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PATRIOT

Cat Commercial Diesel Engine Fluids Recommendations

FUEL

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

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Fuel Specifications

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General Fuel Information

SMCS Code: 1250; 1280

NOTICE

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

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

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

NOTICE

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

NOTICE

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

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.

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

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.

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

NOTICE

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

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

NOTICE

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

General Recommendations and Guidelines

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

Note: These general recommendations and guidelines concerning maintenance and care of fuel and fuel storage systems are not intended to be all inclusive. **Discuss proper fuel safety and health, handling, and maintenance practices with your fuel supplier.** Use of these general recommendations and guidelines does not lessen the engine owners and/or fuel supplier's 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: Caterpillar filters are designed and built to provide optimal performance and protection of the fuel system components.

- Discuss application specific fuel concerns, needs, and requirements with a reputable fuel supplier.
- Purchase fuel from a reputable supplier.
- Use fuel that meets or exceeds Caterpillar requirements for distillate diesel fuel. Refer to the "Caterpillar Specification for Distillate Diesel Fuel for Off-Highway Diesel Engines" table in this Special Publication, "Distillate Diesel Fuel" article.
- Use a properly designed and maintained bulk storage fuel tank.
- Confirm with the filter manufacturer that the fuel filter/filters to be used are compatible with the fuel type that will be filtered.
- 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. Filter the fuel at the last dispensing stage into the engine fuel tank through a filter with a rating of four microns (c) absolute or less. This filtration should be located at the device that dispenses the fuel to the engine fuel tank downstream from any equipment such as transfer pumps that could potentially shed debris into the fluid stream. Series filtration is recommended. The use of wire mesh media (strainer-type filters) are NOT recommended except for 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.
- The use of water separators or water coalesces is also recommended at points of fuel filtration.
- Install and maintain a properly designed and grounded filtration system on bulk storage fuel tanks for continuous filtration of stored fuel. The filter element/elements should be rated at a maximum of 5 microns(c) absolute. Change fuel filters based on manufacturers recommendations.
- Caterpillar offers multiple sizes of bulk fuel filtration and water coalescing units that are recommended for ensuring the availability of clean dry fuel. Refer to Special Publication, PEHJ0156, "Cat Bulk Fuel Filtration Systems" and consult your Caterpillar dealer for more information.
- Test for microbial contamination on a regular basis and take proper corrective action if contamination is present. Properly dispose of cleanup waste according to all applicable regulations and mandates.
- Every 3 months, or sooner if problems are suspected, have a complete analysis of the bulk

storage fuel per the “Caterpillar Specification for Distillate Diesel Fuel for Off-Highway Diesel Engines” table in this Special Publication, “Distillate Diesel Fuel” article. 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.

- Keep the fuel storage tank clean of water, debris and sediment.
- Drain water and sediment from the fuel storage tank weekly. Drain water and sediment before the tank is refilled.
- Keep the area around the fuel tank filler neck clean of debris in order to prevent contamination of the fuel tank.
- As required, clean the inside of the engine fuel tank and the inside of the bulk storage fuel tank.
- Drain water and sediment from the engine fuel tank daily. Drain water and sediment from the tank at the start of each shift. After the fuel tank has been filled, allow the fuel to settle for ten minutes. This will allow the water and sediment to separate from the fuel. Then, drain the water and sediment from the tank.
- Install fuel/water separators at the bulk storage fuel tank dispensing point and install fuel/water separators on the engine. Wire mesh media is NOT recommended.
- Drain the water from the fuel/water separators daily.
- Caterpillar Advanced Efficiency fuel filters are required for distillate fueled diesel engines in order to provide maximum life to the fuel system.
- Change fuel filters at the scheduled interval. Never fill the new secondary fuel filter with fuel before installation. Use the fuel priming pump to remove air from the system.
- Install and properly maintain four micron(c) absolute breather filters on the engine fuel tank vent, and install and properly maintain four micron (c) absolute breather filters on the bulk storage fuel tank vent. Desiccant type breather vent filters are also recommended in order to remove moisture from air entering the fuel tank. Breather filters are typically changed every six months, and desiccant type breather filters are typically changed on saturation. Refer to the literature that was included with the filter. Discuss the availability of desiccant breather vent filters for your application with your filter supplier.

- Top off fixed roof fuel tanks as often as practical in order to reduce tank breathing and in order to reduce the amount of condensation generated water.
- Protect fuel tanks from dirt and water entry.

NOTICE

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

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

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

Note: It is strongly recommended that fuel storage tanks be thoroughly cleaned before converting to Ultra Low Sulfur Diesel (ULSD) (15 ppm or less sulfur) and/or biodiesel/biodiesel blends. Conversion to ULSD and/or biodiesel/biodiesel blends can loosen fuel system and fuel storage tank deposits. Bulk tank continuous filtration unit and dispensing point filters, and onboard engine filters change intervals may need to be shortened for an extended period of time in order to allow for this cleaning effect.

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

Note: Even when all fuel storage maintenance practices that are relevant to your application are followed, Caterpillar recommends a maximum of one year from production for distillate fuel storage, and a maximum of six 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 six months.

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Fuel Information for Diesel Engines

SMCS Code: 1250; 1280

NOTICE

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

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

European sulfur free fuel ≤ 0.0010 percent (≤ 10 ppm (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 or sulfur-free diesel fuel are acceptable in all engines regardless of the engine U.S. EPA Tier or EU Stage requirements.

