH_3$ | Percent | 0.2 | 0.2 |
| Density at 20° C (68° F) | g/L | 1.087 - 1.093 (4) | 1.108 - 1.114 (5) |
| Refractive Index at 25° C (77° F) | | 1.381 - 1.384 (6) | 1.394-1.397 (7) |
| 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) For use in marine engines only
(2) Acceptable range is 31.8 - 33.2 percent
(3) Acceptable range is 39-41 percent
(4) Target value is 1.090 g/L
(5) Target value is 1.112
(6) Target value is 1.382
(7) Target value is 1.3956

i10446085

# DEF Additional Information

**SMCS Code:** 108K

## 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 Diene Monomer(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. The recommended DEF cleanliness target as dispensed into the machine or engine fill tank is ISO 18/16/13. Refer to the Contamination Control Chapter in this Special Publication.

Filtering DEF is recommended when dispensed into the DEF tank to achieve the recommended cleanliness targets. DEF 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, can be used. Paper (cellulose) media and some synthetic filter media are not recommended because of degradation during use. The filter size must be appropriate for the DEF pump design, flow rate, expected pressures and required filter life. Refer to Table 43 below for filtration requirements for Cat engines.

For large engines including 3500 series and C175 engine models, filtration of DEF as it is dispensed from bulk tank is recommended to support the durability designed into the SCR system. Filters should be located between the bulk DEF tank and the ground level DEF receiver nozzle.

Note that Cat Diesel Exhaust Fluid Filter group 491-6779, 40 microns efficiency and Beta value 75 can be used to filter DEF when applicable. Refer to your local Cat dealer for availability.

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.

Table 43

| DEF Filtration Requirements For Bulk Tanks in Specific Applications | | |
|---|---|---|
| **DEF System** | **Filter Requirements (1)** | **Filter location** |
| All Cat engines except those given below in this Table. | Recommended: ≤ 5 microns (µm), Beta value ≥ 1000 Required: ≤ 10 microns (µm), Beta value ≥ 1000 | Inlet to DEF Pump Electronic Tank Unit (PETU) |
| Airless 3500 series and C175 engine models Machine engines (Fast or conventional fill) | | |
| Airless Marine applications | | |
| Air Assisted, Marine applications | ≤ 40 microns (µm), Beta value ≥ 1000 | Inlet to DEF Dosing Cabinet |
| Air Assisted, Locomotive and Electric Power Generation applications | | |

(1) Refer to Caterpillar publication PELJ0133, “Filters, Use of Micron Ratings in the Filter Industry” for clarification of Beta values and filter efficiency

## 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 44

| 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.

## DEF/Urea Solution Recommendations for Marine Engines

The US has adopted/approved NOx Emissions Control Area (ECA) regulations. Per ECAs, vessels that are 2016 and later models, or vessels that are modified to 2016 models, are required to meet Tier III NOx standards. 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 handling and recommendations.

Vessels that are traveling internationally and have on/off NOx controls that allow the vessels to meet ECA regulations must enable NOx controls prior to entering the ECA. For US flagged vessels, the SCR must be activated and deactivated automatically based on input from the Global Positioning System. For US flagged vessels, on/off NOx controls are allowed on engines **>** 30 liters/cylinder and are not allowed on engines < 30 liters/cylinder unless installed on a vessel with propulsion engines >30 liters/cylinder. Otherwise the NOx control systems on Category 1 and 2 engines 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 due to fluid unavailability per 40 CFR part 1042.650(a) by US flagged vessels operating outside of US waters 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, the required DEF solution must meet “ISO 22241-1” (DEF 32.5%) or “ISO 18611-1” (DEF 40%), as well as all the guidelines and quality recommendations given in this chapter. The supplier should provide documentation to prove the urea solution is compliant with the characteristics given in this Special Publication, “DEF Specifications” section.

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.

# Additives Section

# Fuel Additives

i10235976

## Fuel Additive General Information

**SMCS Code:** 1250; 1280

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

In special circumstances, Caterpillar recognizes the need for fuel additives. Fuel additives need to 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) and/or, as appropriate, 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. Caterpillar discourages the use of metallic fuel additives in most applications. Metallic fuel additives should only be used in applications where their use is specifically recommended by Caterpillar.

