M0113102-08 (en-us)
June 2026

Perkins®

Operation and Maintenance Manual

Perkins Diesel Engines Fluids Recommendations

Important Safety Information

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

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

Do not operate or perform any lubrication, maintenance or repair on this product, until you have read and understood the operation, lubrication, maintenance and repair information.

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

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

⚠ WARNING

The meaning of this safety alert symbol is as follows:

Attention! Become Alert! Your Safety is Involved.

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

Operations that may cause product damage are identified by “NOTICE” labels on the product and in this publication.

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

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

⚠ WARNING

When replacement parts are required for this product Perkins recommends using Perkins replacement parts.

Failure to heed this warning can lead to premature failures, product damage, personal injury or death.

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

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Foreword

Fluids/Filters Recommendation

Literature Information

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

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

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

Safety

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

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

Maintenance

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

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

Maintenance Interval Schedule

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

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

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

Aftermarket Products and Warranty

NOTICE

The engine should use the correct specification of fluids and filters. Failure to use the correct specification of fluids and filters could affect your warranty.

When auxiliary devices, accessories, or consumables (filters, additives, catalysts) made by other manufacturers are used on Perkins products, the Perkins warranty is not affected simply because of such use.

However, failures that result from the installation or use of other manufacturers devices, accessories, or consumables are NOT Perkins defects. Therefore, the defects are NOT covered under the Perkins warranty.

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

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

Distillate Fuel Section

Diesel Fuel

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Diesel Fuel Characteristics

Viscosity

The viscosity of the fuel is significant because the fuel serves as a lubricant for fuel system components. Fuels need to have sufficient viscosity. The fuel must lubricate the fuel system in both extremely cold and in extremely hot temperatures.

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

For distillate fuel configured engines, Perkins recommends a fuel viscosity as delivered to rotary fuel injection pumps and high-pressure fuel systems of between 1.4 cSt (min.) and 4.5 cSt (max.).

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.

Cetane Number

The cetane number of the fuel affects the ability of the engine to start. Also, the cetane number affects the interval of time before the engine runs smoothly. Fuels of high cetane rating are easier to ignite. The starting temperature can be improved approximately 7 to 8°C (12 to 15°F) for every increase of ten in the cetane number. Cetane numbers are derived for fuels against proportions of cetane and heptamethylnonane in the standard CFR engine. Refer to “ISO 5165” for the test method.

Note: In Europe for non-road Stage V emissions regulations require minimum Cetane number of 45. In the North America the minimum Cetane number requirement is 40.

Cetane number affect engine cold start ability, exhaust emissions, combustion noise, and altitude performance. Fuel with higher cetane number is desirable and recommended. Higher cetane number fuel is particularly important for operations in cold weather and at high altitude.

Modifying the Cetane Number

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

Additives can also be used to improve the cetane number of a fuel. Additives are evaluated through testing in special test engines. However, the characteristics of fuels with natural cetane number can be different than those characteristics of a fuel addetized to reach the same cetane number. While both fuels may be rated as having the same cetane number, starting may be different.

Cloud Point

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

The cloud point of the fuel is important because the cloud point can limit the performance of the fuel filter. The wax can alter the fuel characteristics in cold weather. Solid wax can fill the fuel filters. The solidified wax will cause filter plugging. Plugged filters cannot remove contaminants from the fuel and hence cannot protect the fuel injection systems. Since fuel must flow through the filters, installing a fuel heater is the most practical way to prevent the problem. A fuel heater will keep the fuel above the cloud point as the fuel flows through the fuel system. The fuel heater will permit the wax to flow through the filters with the fuel.

Modifying the Cloud Point

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

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

Another approach to modify the cloud point is to use cold flow improvement additives. The manufacturer of the fuel can add cold flow improvers to the fuel. Cold flow improvers modify the wax crystals in the fuels. The cold flow improvers do not change the cloud point of the fuel. However, the cold flow improvers keep the wax crystals small enough to pass through standard fuel filters. For mixing precautions, refer to “Pour Point” for more information.

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

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

- “ASTM D2500” Test Method for Cloud Point of Petroleum Products
- “ASTM D5771” Test Method for Cloud Point of Petroleum Products (Optical Detection Stepped Cooling Method)
- “ASTM D5772” Test Method for Cloud Point of Petroleum Products (Linear Cooling Rate Method)
- “ASTM D5773” Test Method for Cloud Point of Petroleum Products (Constant Cooling Rate Method)

Pour Point

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

To measure the pour point, the fuel temperature is lowered below the cloud point in steps of 3°C (5°F) at a time. The temperature is lowered until the fuel does not flow. The pour point is the last temperature that is shown before the flow stops. At the pour point, the wax has solidified out of the fuel. This temperature makes the fuel more solid than liquid. The pour point of the fuel can be improved. This improvement does not require the removal of important elements. This process is the same process that is used to improve the cloud point of a fuel.