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

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.

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

Starting Aids

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

Engine Coolant Heaters

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

With either type of heater, starting aids and/or fuels with higher cetane numbers are less important because the engine is warm. Problems with fuel cloud point can cause the plugging of fuel filters. Problems with fuel cloud point cannot be corrected by engine coolant heaters. 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 in order to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Fuels with a high viscosity might require fuel heaters in order to lower the viscosity to either 4.5 cSt or less for rotary fuel injection pumps or 20 cSt viscosity or less for all other fuel injection pumps.

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.

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Characteristics of Diesel Fuel

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. If the kinematic viscosity of the fuel is lower than 1.4 cSt as supplied to the fuel injection pump or unit injectors, excessive scuffing and seizure can occur.

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

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

Cetane Number

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

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

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

Modifying the Cetane Number

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

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

Cloud Point

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

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

Modifying the Cloud Point

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

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

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

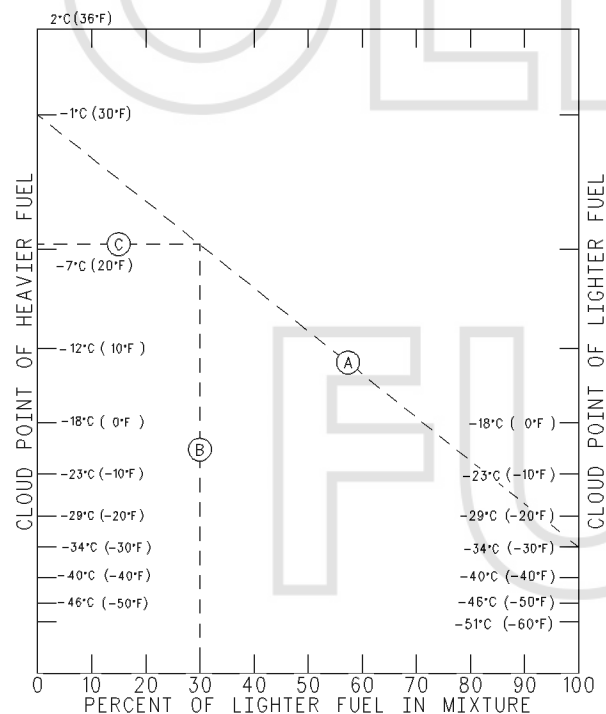


Illustration 1

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Cloud point of fuel mixtures

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

Pour Point

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

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

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

Modifying the Pour Point

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

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

Fuel Specifications Characteristics of Diesel Fuel

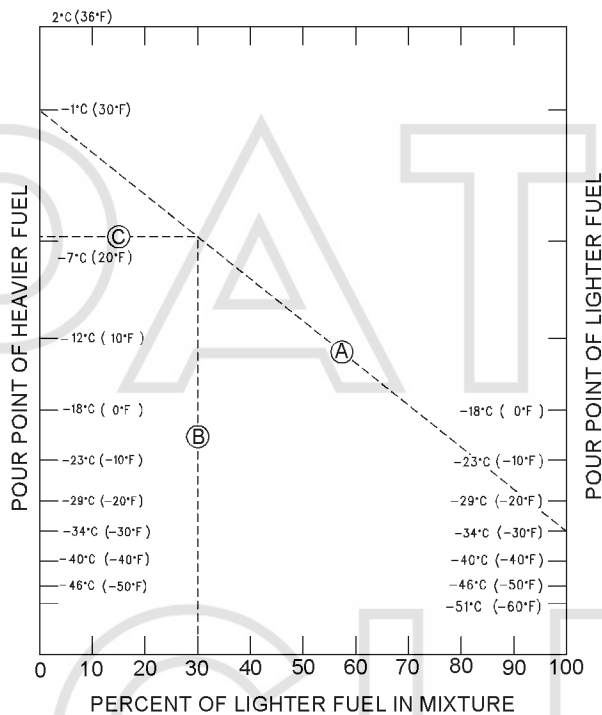


Illustration 2

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Pour point of fuel mixtures

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

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

6. Line "C" and line "A" intersect. Mark this point. Draw a vertical line from this point. Stop the line at the bottom of the table. Label this line "B". The point at the bottom of line "B" reveals the percentage of lighter fuel required to modify the cloud point or the pour point.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Refer to this Special Publication, “Distillate Diesel Fuel” article, “Aftermarket Fuel Additives”, “Cat Diesel Fuel Conditioner”, and “Alternative Fuels - Arctic Applications” topics for guidance.

Diesel Fuel Sulfur

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

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

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

Fuel Specifications Characteristics of Diesel Fuel

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 2010 for nonroad diesel engines and machines. Refer to the U.S. EPA for the required ULSD point of sales dates for various nonroad applications.

Engines certified to nonroad Tier 4 standards (Stage IV in Europe) and are equipped with fuel sulfur sensitive exhaust aftertreatment systems are designed to run on ULSD only. Use of LSD or fuels higher than 15 ppm (mg/kg) sulfur in these engines will reduce engine efficiency and engine durability and will damage emissions control systems and/or shorten their service interval. Failures that result from 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 insure the correct fuels are used.

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

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.