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

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

i09967878

## Diesel Fuel Conditioner

**SMCS Code:** 1250; 1280

Fuels that are per specifications detailed in this publication should not require the use of additives. In case a fuel conditioner is needed to improve certain fuel properties, consult with your fuel supplier or with a reputable provider. Refer to your Cat dealer and to Cat special publication PELJ2095 for more details.

When needed, high performance, multipurpose diesel fuel conditioners are designed to improve:

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

i10428248

## Cat Diesel Fuel System Cleaner

**SMCS Code:** 1250; 1280

**Note:** Cat Diesel Fuel System Cleaner, part number 624-3389, is the only fuel system cleaner available to the end user that is tested and approved by Caterpillar for use in Cat diesel engines.

Cat Diesel Fuel System Cleaner is a proven high-performance detergent product specifically 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, which 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 as previously described, but 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 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 “Diesel Fuel General Information”article in this Special Publication for additional information. Additionally, use of Cat Diesel Fuel System Cleaner does NOT lessen the responsibility of the owner of the engine to use appropriate diesel fuel. Refer to the “Fuel Specification” section in this Special Publication for guidance.

When used as directed, Cat Diesel Fuel System Cleaner has proven to be compatible with nonroad Tier 4 U.S. EPA certified engines that are equipped with aftertreatment devices.

**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.

Caterpillar 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 and biodiesel blends that meet Cat biodiesel recommendations and requirements.

**Note:** Not all fuel system cleaners suitable for use with biodiesel and biodiesel blends. Read and follow all applicable label usage and instructions. Refer to this Special Publication, “Distillate Fuel” section and Special Publication, “Biodiesel” section for further information.

# Oil Additives

i10211061

## Oil Additive General Information

**SMCS Code:** 0645; 1348

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

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

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

- Select the proper Caterpillar  oil or select commercial oil that meets the specifications designated by Caterpillar for the compartment.
- See the appropriate “Lubricant Viscosities for Ambient Temperatures” table in this publication in order to find the correct oil viscosity grade for the machine compartment.
- At the specified interval, service the engine or service the other machine compartments. 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”.

# Maintenance Section

# Contamination Control Guidance

i10437054

## Contamination Control General Information

**SMCS Code:** 0645

### 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.

i10437055

## Contamination Control Measurement

**SMCS Code:** 0645

### 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 mL 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 mL 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 are given in Table 45 .

Table 45

| ISO 4406 Code | Number of particles in 1 mL 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.

i10437058

# Contamination Control Recommendations

**SMCS Code:** 0645

## Cleanliness Standards for Machine Systems

Caterpillar recommends that machine systems be maintained at the factory defined fluid cleanliness targets.

Caterpillar has established minimum fluid cleanliness targets for fuels and fill oils and for machine roll-off. Fluids filled into the machine or engine fill tanks are recommended to be at the target levels provided in Table 46 or cleaner. Cleanliness targets for applicable machine component systems are referred to as “Roll-off” . Roll-off is defined as the cleanliness specification of the fluid that is to be obtained before the machine returns to work after maintenance and or system invasion repair. When system fill fluids and Roll-off are maintained at or cleaner than the “ISO” cleanliness targets, contamination-related effects will be reduced.

Table 46

| **Caterpillar Recommended Fluid Cleanliness Targets(1)** | | |
|---|---|---|
| **Caterpillar Recommended Cleanliness Targets for Fluids Dispensed into Machine or Engine Fill tanks** | Fill oils(2)(3) | ISO -/16/13 |
| | Dispensed fuels | ISO 18/16/13 |
| | Dispensed DEF | ISO 18/16/13 |
| **Caterpillar Recommended Machine Roll-off Cleanliness Targets** | Hydraulic systems (Implement & Steering) | ISO -/18/15 |
| | Electronic Transmissions | ISO -/18/15 |
| | Continuous Variable Transmissions (CVT) | ISO -/18/15 |
| | Mechanical Transmissions | ISO -/21/17 |
| | Differentials, Wheels, and Axles(4) | ISO -/18/15 |

(1) The fluids should meet or exceed the cleanliness requirements of the listed ISO levels.
(2) For engine oils optical particle counters may not be effective. Instead filter 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.
(3) For transmission, gear, differential and axle oils, additives and the viscosity of the oil may interfere with particle counting. An alternative is to use adequate filtration to ensure clean oils prior to filling in the machine compartment.
(4) This cleanliness standard applies only to the Series 700 family of rigid frame trucks, 777 size and larger.