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

Modifying the Pour Point

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

The following illustration contains a table that can be used to find the necessary mixture for two fuels with different pour points. This table is true only if the fuels do not have additives which change the pour point. This table may not apply to ultra low sulfur diesel fuels and should be used only as a general guide. To use the table, you must know the exact pour point of each fuel. This specification can change from one purchase of fuel to the next purchase of fuel. This specification is normally available from personnel at the source of the fuel supply. When fuels that have a lower pour point are not available, this method cannot be used.

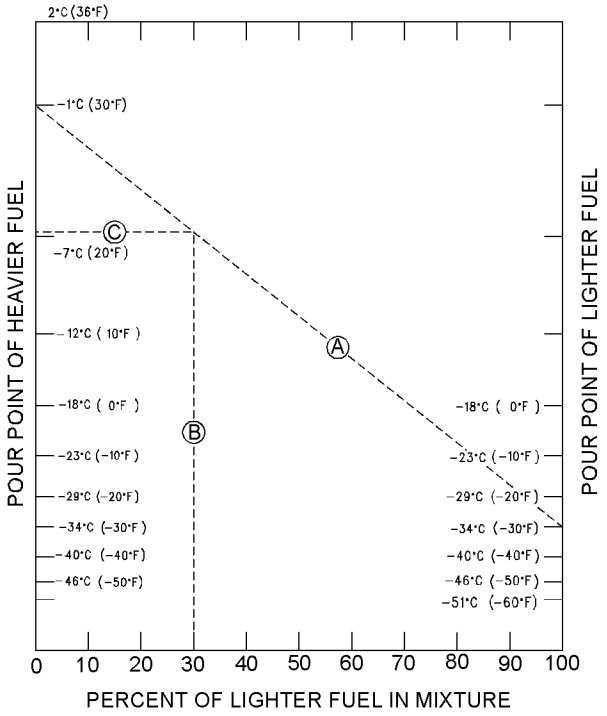


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Pour point of fuel mixtures

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

1. Obtain the specification for the cloud point or the pour point of both fuels from your fuel supplier.

2. Locate the cloud point or the pour point of the heavier fuel on the left side of the table. Mark the point on the table.

3. Locate the cloud point or the pour point of the lighter fuel on the right side of the table. Mark the point on the table.

4. Draw a line between the two points that were established. Label this line “A” .

5. Determine the lowest outside temperature for application operation. Find this point on the left side of the table. Mark this point. Draw a horizontal line from this point. Stop the line at the intersection of line “A” . Label this new line “C” .

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

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

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

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

The standard method to measure the pour point of the fuels is detailed in “ASTM D97 - Standard Test Method for Pour Point of Petroleum Products”.

Lubricity

The lubricity of the fluid describes the ability of the fluid to reduce the friction between surfaces that are under load. This ability reduces the damage that is caused by friction. Fuel injection systems rely on the lubricating properties of the fuel.

Note: The fuel lubricity is important. The lubricity of the fuel should be considered whenever you operate the equipment in temperature extremes, whether extremely hot or extremely cold. Also, you should consider the fuel lubricity whenever you use fuels that are lower in viscosity or that have been hydro-treated. There are many aftermarket additives that are available to treat fuel. If the lubricity of the fuel is an issue, consult your fuel supplier for proper recommendations regarding fuel additives.

The finished fuels as described by Perkins Diesel Fuel Specification, “ASTM D975” or “EN 590” are at the recommended lubricity levels. To determine the lubricity of the fuel, use the “ASTM D6079 High Frequency Reciprocating Rig (HFRR)” test. The maximum allowable wear scar is 0.52 mm (0.0205 inch) at 60° C (140° F). If the lubricity of a fuel does not meet the minimum requirements, consult your fuel supplier. Do not treat the fuel without consulting the fuel supplier. Some additives are not compatible. These additives can cause problems in the fuel system.

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

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

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

Maximum life of the fuel system can be achieved by performing the following tasks: using a preferred distillate diesel fuel, refer to Fuel Recommendations section in this Perkins Diesel Engines Fluids Recommendations, using a reliable fuel supplier and performing proper maintenance of the fuel system. Perkins Advanced Efficiency fuel filters are required for diesel engines that run on diesel fuel to provide maximum life to the fuel system.

Note: Lighter fuels are frequently used in arctic temperatures. Lighter fuels may include the following fuels: Jet A, Jet A-1, JP-8, JP-5, and kerosene. The specifications that apply to these fuels do not include a minimum lubricity requirement. Do not assume that a fuel meets the minimum Perkins 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, which exceeds the limit for sulphur of U.S. ULSD fuel and EU sulphur free diesel at 10 ppm in the EPA Tier 4 and EU Stage III/IV/V regulations as well other higher emissions regulations in other regions.

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

Refer to Additives section, “Fuel Additives” and “Diesel Fuel Conditioner” sections in this Perkins Diesel Engines Fluids Recommendations for more information.