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 NO_x 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:

Fuel Specifications Characteristics of Diesel Fuel

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

Oil Drain Intervals

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

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

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

Moisture Content

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

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

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

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

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

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

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

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

Specific Gravity / API Gravity

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

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

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

Lighter fuels will not produce the rated power. Lighter fuels may also be a blend of ethanol or methanol with diesel fuel. Blending alcohol or gasoline with diesel fuel will create an explosive atmosphere in the fuel tank. In addition, water condensation in the tank can cause the alcohol to separate in the tank.

WARNING

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

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

NOTICE

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

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

Gums and Resins

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

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

The Thermal Stability and Oxidation Stability of Fuel

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

Diesel fuel is being used as a coolant for high-pressure fuel injection systems with high temperature fuel wetted walls. The fuel in the fuel system will be stressed. The thermal stress and an increase in recirculation fuel temperature is often responsible for fuel degradation. Gums, resins, sediment, and deposits will form, which can cause fuel flow restriction through fuel filters and fuel injection systems.

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

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

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

Thermal Stability

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

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

Oxidative Stability Test

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

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

Cat recommends that for diesel, biodiesel, or biodiesel blends that are going to be used several months after purchase, artificially aging the fuel to predict the storage stability, followed by an analysis of the fuel. For most distillate fuels that age the fuel for 7 days at 80° C (176° F) can simulate storage for 4 to 8 months at typical ambient storage temperatures. Analysis of this matured fuel per the methods discussed in this document can then be used to aid in predicting the stability of the fuel after numerous months of storage. Analysis of Diesel fuel should include “Thermal Stability - ASTM D6468”, “Fuel Gums - ASTM D381” and “Fuel Sediments - ASTM D473”. Analysis of biodiesel fuel and biodiesel fuel blends should include “Oxidation - EN14112”, “Acid Value - ASTM D664”, “Viscosity - ASTM D445” and “Sediments - ASTM D2709”.

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

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Fuel Recommendations

SMCS Code: 1250; 1280

NOTICE

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

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

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

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

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

NOTICE

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

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

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Distillate Diesel Fuel

SMCS Code: 1280

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

Caterpillar is not in the position to continuously evaluate and monitor all of the many worldwide distillate diesel fuel specifications and their 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.

Using the Cat distillate diesel fuel specification as the baseline, it is much easier to determine any potential economic and/or performance trade-offs, and overall acceptability when using fuels of varying characteristics and quality levels.

- When required, have the diesel fuel that either is being used or is planned to be used, tested per the Cat distillate diesel fuel specification.
- Use the Cat distillate diesel fuel specification as a fuel quality baseline for comparison of distillate diesel fuel analysis results, and/or 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 well proven fuel additives. Refer to this Special Publication, “Distillate Diesel Fuel” article, “Aftermarket Fuel Additives” and “Cat Diesel Fuel Conditioner” topics for guidance.

To help ensure optimum engine performance, a complete fuel analysis should be obtained before engine operation. The fuel analysis should include all of the properties that are listed in the “Caterpillar Specification for Distillate Fuel for Nonroad Diesel Engines”, Table 14 .

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

Diesel Fuels that meet the specifications in table 14 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 14 requirements.

In Europe, diesel fuels that are identified as meeting the latest version of “European Standard EN590” generally meet the table 14 requirements.

Table 14 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.

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

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

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

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

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

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

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

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.

Using fuels with higher than recommended fuel sulfur levels can or will:

- Reduce engine efficiency and durability
- Increase wear
- Increase corrosion
- Increase deposits
- 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
- Shorten the time period between oil drain intervals (cause the need for more frequent oil drain intervals)
- Increase overall operating costs

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 CaterpillarORS 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.

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

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

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

Note: Caterpillar strongly recommends the filtration of distillate fuel and/or biodiesel/biodiesel blends through a fuel filter with a rating of four microns(c) absolute or less. This filtration should be located on the device that dispenses the fuel to the fuel tank for the engine, and also on the device that dispenses fuel from the bulk storage tank. Series filtration is recommended. 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 "Cat Specification for Distillate Diesel Fuel for Off-Highway Diesel Engines", table 14 .

The values of the fuel viscosity given in table 14 are the values as the fuel is delivered to the fuel injection pumps. For ease of comparison, fuels should also meet the minimum and maximum viscosity requirements at 40° C (104° F) that are stated by the use of either the "ASTM D445" test method or the "ISO 3104" test method. If a fuel with a low viscosity is used, cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Fuels with a high viscosity might require fuel heaters in order to lower the viscosity to either 4.5 cSt or less for rotary fuel injection pumps or 20 cSt viscosity or less for all other fuel injection pumps.