The “fill” fluids cleanliness target is not a fluid “delivery” target. The level of cleanliness for delivered fluids is not specified by Caterpillar. 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 machine 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.

The viscosity and additives of power train oils including transmission, gear, differential, and axle oils can interfere with particle counting. An alternative option is to filter the oils using adequate filtration to ensure clean oils prior to filling in the machine compartments.

**Note:** Particle counting of new multi-viscosity engine oils may not be effective to assess their cleanliness level. Optical particle counters cannot distinguish between particulate contaminants and additives. Instead, filter the new engine oils as described below. Additionally do not use optical particle count for the evaluation of used engine oils because soot levels render oil too dark for optical particle counters. Soot levels in used engine oils should be evaluated by referring to Special Publication, SEBU6250, “Caterpillar Machine Fluids Recommendations”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 machine. The productive life and 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 “Cleanliness Standards for Machine Systems”.
- Refer to the machine Operation and Maintenance Manual for the required maintenance for all machine compartments.

- When you add oil to a machine, use adequate filtration to clean the oil to meet the targets provided in Table 46 .
- Perform scheduled S·O·S Services Oil Analysis for contamination to maintain the recommended “ISO” cleanliness level of fill and machine fluids. Refer to Special Publication, SEBU6250, “Caterpillar Machine Fluids Recommendations”S·O·S Services Oil Analysis. 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 Caterpillar 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 machines with clean fluids. Good practices will enhance component life and reduce downtime associated with contaminants. Your Cat dealer can provide details on proper contamination processes and practices.
- Follow contamination control practices for the workplace and for the worksite. Maintaining clean oil fill fluids saves time and effort and ensures that fill fluids are at the proper cleanliness levels.
- Use properly designed and maintained bulk storage fluids tanks.
- Protect the fluids storage tanks from dirt and water entry by using 4 µm or less absolute efficiency breathers with the ability to remove water.
- Keep the areas around the tanks filler necks clean 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.

## General Recommendations and Contamination Control Guidelines for Fuels

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 to follow all industry standard practices for fuel storage and for fuel handling.

**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.

Clean fuels, as detailed below, are recommended to allow optimal performance and durability of the fuel systems and to reduce power loss, failures, and related down time of engines.

Fuels of “ISO 18/16/13” cleanliness levels or cleaner as dispensed into the engine or machine fuel tank should be used. Reduced power, failures, and related downtime can result if clean fuels are not used. Fuels of “ISO 18/16/13” are 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 to meet required stringent emissions regulations. Peak injection pressures in current fuel injection systems may exceed 206843 kPa (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. Gels and other insoluble compounds can also form in biodiesel fuel at low temperatures or if biodiesel is stored for extended periods. An indication of microbial contamination, detrimental fuel additives interactions, or cold temperature gel is very rapid filter plugging of bulk fuel filters or machine fuel filters.

To reduce downtime due to contamination, follow these fuel maintenance guidelines in addition to the recommendations given in the Special Publication, SEBU6250, “Caterpillar Machine Fluids Recommendations”Contamination Control:

- Use high-quality fuels per recommended and required specifications (refer to the “Fuel” chapter in this Special Publication).
- 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). Engine oils may raise the sulfur level of the fuel and may cause fouling of the fuel system and loss of performance. Engine oils in fuels can also reduce the maintenance intervals of aftertreatment devices in Tier 4 machines.
- Use recommended Cat filtration products, including Cat Advanced Efficiency Fuel Filters. Change your fuel filters per recommended service requirements or as needed. Never fill the new secondary and tertiary fuel filter with fuel before installation. Use the fuel priming pump to remove air from the system.
- Follow proper practices of fuel transport and filtration from storage tank to the machine to allow the delivery of clean fuel to machine tank. Keep the fuel storage tank clean of water, debris, and sediment.
- Filter the fuel coming into the bulk storage fuel tank and at every subsequent transfer into and out of any container and prior to adding to the engine fuel tank preferably through filters with a rating of 20 microns (c) absolute or less. The use of wire mesh media (strainer-type filters) is NOT recommended except when filters with standard media (cellulose or synthetic) are downstream of the wire mesh media filters. Wire mesh filters typically have poor filtration efficiency and can corrode with time, allowing the passing of large particles.
- Caterpillar recommends the use of properly designed and grounded bulk fuel filter / coalescer units which remove both particulate contamination and water in a single pass. These units can clean fuel to “ISO 16/13/11” or cleaner and can remove free water to 200 ppm (mg/kg) or less.
- Caterpillar 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. Refer to Special Publication, PEHJ0156, “Cat Bulk Fuel Filtration Systems”, and consult your Cat dealer for availability of bulk filtration products.
- 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 = 75 up to 200 at 4 microns) 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 that fuel is dispensed at 200 ppm water or less.
- Keep the area around the fuel tank filler neck clean of debris to prevent dirt entry and contamination of the fuel tank.
- Drain your water separators daily per the Operation and Maintenance Manual of your machine.
- Install desiccant type breathers of 4 µm or less absolute efficiency with the ability to remove water on bulk storage tanks.
- Drain your fuel tanks of sediment every 500 hours or 3 months per the Operation and Maintenance Manual of your machine.

- Centrifugal filters may need to be used as a prefilter 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 to achieve the recommended cleanliness level.
- Cover, protect, and ensure cleanliness of all connection hoses, fittings, and dispensing nozzles.
- Test for microbial contamination regularly and take proper corrective action if contamination is present. Properly dispose of cleanup waste according to all applicable local regulations and mandates.
- Every 3 months, or sooner if problems are suspected, analyze the fuel for acid number, density, particle content, water, and microbial growth (tank bottom fuel sample). More tests can also be run per the Special Publication, SEBU6250, “Caterpillar Machine Fluids Recommendations”Distillate Diesel Fuel. Refer to Caterpillar S·O·S Services Fuel Analysis Section of this Chapter. Take corrective action if necessary. Corrective actions may include, but are not limited to, treating the fuel, cleaning of the fuel storage tank/system, and replacing the problematic fuel with fresh fuel.
- When fuels are stored for extended periods, follow all the fuel supplier and tank maintenance procedures. Circulate the fuel regularly through a filter to remove sediments. Test the fuel regularly for acid number, density, particle content, water and microbial growth. Observe trends of these properties to ensure no detrimental changes. The fuel is not recommended for use when its properties change negatively. For fuels containing biodiesel, the storage duration may be significantly reduced. Observe all the guidelines given in this section and in Special Publication, SEBU6250, “Caterpillar Machine Fluids Recommendations”Biodiesel.

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 **and/or Ultra High Efficiency** filters 4 micron (c) absolute fuel filters.

**Note:** Thorough cleaning of fuel storage tanks is strongly recommended 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 filtration unit and dispensing point filters, and onboard engine filters change intervals may need to be shortened for an extended period of time to allow for this cleaning effect.

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

# Fluid Sampling and Analysis

i10437063

## S.O.S Services Fuel Analysis

**SMCS Code:** 0645; 1250

### Caterpillar S·O·S Services Fuel Analysis

Caterpillar has developed a maintenance management tool that evaluates fuels. The Cat tool for fuel analysis is called S·O·S Fuel Analysis and is part of the S·O·S Services Program.

Testing the diesel fuel that goes into your engine is an important tool in your equipment management toolkit. Diesel fuel testing can help identify production limiting issues such as rapid fuel filter plugging, hard starting, white smoke, deposits, accelerated wear, and low power. Diesel fuel testing can also provide extra benefits including helping to identify fuel saving steps, environmental regulation compliance in countries with higher fuel regulations, minimizing Diesel Particulate Filter (DPF) regeneration and maximizing the life of the DPF filter and Diesel Oxidation Catalyst. Some facilities with standby generators may have requirements that fuel is tested regularly. Operations without requirements will benefit from knowing that the fuel in the standby generators is going to provide the expected performance when needed.