Sulfur Level

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

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

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

The list below provides a quick reference for acceptable sulfur levels for diesel fuel that will be used in Perkins 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 Diesel Oxidation Catalyst (DOC) 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 Operation and Maintenance Manual and refer to the aftertreatment device-specific documentation for more information.
- For application 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:

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

- Maintenance intervals and other maintenance practices

Ultra-Low Sulfur Diesel (ULSD)

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

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

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

ULSD fuel can be used in any engine designed to run on diesel fuel. Perkins 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 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 application (fuel supply tank, transfer pump, transfer hose, nozzle, and others) is properly grounded and bonded is important. Consult with your fuel or fuel system supplier to ensure that the delivery system is in compliance with fueling standards for proper grounding and bonding practices.

The standard methods for testing conductivity of diesel fuel are:

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

Sulfur-free Diesel Fuel

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

Low Sulfur Diesel (LSD)

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

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

Diesel Fuel Sulfur Impacts

Sulfur in the fuel results in the formation of Sulfur Dioxide (SO_2) and Sulfur Trioxide (SO_3) gases during the combustion process. When combined with water in the exhaust gas SO_2 and SO_3 can form acids. The acids can impact engine components and engine lubricants.

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

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

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

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

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

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

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

- All emissions laws, regulations, and mandates are followed
- The engine/engines are not equipped with aftertreatment device/devices
- All appropriate guidelines and maintenance practices as stated in the engine Operation and Maintenance Manual are followed
- All appropriate guidelines and maintenance practices as stated in this Perkins Diesel Engines Fluids Recommendations are followed
- Operating in otherwise low to moderate severity applications
- Your Perkins distributor is consulted and approves
- You refer to this Perkins Diesel Engines Fluids Recommendations, and you refer to your specific Perkins engine and/or refer to your specific application Operation and Maintenance Manual for more guidance and exceptions

Oil Drain Intervals

Note: DO NOT USE ONLY THIS Perkins Diesel Engines Fluids Recommendations AS A BASIS FOR DETERMINING OIL DRAIN INTERVALS.

Fuel sulfur level impacts the oil drain interval. For detailed information, refer to the Oil Analysis section in this Perkins Diesel Engines Fluids Recommendations.

- Oil sampling analysis is recommended.
- Oil sampling analysis is strongly recommended to determine oil drain intervals when using fuel with sulfur levels between 0.05 percent (500 ppm) and 0.5 percent (5000 ppm).
- Oil sampling analysis is required to determine oil drain intervals when using fuel with sulfur levels above 0.5 percent (5000 ppm).
- Consult your Perkins distributor for guidance when fuel sulfur levels are above 0.1% (1000 ppm).

Volatility

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

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

Contamination

Problems with fuel filters can occur at any time. The cause of the problem can be water in the fuel or moisture in the fuel. At low temperatures, moisture causes special problems. There are three types of moisture in fuel: dissolved moisture (moisture in solution), free and dispersed moisture in the fuel and free and settled 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 mg/kg or 0.003 percent) at 4°C (40°F).

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

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

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

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

1. Remove the fuel filters.

2. Cut the fuel filters open.

3. Inspect the fuel filter before the filter warms. This inspection will show that the filter is filled with particles of either ice or wax.

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

Specific Gravity / API Gravity

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

Note: The settings for the fuel mixture should not be adjusted to compensate for a loss of power with fuels that are lighter. The life of fuel system components can be decreased with fuels that are very light because lubrication will be less effective as a result of the lower viscosity. This issue is compounded if the fuel does not have sufficient lubricity. Refer to “Lubricity and Low Sulfur Fuel Diesel (LSD) and Ultra Low Sulfur Diesel (ULSD) Fuel” in this Perkins Diesel Engines Fluids Recommendations Characteristics Of Diesel Fuel section.

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 the fuel tank. Alcohol or gasoline must not be used in order to dilute diesel fuel. Failure to follow this instruction may result in death or personal injury.

NOTICE

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

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

Gums and Resins

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

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

Stability

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

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

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

Biodiesel and blends of biodiesel have poor thermal stability and oxidation stability compared to petroleum distillate diesel fuels. The use of these biodiesels and blends of biodiesel can accelerate the problems that are addressed in this Perkins Diesel Engines Fluids Recommendations. 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 Perkins Diesel Engines Fluids Recommendations. But darkened fuel color can be an indicator of degradation leading to concerns about the stability of darkened fuel. Thermal oxidation and oxidative stability tests should be run to confirm actual fuel degradation.

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

Aviation Kerosene Fuels

Following kerosene and jet fuel specifications are acceptable alternative fuels, and may be used on a contingency base for emergency or continuous use, where standard diesel fuel is not available and where legislation allows their use:

- “MIL-DTL-83133 NATO F34 (JP-8)”
- “MIL-DTL-83133 NATO F35”
- “MIL-DTL-5624 NATO F44 (JP-5)”
- “MIL-DTL-38219 (USAF) (JP7)”
- “NATO F63”
- “NATO XF63”
- “ASTM D1655 JET A”
- “ASTM D1655 JET A1”

These fuels specifications may be used in engine models up to and including Tier 3/ Stage 3A engines (or any engine models that are NOT equipped with aftertreatment system). Jet fuels have not been released for EPA Tier 4 / EU Stage IIIb/IV/V and other higher emissions regulations, engine models equipped with aftertreatment system as it will affect performance and could lead to the damage of the aftertreatment system.