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

Fuel Specifications
Distillate Diesel Fuel

Table 14

Cat Specification for Distillate Fuel for Nonroad Diesel Engines			
Specifications	Requirements	ASTM Test	ISO Test
Aromatics	35% maximum	"D1319"	"ISO 3837"
Ash	0.01% maximum (weight)	"D482"	"ISO 6245"
Carbon Residue on 10% Bottoms	0.35% maximum (weight)	"D524"	"ISO 4262"
Cetane Number ⁽¹⁾	40 minimum (DI engines)	"D613" or "D6890"	"ISO 5165"
	35 minimum (PC engines)		
Cloud Point	The cloud point must not exceed the lowest expected ambient temperature.	"D2500"	"ISO 3015"
Copper Strip Corrosion	No. 3 maximum	"D130"	"ISO 2160"
Distillation	10% at 282° C (540° F) maximum	"D86"	"ISO 3405"
	90% at 360° C (680° F) maximum ⁽²⁾		
	90% at 350° C (662° F) maximum ⁽²⁾		
Flash Point	legal limit	"D93"	"ISO 2719"
Thermal Stability	Minimum of 80% reflectance after aging for 180 minutes at 150° C (302° F)	"D6468"	No equivalent test
Density at 15° C (59° F) ⁽³⁾	800 kg/m ³ minimum	"D287"	No equivalent test
	860 kg/m ³ maximum		
Pour Point	6° C (10° F) minimum below ambient temperature	"D97"	"ISO 3016"
Sulfur	⁽⁴⁾	"D5453" or "D2622"	"ISO 20884"
Kinematic Viscosity	1.4 cSt minimum and 20.0 cSt maximum as delivered to the fuel injection pumps	-	-
	1.4 cSt minimum and 4.5 cSt maximum as delivered to the rotary fuel injection pumps		
Water and Sediment	0.05% maximum	"D1796"	"ISO 3734"
Water	0.05% maximum	"D1744"	No equivalent test
Sediment	0.05% maximum (weight)	"D473"	"ISO 3735"
Gums and Resins ⁽⁵⁾	10 mg per 100mL maximum	"D381"	"ISO 6246"
Lubricity	0.52 mm (0.0205 inch) maximum at 60° C (140° F)	"D6079"	No equivalent test
Cleanliness	⁽⁶⁾	"D7619"	"ISO 4406"

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

(continued)

(Table 14, contd)

- (2) Distillation of 90% at 350° C (662° F) maximum is recommended for Tier 4 engines and preferred for all engines. Distillation of 90% at 350° C (662° F) is equivalent to 95% at 360° C (680° F). Distillation of 90% at 360° C (680° F) maximum is acceptable for Pre-Tier 4 engines.
- (3) The density range allowed includes #1 and #2 diesel fuel grades. Fuel density varies depending on the sulfur level, where high sulfur fuels have higher densities. Some unblended (neat) alternative fuels have lower densities, which are acceptable if the other properties fall within this spec.
- (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
- (5) Follow the test conditions and procedures for gasoline (motor).
- (6) Recommended cleanliness level for fuel as dispensed into machine or engine fuel tank is "ISO 18/16/13" or cleaner per "ISO 4406" or "ASTM D7619". Refer to the "Recommendations for Cleanliness of Fuels" in this chapter

There are many other diesel fuel specifications that are published by governments and by technological societies. Usually, those specifications do not review all the requirements that are addressed in the "Caterpillar Specification for Distillate Fuel for Off-Highway Diesel Engines", Table 14. To help ensure optimum engine performance, a complete fuel analysis should be obtained before engine operation. The fuel analysis should include all of the properties that are listed in the "Cat Specification for Distillate Fuel for Off-Highway Diesel Engines", Table 14.

NOTICE

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

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

WARNING

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

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

Contamination Control Recommendations for Fuels

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

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

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

Fuel Specifications

Distillate Diesel Fuel

- Use high quality fuels per recommended and required specifications (refer to the “Fuel” chapter in this Special Publication).
- Fill machine fuel tanks with fuels of “ISO 18/16/13” cleanliness level or cleaner, in particular for engines with common rail and unit injection systems. When you refuel the machine, filter the fuel through a 4 µm absolute filter (Beta 4 = 75 up to 200) in order to reach the recommended cleanliness level. This filtration should be located at the device that dispenses the fuel to the engine or machine fuel tank. In addition, filtration at the dispensing point should have the ability to remove water to ensure fuel is dispensed at 500 ppm water or less.
- Caterpillar recommends the use of bulk fuel filter / coalescer units which remove both particulate contamination and water in a single pass. These units have the ability to clean fuel to “ISO 16/13/11” or cleaner and remove free water to 500 ppm (mg/kg) or less. Cat offers heavy duty filter / coalescer units to accommodate fueling rates from 50 to 300 gpm (gallons per minute). Cat custom designs filter / coalescer units specifically for the conditions of fuel at the worksite if needed.
- Ensure that you use Cat Advanced Efficiency Fuel Filters . Change your fuel filters per recommended service requirements or as needed.
- Drain your water separators daily per the Operation and Maintenance Manual of your machine.
- Drain your fuel tanks of sediment every 500 hours or 3 months per the Operation and Maintenance Manual of your machine.
- Install and maintain a properly designed bulk filter / coalescer filtration system. Continuous bulk filtration systems may be required to ensure dispensed fuel meets the cleanliness target. Refer to your Cat dealer for availability of bulk filtration products.
- Centrifugal filters may need to be used as a pre-filter with fuel that is severely contaminated with gross amounts of water or large particulate contaminants. Centrifugal filters can effectively remove large contaminants, but may not be able to remove the very small abrasive particles required to achieve the recommended “ISO” cleanliness level. Bulk filter / coalescers are necessary as a final filter in order to achieve the recommended cleanliness level.
- Install desiccant type breathers of 4 µm or less absolute efficiency with the ability to remove water on bulk storage tanks.

- Follow proper practices of fuel transport and filtration from storage tank to the machine in order to allow the delivery of clean fuel to machine tank. Fuel filtration can be installed at each transport stage in order to keep the fuel clean.
- Cover, protect and ensure cleanliness of all connection hoses, fittings and dispensing nozzles.