### S·O·S Services Fuel Analysis

The Cat S·O·S Fuel Analysis program provides testing of the fuel for the properties listed below. The actual analyses provided may vary depending on your requirements and reasons for testing. Consult your local Cat Dealer for complete information and assistance about the S·O·S Fuel Analysis program.

- Biodiesel content
- Sulfur content
- Water contamination
- Particle cleanliness level
- Microbial growth
- Identification of elements that can increase deposit formation
- Identification of fuel conditions that can indicate contamination or adulteration
- Identification of fuel conditions that can indicate increased abrasive wear, adhesive wear, or wear in the combustion chamber
- Identification of fuel characteristics that can indicate low power
- Indication of fuel to perform in cold weather
- Identification of fuel conditions that can increase filter plugging
- Indication of fuel condition during storage
- Indication of ability of fuel to perform at startup

The results are reported and appropriate recommendations are provided.

A properly administered S·O·S Services Program can reduce repair costs and lessen the impact of down time. S·O·S Fuel Analysis is a key component of this program and can ensure that your fuel is stored in a clean environment, meets government requirements, and can meet the expected guidelines for performance in your engine. Consult your Cat Dealer to determine your fuel testing needs and establish a regular testing interval based on those needs. Consult the Special Publication, “Diesel Fuel Specification” section, Special Publication, “Biodiesel Fuel Specification” specification, and the “Contamination Control” section of this Special Publication for related details on fuel recommendations including cleanliness.

### Obtaining S·O·S Fuel Samples

Fuel sampling methods depend on the type of fuel tank to be sampled. Storage tanks may have an automatic sampling valve at different levels. Storage tanks without an automatic sampling valve require a tank sampling device (commonly known as a “Bacon Bomb” or “Sample Thief”). Refer to “Fuel Sampling Guide” PEDJ0129, for more information and instructions on proper sampling techniques. Fuel analysis sampling kits can be obtained from your local Cat Dealer. Size of fuel sample needed may be dependent upon the list of tests required.

i10437065

## S·O·S Services Oil Analysis

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

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

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

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

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

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

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

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

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

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

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

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

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

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

## Obtaining S·O·S Oil Samples

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

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

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

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

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

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

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

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

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

## Oil Sampling Interval

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

General recommendations for oil sampling intervals for engines and machine compartments are given in Table 47 in this Section.

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

For other acceptable oil types and specifications, refer to the “Lubricant Viscosities for Ambient Temperatures” Tables in this Special Publication.

Refer to the Operation and Maintenance Manual that came with your machine for the recommended oil change intervals for each compartment.

Table 47

| Compartment | Recommended Sampling Interval (1) | Sampling Valve | Oil Type |
|---|---|---|---|
| **Engine** | 250 Hours | Yes | Cat DEO<br>Cat DEO-ULS |
| **Transmission** | 500 Hours | Yes | Cat TDTO<br>Cat TDTO-TMS |
| **Hydraulics** | 500 Hours | Yes | Cat HYDO Advanced |
| **Differential and Final Drive** | 500 Hours | No | Cat TDTO<br>Cat FDAO |

(1) These sampling intervals are general. Refer to your engine or machine OMM for sampling intervals specific to your engine or machine.

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

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

Recommended S·O·S sampling intervals have been determined by Caterpillar to maximize engine and component life. Table 47 in this Section provides the generally recommended sampling intervals. However, in severe service applications, more frequent oil sampling is recommended. Severe service for lubricated compartments occurs at high loads, in high temperatures, and in dusty conditions. If any of these conditions exist, work with your Cat Dealer to determine an appropriate sampling interval. In some cases, this may be half the normal recommended interval or even more frequently. These additional samples will increase the chance of detecting a potential failure and reducing unexpected down time.

## Determining Optimum Oil Change Intervals

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

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

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

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

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

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

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

The process for extending engine oil drains is available in the brochure “Optimizing Oil Change Intervals”PEHJ0192. This process is basically the same for all lubricated compartments on a Cat machine. Work with your Cat dealer to select the proper high-performance Cat lubricant for your extended oil drain program. Your Cat dealer has additional resources to guide you in the extended oil drain process.