NOTICE
These fuels are only acceptable when used with appropriate lubricity additive and must meet minimum requirements of the “Perkins Specification for Distillate Fuel for Nonroad Diesel Engines” listed in table in Distillate Diesel Fuel section of this Perkins Diesel Engines Fluids Recommendations. The lubricity of these fuels must not exceed wear scar diameter of 0.46 mm (0.01811 inch) as per “ISO 12156-1” . Refer to the “Lubricity” section of this Perkins Diesel Engines Fluids Recommendations.

Note: Minimum cetane number of 40 is recommended otherwise cold starting problems or light load misfire might occur. Since jet fuel specifications do not mention cetane requirements, it is recommended that a fuel sample is taken to determine the cetane number.

Note: Fuels must have minimum viscosity of 1.4 cSt delivered to the fuel injection pump. Cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. It is recommended that the actual viscosity of the fuel is measured to determine if a fuel cooler is needed. Refer to “Viscosity” section of this Perkins Diesel Engines Fluids Recommendations.

Note: Rated power loss of up to 10 percent is possible due to lower density and lower viscosity of jet fuels compared to diesel fuels.

The user must be aware of the following when using these fuels. Jet fuels are distilled at lower temperatures than diesel fuel oils and hence will have lower viscosity, density, and lubricating properties. Jet fuels may cause reduced engine life and performance:

- Reduction in fuel pump life and injectors life due to low lubricity and viscosity
- Loss in power (up to 10 percent) caused by low density and viscosity
- Increased fuel consumption
- Possible hot restart problems due to low viscosity
- Possible cold start problems due to low cetane number
- Possible light loads misfire due to low cetane number

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Diesel Fuel Specifications

Using the Perkins 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 is either is being used or is to be used, tested per the Perkins distillate diesel fuel specification.
- Use the Perkins 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 Perkins fuel specification limits have explainable consequences.

- Some fuel parameters that are outside of the specification limits can be compensated for (for example, fuel can be cooled to address low viscosity and soon).
- Some fuel parameters that are outside of specification limits, may be improved with the use of appropriate amounts of well-proven fuel additives.

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

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

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

In North America, diesel fuels that are identified as meeting the latest version of “ASTM D975” Grades No. 1-D or No. 2-D (all listed sulfur levels) generally meet the “Perkins Specification for Distillate Fuel for Nonroad Diesel Engines” table 1 requirements.

In Europe, diesel fuels that are identified as meeting the latest version of “European Standard EN590” generally meet the “Perkins Specification for Distillate Fuel for Nonroad Diesel Engines” table 1 requirements.

“Perkins Specification for Distillate Fuel for Nonroad Diesel Engines” refers to diesel fuels that are distilled from conventional sources (crude oil, shale oil, oil sands, and so on). Diesel fuels from other sources could exhibit detrimental properties that are not defined or controlled by this specification.

Table 1

Perkins Specification for Distillate Fuel for Nonroad Diesel Engines			
Specifications	**Requirements**	**ASTM Test**	**ISO Test**
Aromatics	35% volume, maximum	“D1319”	“ISO 5186”
Ash	0.01% maximum (weight)	“D482”	“ISO 6245”
Density at 15° C (59° F)(1)(2)	800 kg/m^3 minimum 860 kg/m^3 maximum	“D4052”, “D287”	“ISO 3675”, “ISO 12185”
Cetane Number	40 minimum (DI engines)(3)	“D613”	“ISO 5165”
	40minimum (PC engines)		
Cetane Index	40, minimum	“D976”	“ISO 4264”
Flash Point	legal limit	“D93”	“ISO 2719”
Carbon Residue on 10% distillation residue - Ramsbottom, % mass	0.30% mass, maximum	“D524”	“ISO 10370”
Oxidation Stability	25 g/m^3, maximum	“D2274”	“ISO 12205”
Thermal Stability	Minimum of 80% reflectance after aging for 180 minutes at 150° C (302° F)	“D6468”, “D3241”	No equivalent test
Copper Strip Corrosion (Control temperature 50° C (122° F) minimum)	No. 3 maximum	“D130”	“ISO 2160”
Distillation, vol recovered	10%, Record	“D86”	“ISO 3405”
	90% at 360° C (680° F) maximum (4)		
	90% at 350° C (662° F) maximum (4)		
Lubricity (HFRR Wear Scar)	0.52 mm (0.0205 inch) maximum at 60° C (140° F)	“D6079”/“D7688”	“ISO 12156–1.3”
Pour Point	6°C (10°F) minimum below ambient temperature	“D97”	
Cloud Point	The cloud point must not exceed the lowest expected ambient temperature.	“D2500”	“ISO 3015”
Sulfur by weight	(5)	“D5453”, “D2622”, “D129” (based on the sulfer level)	“ISO 20846”, “ISO 20884”
Kinematic Viscosity at 40° C (104° F) for fuel delivered to the fuel injection pump	1.4 mm^2/s (cSt) minimum and 4.5 mm^2/s (cSt) maximum	“D445”	“ISO 3104”
Contaminants			
Solids	10 mg/l	“D6217”	“ISO 12662”
Sediment	0.05% maximum (weight)	“D473”	No Equivalent Test
Water/Sediment	0.05% maximum	“D2709”	“ISO 3734”
Water	0.02% maximum	“D1744”	“ISO 12937”