NOTICE

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

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

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

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.

Heavy Fuel Oil, Residual Fuel, Blended Fuel

NOTICE

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

Alternative Fuels - Cold Weather Applications

In extreme cold ambient conditions, you may choose to use the distillate fuels that are specified in table 15. However, the fuel that is selected must meet the requirements that are specified in the “Cat Specification for Distillate Diesel Fuel for Off-Highway Diesel Engines”, Table 14. These fuels are intended to be used in operating temperatures that are down to $-54\text{ }^{\circ}\text{C}$ ($-65\text{ }^{\circ}\text{F}$).

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

Note: The fuels that are listed in table 15 typically have much higher sulfur levels than the 50 ppm maximum sulfur allowed in the European Standard “EN 590:2004”. The sulfur content of these fuels typically far exceeds 50 ppm. These fuels typically will not be acceptable for use in areas that restrict maximum fuel sulfur levels to 50 ppm or less.

The fuel that is selected must meet the requirements that are specified in “Cat Specification for Distillate Diesel Fuel for Off-Highway Diesel Engines”, table 14. Cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Consult the supplier for the recommended additives in order to maintain the proper fuel lubricity.

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

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

Table 15

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 15 must be at least 40. If the viscosity is below 1.4 cSt at $40\text{ }^{\circ}\text{C}$ ($104\text{ }^{\circ}\text{F}$), use the fuel only in temperatures below $0\text{ }^{\circ}\text{C}$ ($32\text{ }^{\circ}\text{F}$). Do not use any fuels with a viscosity of less than 1.2 cSt at $40\text{ }^{\circ}\text{C}$ ($104\text{ }^{\circ}\text{F}$).

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

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

Renewable and Alternative Fuels

Renewable fuels are derived from renewable resources such as planted crops and crop residues (referred to as biomass), waste, algae, cellulosic material, yard and food waste, etc. Renewable fuels reduce the carbon footprint of the fuels compared to fossil fuels on a Life Cycle Analysis basis. Caterpillar, through its sustainability initiatives, supports the development and use of renewable fuels.

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

Caterpillar is not in a position to test all varieties of renewable and alternative fuels that are advertised in the market place. If a renewable or alternative fuel fulfills the performance requirements described in Cat Fuel Specification, the latest version of "ASTM D975", the latest version of "EN 590", or the latest version of the paraffinic fuel specification "CEN TS 15940" (which defines quality requirements for Gas to Liquids (GTL), Biomass to Liquids (BTL) and hydrotreated vegetable oil (HVO)), then this fuel or a blend of this fuel (blended with appropriate diesel fuel) can be used as a direct replacement of petroleum diesel in Cat engines. Consult with the fuel supplier and with your Cat dealer to ensure that the cold-weather performance of the fuel is appropriate to the expected ambient temperatures at the operation sites and to ensure elastomer compatibility. Certain elastomers used in older engines (such as engines manufactured up to the early 1990s) may not be compatible with the new alternative fuels.

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

Aftermarket Fuel Additives

There are many different types of fuel additives that are available to use. 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.

Cat Diesel Fuel Conditioner

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

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

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

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

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

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

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

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

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

NOTICE

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

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

When used as directed, Cat Diesel Fuel Conditioner has proven to be compatible with non-road Tier 4 U. S. EPA certified engines that are equipped with aftertreatment devices.

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

NOTICE

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

Cat Diesel Fuel System Cleaner

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

Fuel Specifications Biodiesel

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

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/biodiesel blends that meet Cat biodiesel recommendations and requirements. Note that not all fuel cleaners are suitable for use with biodiesel/biodiesel blends. Read and follow all applicable label usage instructions. Also, refer to this Special Publication, “Distillate Diesel Fuel”, article and also refer to the “Biodiesel” article, which includes Cat biodiesel recommendations and requirements.

When used as directed, Cat Diesel Fuel System Cleaner has proven to be compatible with non-road 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.

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Biodiesel

SMCS Code: 1280

NOTICE

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

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

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

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

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

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

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

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

Note: Cat follows the latest revision of “ASTM D7467” specification for B6-B20 blends. Biodiesel fuel must meet defined quality standards. Cat recommendations for acceptable biodiesel blend for most engines have been changed to B20. Details on the use of higher blends are given in this “Biodiesel” section of this Special Publication.

NOTICE

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.

NOTICE

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

Recommendations for the Use of Biodiesel in Caterpillar Off-Highway Engines

Refer to table 16 and 17 to the details provided in this section for biodiesel fuel requirements.