## Cat Lubricants for Extended Oil Drains

All Cat lubricants are high performance products, and are recommended for extended oil drains. Within each group of Cat lubricants, there are products available at different performance levels. Your Cat dealer has the list of Cat lubricants that are available in your region of the world. Work with your Cat dealer to select the best Cat lubricant for your extended oil drain program.

## Fuel Sulfur Impact on Engine Oil

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

For Cat machines operating under emissions regulations such as US EPA Tier4, EU Stage V or other emission regulations controls, the maximum fuel sulfur level permitted by regulations in the US is 0.0015% or 15 ppm. Maximum permitted fuel sulfur levels in other emissions regulated countries may vary from .0015% or 15 ppm slightly and must be followed.

Cat diesel engines that do not use emissions reduction devices (do not operate under emissions regulations), or meet Tier1, Tier2, or Tier3 emissions levels may run on diesel fuels that exceed 0.0015% sulfur. However, using higher sulfur fuels may shorten the oil change interval.

**In order to help protect your engine and optimize oil drain intervals for engine applications and duty cycles**, it is important to use S·O·S Services oil analysis to determine if the sulfur has degraded the oil. **Use Cat S·O·S Services oil analysis per the following general guidelines:**

- Recommended normally

- For fuel sulfur level up to 0.05 percent (500 ppm), no additional sampling is required. Follow the recommended oil sampling in the machine OMM
- For fuel sulfur level of > 0.05 percent to 0.5 percent (500 ppm to 5000 ppm), S·O·S services oil analysis is strongly recommended to determine oil drain intervals. Sample the oil every 250 hours until a trend is established, then sample as needed.
- For fuel sulfur level of > 0.50 percent (>5000 ppm), S·O·S services oil analysis is required to determine oil drain intervals. Sample oil every 125 hours until a trend is established, then sample as needed.

These recommendations apply for Cat DEO-ULS and DEO oils.

**Note:** Engine operating conditions play a key role in determining the effect that fuel sulfur will have on engine deposits and on engine wear. Refer to the Diesel Fuel Chapter in this Special Publication and consult your Cat dealer for guidance when fuel sulfur levels are above 0.2% (2000 ppm) 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.

Consult a trained S·O·S Services analyst when making oil drain decisions based on oil sample results.

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 Special Publication, “Diesel Fuel Characteristics” section for more information.

**Note:** For PC (Precombustion Chamber) diesel engines, which are mainly 1990 and older engines, the minimum new oil TBN must be 20 times the fuel sulfur level.

For fuel and coolant analysis and use of S·O·S services, refer to the “Diesel Fuel” and “Coolants” chapters in this Special Publication.

**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 0.2% (2000 ppm).

i10728398

# S·O·S Services Coolant Analysis

**SMCS Code:** 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.

- Initial 500 service hours
- Every Year or every 2000 hours, whichever comes first

Perform this analysis at the interval that occurs first for new systems, for refilled systems, or for converted systems that use Cat ELC (Extended Life Coolant), Cat ELC (Extended Life Coolant) Advanced or Cat DEAC (Diesel Engine Antifreeze/Coolant). This 500 hour check will also check for any residual cleaner that may have contaminated the system.

## Recommended Interval for S·O·S Services Coolant Sample

The following table contains the recommended sampling interval for all coolants that meet Cat EC-1 (Engine Coolant specification - 1). This is also the recommended sampling interval for all conventional heavy-duty coolant/antifreeze.

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

Table 48

| Recommended Interval | | |
|---|---|---|
| **Type of Coolant** | **Level 1** | **Level 2** |
| Cat DEAC and Conventional Heavy-Duty Coolants | Every 250 hours | Yearly |
| Cat ELC, Cat ELC Advanced and Commercial EC-1 coolants | Optional or every 500 hours | Yearly or every 500 hours |

**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.

Refer to your machine Operation and Maintenance Manual for recommendations specific to your machine.