(continued)

(Table 1, contd)

Perkins Specification for Distillate Fuel for Nonroad Diesel Engines			
Specifications	**Requirements**	**ASTM Test**	**ISO Test**
Cleanliness	(6)	“D7619”	“ISO 4406”
Appearance	Clear and Bright	“D4176”	No equivalent test

(1) The equivalent API gravity of 875.7 kg/m^3 is 30 and for 801.3 kg/m^3 is 45 (per “ASTM D287” test method temperature of 15.56° C (60° F)).
(2) The density range allowed included # 1 and # 2 diesel fuel grades. Fuel density varies depending on sulfur levels, where high sulfur fuels have higher densities. Some unblended (neat) alternative fuels have lower densities than diesel fuel. This density is acceptable if the other properties of the alternative fuel fall within this specification.
(3) For EU Stage 5 emission regulation minimum Cetane number is 45
(4) Distillation of 90% at 350° C (662° F) maximum is recommended for Tier 4 engines and preferred for all engines. Distillation of 90% at 350° C (662° F) is equivalent to 95% at 360° C (680° F). Distillation of 90% at 360° C (680° F) maximum is 360° C (680° F). Distillation of 90% at 360° C (680° F) maximum is acceptable for Pre-Tier 4 engines.
(5) 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 Perkins distributor for guidance when sulfur levels are above 0.1% (1000 ppm). Certain Perkins 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 Perkins distributor
(6) Recommended cleanliness level for fuel as dispensed into application 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 section

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

Warnings and Notices

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

The “Perkins Specification for Distillate Fuel for Nonroad Diesel Engines” listed in table 1 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, and so on) when used in Perkins diesel engines.

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

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

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

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

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

ULSD fuel or sulfur-free diesel fuels are applicable for use 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 “Diesel Fuel Sulfur Impacts” in the Characteristics of Diesel Fuel section and theLubricant Information of this Perkins Diesel Engines Fluids Recommendations.

Blending waste or used crankcase oil products in to the fuel will raise the sulphur level of the fuel, resulting in the fuel exceeding the regulatory limits and may cause fouling of the fuel system and loss of performance.

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 Perkins ORS designed for large engines). Perkins 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.

ULSD and any other fuel used in Perkins engines have to be properly formulated and addetized by the fuel supplier and have to meet the requirements as detailed in this Perkins Diesel Engines Fluids Recommendations. Fuels that are defined as “ASTM D975” Grade No. 1-D S15 or “ASTM D975” Grade No. 2-D S15 generally meets Perkins requirements for ULSD.

Refer to this Perkins Diesel Engines Fluids Recommendations Characteristics Of Diesel Fuel section for more pertinent information concerning fuel lubricity, fuel oxidative stability, fuel sulfur, and aftertreatment devices. Also refer to the latest version of “ASTM D975” , the latest version of “EN 590”, the specific engine Operation and Maintenance Manual, and to aftertreatment device documentation for guidance.

Note: Perkins strongly recommends the filtration of distillate fuel and/or biodiesel/biodiesel blends through a fuel filter with a rating of four microns absolute or less. This filtration should be on the device that dispenses the fuel to the fuel tank for the engine, and also on the device that dispenses fuel from the bulk storage tank. Series filtration is recommended. Perkins recommends that the fuel dispensed into the application 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 Perkins 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 “Perkins Specification for Distillate Fuel for Nonroad Diesel Engines” listed in table 1 . Ensure that all the footnotes are read and understood.

For further guidance related to many of the fuel characteristics that are listed, refer to “Perkins Specification for Distillate Fuel for Nonroad Diesel Engines” listed in table 1 .

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

NOTICE
To meet expected fuel system component life, 4 micron absolute or less secondary fuel filtration is required for all Perkins diesel engines that are equipped with high-pressure fuel systems. Also, 4 micron absolute or less secondary fuel filtration is required for all Perkins diesel engines that are equipped with electronic unit injected fuel systems. For all other Perkins diesel engines (mostly older engines with pump, line and nozzle or mechanical unit injector type fuel systems), the use of 10 micron absolute or less secondary fuel filtration is strongly recommended.

Note: All current Perkins diesel engines have Perkins Advanced Efficiency fuel filters installed at the manufacturing facility.

⚠ WARNING

Mixing alcohol or gasoline with diesel fuel can produce an explosive mixture in the engine crankcase or the fuel tank. Alcohol or gasoline must not be used in order to dilute diesel fuel. Failure to follow this instruction may result in death or personal injury.

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Diesel Fuel Application

Heavy Fuel Oil

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

Cold-Weather Applications

In extreme cold ambient conditions, you may choose to use the distillate fuels that are specified in table 2 . However, the fuel that is selected must meet the requirements that are specified in the “Perkins Specification for Distillate Fuel for Nonroad Diesel Engines” listed in table 2 . These fuels are intended to be used in operating temperatures that are down to −54 °C (−65 °F).