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

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

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

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

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

Fuel Specifications
Biodiesel

Table 16

Recommendations for biodiesel fuel application in Cat Off-Highway engines		
Production year/Tier/Stage	Engine model	Biodiesel acceptable blend levels
Tier 2 / Stage II or earlier Emissions Regulations	3003-3034, 3044, 3046, 3054, 3056, 3064, and 3066, 3054C (mechanical), 3054E (electronic) and 3056E (electronic). C0.5, C0.7, C1.1, C1.5, C1.6, C2.2, C3.4, C2.6, C3.3B. Certain C4.4 (S/N 44400001-04303), Certain C6.6 (S/N CE600001-14623 (Machines) and S/N 66600001-09015 (Industrial))	Up to B5 ⁽¹⁾
Tier 4 Interim / Stage IIIa (without aftertreatment)	C1.8, C2.4, C3.3B, C3.4	
Tier 4 Interim / Stage IIIb (with aftertreatment devices)	C3.8	
Tier 4 Interim / Stage IIIb and beyond (with aftertreatment devices)	ACERT engines: C3.4B, C4.4, C6.6, C7.1, C9.3, C13, C15, C18, C27, and C32	Up to B20
All years, except for the engine models listed above	C0.5 through C2.2 ⁽²⁾ Certain C4.4 ACERT (S/N C4E05524-Up (Machines) and 44404304 -Up (Industrial)), C4.4 (Mechanical), C6.4, and certain C6.6 ACERT (S/N CE614624-Up (Machines) and 66609016-Up (Industrial))	Up to B20 (For use of higher blend levels up to B100, consult your Cat dealer)
All years	3114, 3116, 3126, 3176, 3196, 3208, 3306, 3406, 3408, 3412, 3456, 3406E, 3408E, 3412E, 3500 Series, and 3600 Series C-9, C10, C-12, C-15, C-16, C-18, C280 Series, CM20, CM25, and CM32 ACERT engines ⁽²⁾ C7, C9, C9.3, C11, C13, C15, C18, C27, C32, and C175	

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

⁽²⁾ Models without aftertreatment only

Table 17

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

⁽¹⁾ Refer to Table 19 in the Biodiesel section of this Special Publication.

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

Note: For Tier 4 certified/ Stage IIIB and newer engine models that are equipped with aftertreatment devices, use only the biodiesel blend levels that are recommended in “Recommendations for biodiesel fuel application in Caterpillar Off-Highway Engines” in this Special Publication, table 16 . Use of biodiesel blend levels higher than the recommendations provided in table 16 can adversely affect engine and aftertreatment components. There may be contaminants present in biodiesel. The repair of any engine or aftertreatment components due to such contamination or due to other biodiesel impacts would not be covered under the Cat warranty for materials and/or the warranty for workmanship. Refer to “Additional Maintenance Requirements” topic in this Special Publication, “Biodiesel” article.

Note: For 2006 and older engine models, for use of blends of biodiesel above B20 (20 percent), refer to “Guidelines and potential impacts associated with the use of biodiesel and biodiesel blends” table 18 in this Special Publication for the guidelines and impacts of using high biodiesel blends. Consult your Caterpillar dealer for guidance. Cat S·O·S Services oil analysis program is required when biodiesel or blends that are B20 (20 percent) or above are used.

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, Cat recommends either of the following treatments:

- Cat Diesel Fuel System Cleaner (Part number 343-6210)
- Cat Diesel Fuel Conditioner (Part number 256-4968)

Cat Diesel Fuel System Cleaner, used as needed or on an on-going basis, is most effective at cleaning and preventing the formation of fuel-related deposits. Cat Diesel Fuel Conditioner can be used to improve fuel stability and can help prevent the formation of fuel-related deposits.

Additional maintenance requirements

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

- Crankcase oil fuel dilution can be higher when biodiesel and/or biodiesel blends are used. This increased level of fuel dilution when using biodiesel and/or biodiesel blends is related to the typically lower volatility of biodiesel. In-cylinder emissions control strategies utilized in many of the latest engine designs may lead to a higher level of biodiesel concentration in the sump. The long-term effect of biodiesel concentration in crankcase oil is currently unknown. **The use of Cat S·O·S Services oil analysis is 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)).
- Biodiesel fuel contains metal contaminants (phosphorous, sodium, potassium, calcium, and/or magnesium) that form ash products upon combustion in the diesel engine. The ash can affect the life and performance of aftertreatment emissions control devices and can accumulate in Diesel Particulate Filters (DPF). The ash accumulation may cause the need for more frequent ash service intervals and/or cause loss of performance.

Fuel System Deposits

Biodiesel and biodiesel blends are known to cause an increase in fuel system deposits, most significant of which are deposits within the fuel injector. These deposits can cause a loss in power due to restricted or modified fuel injection or cause other functional issues associated with these deposits. Cat Diesel Fuel System Cleaner (part number 343-6210), used as needed or on an on-going basis, is most effective in cleaning and preventing the formation of deposits. Cat Diesel Fuel Conditioner (part number 256-4968) helps to limit deposit issues by improving the stability of biodiesel while also hindering the production of new deposits. **Therefore, the use of Cat Diesel Fuel System Cleaner and/or Cat Diesel Fuel Conditioner is strongly recommended when running biodiesel and biodiesel blends, especially when using B20 or higher blend levels.** Refer to this Special Publication, “Distillate Diesel Fuel”, article, “Cat Diesel Fuel Conditioner” and “Cat Diesel Fuel System Cleaner” topics in this Special Publication, “Distillate Diesel Fuel” for additional information.

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

Guidelines

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

Note: For these recommendations, the cautions, guidelines, and recommendations applicable to biodiesel (B100) are also applicable to biodiesel blends (B2, B5, B20, and so on). The impacts of biodiesel blends higher than B20 are, in general, more severe than the impacts of biodiesel blends of B20 or lower. Refer to Table 18 of this Biodiesel section for more details.