## 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.

# Reference Information Section

# Reference Materials

i07422670

## Reference Material

**SMCS Code:** 1000; 7000

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

publications.cat.com

# Index

**A**

Additives Section ..... 90
Alternative Fuels Section ..... 26

**B**

Biodiesel Fuel ..... 26
Biodiesel Fuel Application ..... 36
  Marine Engine Applications ..... 38
  Nonroad Engine Applications ..... 36
Biodiesel Fuel Characteristics ..... 30
  Equipment Impact ..... 31
  Stability ..... 30
Biodiesel Fuel General Information ..... 26
  Additives ..... 30
  Aftertreatment ..... 29
  Biodiesel Blends ..... 26
  Cleanliness ..... 28
  Impact on Engine Oil ..... 29
  Storage and Maintenance ..... 29
Biodiesel Fuel Specifications ..... 34
  Caterpillar Specifications ..... 34

**C**

Cat Diesel Fuel System Cleaner ..... 90
Contamination Control General Information ... 93
  Defining Contamination ..... 93
Contamination Control Guidance ..... 93
Contamination Control Measurement ..... 93
  Measuring Cleanliness ..... 93
Contamination Control Recommendations ..... 94
  Cleanliness Standards for Machine Systems ..... 94
  General Contamination Control Recommendations or Practices ..... 95
  General Recommendations and Contamination Control Guidelines for Fuels ..... 96
Coolant Applications ..... 72
  Cat ELC and Cat ELC Advanced ..... 72
  Cat ELC and Cat ELC Advanced Cooling System Maintenance ..... 74
  Commercial Heavy-Duty Coolant/Antifreeze and SCA (Supplemental Coolant Additive) ..... 81
  Conventional Coolant/Antifreeze Cooling System Maintenance ..... 78
  Diesel Engine Antifreeze/Coolant (DEAC) .. 77
  Extended Life Inhibitor (ELI) ..... 76
  Supplemental Coolant Additive (SCA) ..... 78
  Water/Supplemental Coolant Additive (SCA) ..... 82
Coolant Characteristics ..... 66
  Additives ..... 67
  Glycol ..... 67
  Water ..... 66
Coolant General Information ..... 64
  Coolant Terminology ..... 65
Coolant Section ..... 64
Coolant Specifications ..... 68

**D**

DEF Additional Information ..... 87
  Bulk storage ..... 87
  Cleanliness ..... 87
  DEF/Urea Solution Recommendations for Marine Engines ..... 88
  Handling ..... 87
  Stability ..... 88
DEF General Information ..... 84
  DEF Guidelines ..... 85
  DEF Recommendations for SCR Aftertreatment Systems ..... 84
  General Information ..... 84
DEF Specifications ..... 86
  General Characteristics of DEF ..... 86
Diesel Engine Oil (DEO) ..... 44
Diesel Engine Oil (DEO) Applications ..... 54
  Cold-Weather Applications ..... 58
  Fuel Sulfur Impact on Engine Oil ..... 55
  Recommendation for US EPA Tier 4 Certified Nonroad Engines ..... 54
  Severe Applications ..... 56
  Warm-Up Procedures for Machines that are used in Cold Weather (Generic) ..... 59
Diesel Engine Oil (DEO) Characteristics ..... 47
  Lubricant Viscosity Recommendations (3116 and 3126 Marine Engines) ..... 48
  Lubricant Viscosity Recommendations for Direct Injection (DI) and Precombustion Chamber (PC) engines ..... 47
  Selecting the Viscosity ..... 47
Diesel Engine Oil (DEO) General Information ..... 44
  Cat Lubricants for Extended Oil Drains ..... 47
  Caterpillar Fluids ..... 45