Note: The fuels that are listed in table 2 may have higher sulfur levels than the 15 ppm maximum sulfur allowed for ULSD. The sulfur levels for these fuels may exceed 50 ppm maximum sulfur allowed in “EN590:2004”. These fuels may not be acceptable for use in areas that restrict maximum fuel sulfur levels to 15 ppm maximum or to 50 ppm maximum.

The jet fuels described in Table 2 are of lower viscosity than “ASTM D975” Grade No. 2 diesel. To meet the viscosity requirements given in table 2 , cooling of the fuel may be required to maintain 1.4 cSt or greater viscosity at the fuel injection pump. Ensure that the lubricity of these fuels is per the requirements given in table 2 . Consult the supplier for the recommended additives to maintain the proper fuel lubricity.

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

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

Table 2

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

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

Note: Fuel cooling may be required to maintain the minimum viscosity of 1.4mm^2/s (cSt) at the fuel injection pump.

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

These fuels specifications may be used in engine models up to and including Tier 3/ Stage 3A engines (or any engine models that are NOT equipped with aftertreatment system). Jet fuels have not been released for EPA Tier 4 / EU Stage IIIb/IV/V and other higher emissions regulations, engine models equipped with aftertreatment system as it will affect performance and could lead to the damage of the aftertreatment system.

Starting Aids

The use of a starting aid is a conventional method of assistance for cold starts in low temperature conditions. Various starting aids are available for Perkins engines. Follow the recommendations that are provided by the manufacturer of the starting aid. Refer to the “Aftermarket Products and Warranty” article in the Warranty Information section of this special publication.

Engine Coolant Heaters

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

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

Fuel Heaters

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

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

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

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

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

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

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

⚠ WARNING

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

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

For additional information on fuel heaters, consult your Perkins distributor.

De-icers

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

Diesel Fuels for Marine Engines

The information and guidelines given in this section of the Perkins Diesel Engines Fluids Recommendations apply to marine engines that use diesel fuels. Follow these guidelines to reduce the risk of engine downtime. Refer to your engine Operation and Maintenance Manual for details specific to your marine engine. Consult your Perkins distributor 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, 2015ships 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 the engine Operation and Maintenance Manual for fuels information for your engine.

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

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

Alternative Fuels Section

Biodiesel Fuel

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Biodiesel Fuel General Information

Biodiesel Blends

Table 3

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

(1) Refer to this Special Publication, Biodiesel Fuel Application section

NOTICE
These recommendations are subject to change without notice. Consult your local Perkins distributor for the most up-to-date recommendations.

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

Example:

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

The quality of biodiesel fuel is critical to its successful use. Biodiesel fuel that is not per the specification that is detailed in this Perkins Diesel Engines Fluids Recommendations , “Biodiesel Fuel Specifications" section may result in performance issues and engine downtime.

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

Biodiesel fuels covered in this section are acceptable for use in Perkins engines per the guidance and recommendations given. Applicable specifications, blend levels, and guidance for biodiesel fuels are detailed in this Perkins Diesel Engines Fluids Recommendations.

Table 4

Biodiesel Fuel Quality Recommendations for Perkins Engines		
Fuel	**Specification(1)**	**Details**
B5 (2)	Perkins Distillate Diesel Fuel Specification or “ASTM D975” or “EN590”	A blend of 5 percent by volume of B100 and 95 percent by volume of diesel fuel.
B20	“ASTM D7467” or “EN16709” and “API gravity 30-45”	A blend of 20 percent by volume of B100 and 80 percent by volume of diesel fuel.
B30	“EN16709” and “API gravity 30-45”	A blend of 30 percent by volume of B100 and 70 percent by volume of diesel fuel.
B100	Perkins Distillate Diesel Fuel Specification (3) or “ASTM D6751” or “EN14214”	Neat biodiesel fuel (100 percent) used for blending with diesel fuel to get the desired blend level.
Distillate Diesel Fuel	Perkins Distillate Diesel Fuel Specification, (4)	Diesel fuel used for blending with biodiesel fuel to get the desired blend level.

(1) Some regions or countries may have their own fuel specifications. Follow the local requirements and regulations and use the fuel of highest quality.
(2) The same specifications also apply to B7 and B8, which are common blend levels in some regions.
(3) Refer to table Perkins Diesel Engines Fluids Recommendations , “Biodiesel Fuel Specifications".
(4) Refer to table 9, Perkins Specification for Distillate Fuel for Off-Highway Diesel Engines of this Perkins Diesel Engines Fluids Recommendations.

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

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

- “ASTM D7371” - “Test Method for Determination of Biodiesel (Fatty Acid Methyl Esters) Content in Diesel Fuel Oil Using Mid Infrared Spectroscopy (FTIR-ATR-PLS Method)”
- “EN 14078” - “Liquid Petroleum Products - Determination of fatty acid methyl esters (FAME) in middle distillates -Infrared spectroscopy method”

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

NOTICE
These recommendations are subject to change without notice. Consult your local Perkins distributor for the most up-to-date recommendations.