Note: Fuel storage tanks need to be cleaned thoroughly before converting to biodiesel/biodiesel blends. Conversion to biodiesel/biodiesel blends can loosen fuel system and fuel storage tank deposits. Bulk tank continuous filtration unit and dispensing point filters, and onboard engine filters change intervals should be shortened for an extended period in order to allow for this cleaning effect.

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”. For more information on the “BQ-9000” program, go to “www.BQ-9000.org”.

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

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

Table 18

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

(continued)

(Table 18, contd)

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

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

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

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

The following are the paragraph reference numbers:

1. The oil change interval can be negatively affected by the use of biodiesel. Use S·O·S Services oil analysis in order to monitor the condition of the engine oil. S·O·S Services oil analysis will also help determine the oil change interval that is optimum.
2. Confirm with the filter manufacturer that the fuel filter/filters to be used are compatible with biodiesel. Fuel water separators are preferred when biodiesel is used.

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

3. Conversion to biodiesel can loosen fuel system deposits. Fuel filter change intervals should be shortened for an extended period in order to allow for this cleaning effect when converting used engines to biodiesel. Filter change interval of 50 hours or less is recommended following the initial conversion to B20 biodiesel blend.
4. Filter biodiesel and biodiesel blends through a fuel filter with a rating of four microns(c) absolute or less. Filters should be located on the device that dispenses the fuel to the fuel tank for the engine. Filters should be located on the device that dispenses fuel from the bulk storage tank. Series filtration is recommended.

5. In a comparison of distillate fuels to biodiesel, neat biodiesel (B100) typically provides less energy per gallon by 5 percent to 8 percent. Do NOT attempt to change the engine rating in order to compensate for the power loss. Engine problems may occur when the engine is converted back to 100 percent distillate diesel fuel. Any adjustments to the engine in service may result in violation of emissions regulations such as the U.S. EPA anti-tampering provisions.
6. Compatibility of the elastomers with biodiesel is currently being monitored. The condition of seals and hoses should be monitored regularly. Biodiesel may soften, degrade, or leak from some types of elastomers used in seals and hoses. The higher biodiesel blend has a greater the risk of elastomer-related issues.
 - a. In general, Cat engines built early to mid 90s use Viton seals and Viton O-rings in the fuel system. Viton is compatible with biodiesel.
 - b. Nitrile hoses typically used in some fuel transfer lines are not compatible with biodiesel. Monitor the condition of the hoses and confirm with the hose manufacturer that the hoses are compatible with the biodiesel blend used. If necessary, replace with hoses of compatible materials.
7. Biodiesel may pose low ambient temperature problems for both storage and operation. At low ambient temperatures, biodiesel fuel may need to be stored in a heated building or a heated storage tank. The fuel system may require heated fuel lines, filters, and tanks. Filters may plug and fuel in the tank may solidify at low ambient temperatures if precautions are not taken. Consult your biodiesel supplier for assistance in the blending and attaining of the proper cloud point for the fuel.

Note: The performance of cold flow improvers can be reduced in the presence of biodiesel fuel. Consult the fuel supplier for appropriate cold flow improvers if needed.
8. Biodiesel can be produced using various renewable sources. The source used can affect product performance. Two of the fuel characteristics affected are cold flow and oxidation stability. Cold flow affects filter plugging and oxidation stability affects deposit formation and biodiesel fuel storage duration and life. Consult your fuel supplier for guidance.
9. Biodiesel has poor oxidation stability, which may accelerate fuel oxidation in the fuel system. Engines with an electronic fuel system operate at higher temperatures, which may accelerate fuel oxidation. Oxidized fuel can form deposits in fuel injection systems and in fuel systems in general. Refer to this Special Publication, "Distillate Diesel Fuel" article, "Aftermarket Fuel Additives", "Cat Diesel Fuel Conditioner", and "Cat Diesel Fuel System Cleaner" topics for information concerning oxidation stability and other fuel additives.
10. Poor oxidation stability of biodiesel can result in long-term storage problems. Biodiesel should be used within a limited time from production. In order to ensure appropriate storage duration, testing of the stored biodiesel is recommended. Tests should include oxidation, acid number, viscosity, and sediments. Tests should be conducted periodically to ensure that biodiesel is per specification. Antioxidants are recommended to improve stability of biodiesel. Cat Diesel Fuel Conditioner, part number 256-4968, or appropriate commercial additives are recommended. Consult your fuel supplier for more information.
 - a. B20 biodiesel blend can generally be stored up to 8 months. Testing of B20 blends is recommended at 4 months of storage and on a monthly basis thereafter to ensure that the fuel has not degraded.
 - b. B100 biodiesel can generally be stored up to 4 months. Testing of B100 is recommended at 2 months of storage and every two weeks thereafter to ensure that the fuel has not degraded. The use of appropriate additives is required if B100 is stored more than 4 months. Consult your fuel supplier for more information.
 - c. B100 should be stored at temperatures of 3 degrees C to 6 degrees C (5 degrees F to 10 degrees F) above the cloud point.
11. Due to poor oxidation stability and other potential issues, engines with limited operational time (such as seasonal use or standby power generation) either not use biodiesel/biodiesel blends or, while accepting some risk, limit biodiesel to a maximum of B5. Examples of applications that should limit the use of biodiesel are the following: Standby Generator sets and certain emergency vehicles. For more information, refer to the "Seasonal Operation" section.