Determining Optimum Oil Change Intervals ..... 46
Diesel Engine Oil (DEO) Specifications ..... 50
Cat Diesel Engine Oils Recommendations ..... 50
Commercial Engine Oil ..... 52
Diesel Exhaust Fluid (DEF) ..... 84
Diesel Fuel ..... 5
Diesel Fuel Application ..... 23
Cold-Weather Applications ..... 23
Diesel Fuels for Marine Engines ..... 24
Heavy Fuel Oil ..... 23
Starting Aids ..... 23
Diesel Fuel Characteristics ..... 11
Cetane Number ..... 11
Cloud Point ..... 11
Contamination ..... 17
Gums and Resins ..... 18
Lubricity ..... 13
Pour Point ..... 12
Specific Gravity / API Gravity ..... 17
Stability ..... 18
Viscosity ..... 11
Volatility ..... 16
Diesel Fuel Conditioner ..... 90
Diesel Fuel General Information ..... 5
**Cleanliness** ..... 7
**Diesel Fuel Types** ..... 5
**Injector Health** ..... 9
**Regulatory** ..... 10
Seasonal Operation ..... 10
**Storage and Maintenance** ..... 9
Diesel Fuel Specifications ..... 18
Cat Specifications ..... 18
Warnings and Notices ..... 21
Distillate Fuel Section ..... 5

**E**

Engine Coolant ..... 64
Engine Oil Section ..... 44
Exhaust Aftertreatment Section ..... 84

**F**

Fluid Sampling and Analysis ..... 99
Foreword ..... 4
Fluids/Filters Recommendation ..... 4
Fuel Additive General Information ..... 90
Fuel Additives ..... 90

**G**

Grease ..... 60
Grease Applications ..... 61
Cat Ball Bearing Grease ..... 61
Cat Utility Grease ..... 61
Cat White Assembly Grease ..... 61
Grease General Information ..... 60

**H**

Heavy Fuel Oil/Residual Fuel/Blended Fuel ... 43

**I**

Important Safety Information ..... 2

**L**

Leak Detection ..... 62

**M**

Maintenance Section ..... 93
Marine Transmission Oil ..... 63
Cat Transmission/Drive Train Oils ..... 63
Commercial Marine Transmissions ..... 63

**O**

Oil Additive General Information ..... 92
Oil Additives ..... 92
Other Fuels ..... 43
Other Lubricants Section ..... 60

**P**

Pyrolysis ..... 42
Pyrolysis Fuels ..... 42

**R**

Reference Information Section ..... 105
Reference Material ..... 105
Reference Materials ..... 105
Renewable Diesel ..... 39
Renewable Diesel/Hydrotreated Vegetable Oil (HVO) ..... 39

**S**

S.O.S Services Fuel Analysis ..... 99
Caterpillar S·O·S Services Fuel Analysis .... 99
S·O·S Services Coolant Analysis ..... 103

New Systems, Refilled Systems, and Converted Systems ..... 103
Recommended Interval for S·O·S Services Coolant Sample ..... 104
S·O·S Services Coolant Analysis (Level 1) ..... 104
S·O·S Services Coolant Analysis (Level 2) ..... 104
S·O·S Services Oil Analysis ..... 99
More Frequent S·O·S Sampling Improves Life Cycle Management ..... 102
Obtaining S·O·S Oil Samples ..... 100
Oil Sampling Interval ..... 101
Special-Purpose Cat Lubricants ..... 62
Specialty Lubricants ..... 62
Synthetic Diesel/E-Diesel/Gas-to-Liquid (GTL) ..... 41
Synthetic Fuels ..... 41

**T**

Table of Contents ..... 3

# Product and Dealer Information

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

**Delivery Date:** _____

## Product Information

Model: _____

Product Identification Number: _____

Engine Serial Number: _____

Transmission Serial Number: _____

Generator Serial Number: _____

Attachment Serial Numbers: _____

Attachment Information: _____

Customer Equipment Number: _____

Dealer Equipment Number: _____

## Dealer Information

Name: _____ Branch: _____

Address: _____

_____

_____

| | Dealer Contact | Phone Number | Hours |
|---|---|---|---|
| Sales: | _____ | _____ | _____ |
| Parts: | _____ | _____ | _____ |
| Service: | _____ | _____ | _____ |

SEBU6251
©2025 Caterpillar
All Rights Reserved

CAT, CATERPILLAR, LET'S DO THE WORK, their respective logos, "Caterpillar Corporate Yellow", the "Power Edge" and Cat "Modern Hex" trade dress as well as corporate and product identity used herein, are trademarks of Caterpillar and may not be used without permission.