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

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

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

Biodiesel fuel that meets Perkins and industry recommended specifications. Refer to table (Refer to Perkins Diesel Engines Fluids Recommendations , “Biodiesel Fuel Specifications"). Biodiesel fuel that meets Perkins and industry recommended specifications offers the following advantages:

- Renewable fuel, nontoxic, and biodegradable
- Reduces tailpipe Particulate Matter (PM), Hydrocarbon (HC), and Carbon Monoxide (CO) emissions from most modern diesel engines
- High lubricity, hence reduces friction
- High cetane number

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

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

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

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

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

Cleanliness

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

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

Perkins Diesel Fuel System Cleaner (Part number T400012). Perkins, used as needed or on an on-going basis, is most effective at cleaning and preventing the formation of fuel-related deposits.

Refer to the “Fuels Additives” section in this Perkins Diesel Engines Fluids Recommendations for additional information. Consult your Perkins distributor for availability of Perkins Diesel Fuel System Cleaner. In case a fuel conditioner is needed to improve certain fuel properties, consult with your fuel supplier or with a reputable provider.

In North America, obtain biodiesel from BQ-9000 accredited producers and BQ-9000 certified marketers. Look for the BQ-9000 biodiesel quality accreditation program certification logo that is available to distributors that meet the requirements of BQ-9000. In other areas of the world, the use of biodiesel that is BQ-9000 accredited and certified, or that is accredited and certified by a comparable biodiesel quality body to meet similar biodiesel quality control standards, is required. For more information on the BQ-9000 program, go to:

http://www.BQ-9000.org

Storage and Maintenance

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

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

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

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

Impact on Engine Oil

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

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

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

To reduce any potential impact of biodiesel fuel dilution on crankcase oil, **the use of oil analysis is strongly recommended when up to B20 (20 percent) and lower biodiesel blends are used, and required when using biodiesel/biodiesel blends that are B20 or above.** When requesting oil analysis, be sure to note the level of biodiesel being used (B5, B20, and so on).

Aftertreatment

Biodiesel fuels as defined in the current ASTM specifications, may contain phosphorous, alkali and alkaline metals (sodium, potassium, calcium, and magnesium) due to processing techniques or due to the natural contents of the biodiesel feedstock. When present in biodiesel, these metals form ash upon combustion in the engine. The ash accumulates in the aftertreatment systems such as Diesel Particulate Filters (DPF), DOC or other systems. The ash can affect the life and performance of aftertreatment emissions control devices and may cause the need for more frequent ash service intervals. For these reasons, biodiesel fuels that contain ash forming metals, even at the concentration levels defined in the current specifications, are limited to B20 blend levels in the engines with aftertreatment devices.

Local and regional regulations may also restrict the blend levels allowed in engines of certain emissions levels.

EU Stage V regulations REQUIRE the biodiesel blends used in engines operated within the European Union (EU) to be ≤ 8 percent volume/volume unless specified otherwise in the engine Operation and Maintenance Manual

Note: Note that some Perkins engines that are certified per EU Stage V can use up to B20 biodiesel blends. Refer to the engine or machine Operation and Maintenance Manual, PerkinsDiesel Engines Fluids Recommendations, “Biodiesel Fuel Application"and Perkins Diesel Engines Fluids Recommendations , “Biodiesel Fuel Specifications".

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

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

Additives

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

Biodiesel fuel must be per the quality recommendations given in Perkins Diesel Engines Fluids Recommendations , “Biodiesel Fuel Specifications". Otherwise, the fuel may result in performance issues and engine downtime.

Perkins strongly recommends that Perkins Diesel Fuel System Cleaner be used with biodiesel and biodiesel blends. Perkins Diesel Fuel System Cleaner is suitable for use with biodiesel or biodiesel blends that meet Perkins biodiesel recommendations and requirements. Refer to Perkins Diesel Engines Fluids Recommendations, “Additives” section for further information on Perkins additive recommendations.

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

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Biodiesel Fuel Characteristics

Stability

Biodiesel fuels key difference from diesel fuel is the ester chemical group (contains two oxygen atoms) in every biodiesel molecule. Biodiesel may also have double bonds (unsaturation) in the carbon chain that can vary based on the feedstock. Due to the ester chemical group and the unsaturation, the oxidation stability of biodiesel fuels is typically lower than that of diesel fuel. The oxidation stability of biodiesel and biodiesel blends is controlled in ASTM specifications, “D6751” for B100 and “D5467” for B20. Biodiesel fuels that do not conform to these specifications can oxidize quickly during use due to the high temperature and pressure conditions in the engine or during storage and handling practices. Oxidized biodiesel forms acids, gums, high viscosity and deposits, which can plug filters, form deposits, particularly in the fuel injector, and reduce the performance of fuel systems. **Biodiesel fuels meeting or exceeding the oxidation stability limits is critical** to avoid poor performance and downtime of engines.