- a. Addition of Cat Diesel Fuel Conditioner, part number 256-4968, is recommended for standby generator sets and emergency vehicles using biodiesel/biodiesel blends. The conditioner should be added when the engine is fueled or as early as possible when the fuel is delivered and stored. Preferably, the conditioner or additive should be added as soon as possible after the fuel is produced.
 - b. For standby generator sets and emergency vehicles that use biodiesel, sample the fuel in the engine tank monthly. Test the fuel for acid number and oxidation stability. If the test results show that the fuel is degraded and not in specification (provided in Table 19 in this "Biodiesel" section), drain the tank, 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
 - c. For standby generator sets and emergency vehicles that use biodiesel, use fuel with oxidation stability 10 hours or more per "EN 14112" test method.
- 12.** Biodiesel is an excellent medium for microbial contamination and growth. Microbial contamination and growth can cause corrosion in the fuel system and premature plugging of the fuel filter. Consult your supplier of fuel and additive for assistance in selecting appropriate anti-microbial additives.
- 13.** Care must be taken in order to remove water from fuel tanks. Water accelerates microbial contamination and growth. When biodiesel is compared to distillate fuels, water is naturally more likely to exist in the biodiesel.
- 14.** Biodiesel dilution of engine oil may result in oil side leaks due to incompatibility of the seals that are typically used on the oil side. Liner seals and oil cooler seals may be affected by biodiesel dilution. Monitor the condition of the oil side seals and consult your Caterpillar dealer for appropriate replacement if needed.
- 15.** Biodiesel is not compatible with some metals. Biodiesel higher than B20, will oxidize and form sediments upon long-term contact with lead, zinc, tin, copper, and copper alloys such as brass and bronze. Consult your dealer for more information.

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

Seasonal Operation

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. Follow the recommendations provided in this section and the guidelines given below to reduce the risk:

- Addition of Caterpillar Diesel Fuel Conditioner , part number 256-4968, 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 Caterpillar Diesel Fuel System Cleaner, part number 343-6210, is recommended when the engine is first operated after the prolonged shutdown period and preferably for a total of two tanks of fuel. Follow the recommendations provided in the Caterpillar Diesel Fuel System Cleaner section in the "Fuel" article in this Special Publication.

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

Biodiesel Specification

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

The final blend of biodiesel as used in the engine must meet the requirements that are stated in table 19 this "Biodiesel" article.

Fuel Specifications
Biodiesel

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 plug fuel filters when fuel temperatures are below -12°C (10.4°F).

Table 19

Cat Specification for Biodiesel Fuel				
Property	Test Method	Test Method	Units	Limits
	United States	International	Specific Properties of Fuel	
Density at 15°C	"ASTM D1298"	"ISO 3675"	g/cm ³	0.86-0.90
Viscosity at 40°C	"ASTM D445"	"ISO 3104"	mm ² /s (cSt)	1.9-6.0
Flash Point	"ASTM D93"	"ISO 3679"	°C	93 minimum
Pour Point - Summer - Winter	"ASTM D97"	"ISO 3016"	°C	6 °C (10 °F) minimum below ambient temperature
Cloud Point	"ASTM D2500"		°C	Report
Sulfur Content	"ASTM D5453"	"ISO 20846" "ISO 20884"	percent weight	0.0015 maximum
Distillation - 10 percent Evaporation - 90 percent Evaporation	"ASTM D1160"		°C	To Be Determined 360
Carbon Residue, Conradson (CCR)	"ASTM D4530"	"ISO 10370"	percent weight	0.05 maximum
Cetane Number	"ASTM D613"	"ISO 5165"		45 minimum
Sulfated Ash	"ASTM D874"	"ISO 3987"	percent weight	0.02 maximum
Water/Sediment Content	"ASTM D2709"	"ISO 12937"	percent volume	0.05 maximum
Copper Corrosion	"ASTM D130"	"ISO 2160"		No. 1
Oxidation Stability	"EN 14112"	"EN 14112"	hours	3 minimum
Esterification	"EN 14103"	"EN 14103"	percent volume	97.5 minimum
Acid Value	"ASTM D664"	"EN 14104"	mg KOH/g	0.5 maximum
Methanol Content	"EN 14110"	"EN 14110"	percent weight	0.2 maximum
Monoglycerides	"ASTM D6584"	"EN 14105"	percent weight	0.8 maximum
Diglycerides	"ASTM D6584"	"EN 14105"	percent weight	0.2 maximum
Triglycerides	"ASTM D6584"	"EN 14105"	percent weight	0.2 maximum
Free Glycerin	"ASTM D6584"	"EN 14105"	percent weight	0.02 maximum
Total Glycerin	"ASTM D6584"	"EN 14105"	percent weight	0.240 maximum
Phosphorus Content	"ASTM D4951"	"EN 14107"	percent weight	0.001

(continued)

(Table 19, contd)

Cat Specification for Biodiesel Fuel				
Property	Test Method	Test Method	Units	Limits
	United States	International	Specific Properties of Fuel	
Calcium and Magnesium combined	"EN 14538"	"EN 14538"	ppm	5 maximum
Sodium and Potassium combined	"EN 14538"	"EN 14538"	ppm	5 maximum
Cold Soak Filterability	"ASTM D7501"	–	seconds	360 maximum
Cleanliness	"ASTM D7619"	"ISO 4406"	–	(1)

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

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

Referenced Documents

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