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

Perkins Diesel Fuel System Cleaner (Part number T400012). Perkins, used as needed or on an on-going basis, is most effective at cleaning and preventing the formation of fuel-related deposits.

Refer to the “Perkins Diesel Fuel System Cleaner” topic in the Distillate Diesel Fuel section of this Perkins Diesel Engines Fluids Recommendations for additional information. Consult your Perkins distributor for availability of Perkins Diesel Fuel System Cleaner. In case a fuel conditioner is needed to improve certain fuel properties, consult with your fuel supplier or with a reputable provider.

If additional information is needed on diesel fuel characteristics, refer to Perkins Diesel Engines Fluids Recommendations, “Diesel Fuel Characteristics".

Equipment Impact

Guidelines

Information provided in Table 5 refers to biodiesel and biodiesel blends that fully comply with the appropriate specifications as described in the Biodiesel Fuel section of this Perkins Diesel Engines Fluids Recommendations and to handling and maintenance procedures that follow recommended guidelines.

Table 5

Guidelines and Potential Impacts Associated with the Use of Biodiesel and Biodiesel Blends In Perkins Engines(1)					
Paragraph reference	**Impact**	**B8-B20**	**B21-B30**	**B31-B50**	**B51-B100**
1	Reduction of oil change interval	No risk	Not noted in Perkins engines	Medium	High
2	Fuel filters compatibility risk	No risk	Not noted in Perkins engines	Medium risk	Medium risk
3	Loosening of fuel systems deposits upon conversion to biodiesel	More than ULSD	Medium	High	High
4	Bulk filtration of biodiesel	≤4 microns absolute, required	≤4 microns absolute required	≤4 microns absolute required	≤4 microns absolute required
5	Energy content of biodiesel	Minor loss of 1-2 percent	Minor loss of 1-2 percent	Potentially detectable loss of 2-4 percent	Detectable loss of 5-8 percent
6	Elastomers compatibility	Not noted in Perkins engines with required material	Not noted in Perkins engines with required material	Not noted in Perkins engines with required material	Not noted in Perkins engines with required material
7	Hose compatibility	Low risk of softening	Softening may occur	Softening is likely	Softening is likely
8	Low ambient temperature issues for both storage and operation	Gelling can start higher than 0 °C(32 °F)	Gelling at increasing temperatures compared to diesel fuel	Gelling at increasing temperatures compared to diesel fuel	Gelling at increasing Temperature, -2 to 18 °C
9	Oxidation stability-Injector deposits	Not noted in Perkins engines	Not noted in Perkins engines	Increasing risk	Increasing risk
10	Oxidation stability-Duration of storage(2)	8 months - start testing at 4 months(5)	8 months - start testing at 4 months(5)	6 months - start testing at 2 months(3)(4)	4 months - start testing at 2 months(5)(6)

(continued)

(Table 5, contd)

Guidelines and Potential Impacts Associated with the Use of Biodiesel and Biodiesel Blends In Perkins Engines[1]					
Paragraph reference	**Impact**	**B8-B20**	**B21-B30**	**B31-B50**	**B51-B100**
11	Use in engines with limited operational time	Unacceptable[8]	Unacceptable[8]	Unacceptable[7]	Unacceptable[8]
12	Microbial contamination and growth	Increasing. Testing required - treat at trace levels	Increasing. Testing required - treat at trace levels	High. Testing required - treat at trace levels	High. Testing required - treat at trace levels
13	Need for water removal	Increasing	Increasing	High	High
14	Metal incompatibility	Incompatible with certain materials	Incompatible with certain materials	Incompatible with certain materials	Incompatible with certain materials
15	Glycerides, total, free, mono, di (if not per spec)	Detectable impact	Detectable impact	Medium impact	High impact

(1) Information provided in this Table refers to biodiesel and biodiesel blends that fully comply with the appropriate specifications as described in Special Publication, “Biodiesel Fuel Specifications" and per following recommended maintenance procedures.
(2) Testing of biodiesel or biodiesel blend during storage is strongly recommended. Tests should include oxidation, acid number, viscosity and sediments. Tests should be conducted periodically to ensure biodiesel is per specification. Antioxidants are allowed to improve stability. Consult with your fuel supplier for more information.
(3) Testing is recommended at the indicated duration of storage and on a monthly basis thereafter. Tests should include oxidation, acid number, viscosity and sediments.
(4) B100 should be stored at temperatures of 3 degrees C to 6 degrees C (5 degrees F to 10 degrees F) above the cloud point.
(5) Testing is recommended at the indicated duration of storage and on a monthly basis thereafter. Tests should include oxidation, acid number, viscosity and sediments.
(6) 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.
(7) If B30, B40, or B50 are used in engines of limited operational time, it is recommended that a stabilizer additive is added at the beginning of the storage period. Follow all storage recommendations.
(8) If B30 or B35 are used in engines of limited operational time, it is recommended that a stabilizer additive is added at the beginning of the storage period. Follow all storage recommendations.

The following are details of the Risks and Guidelines that are listed in Table 5 . Refer to the paragraph reference numbers:

1. When using biodiesel fuel, dilution of oil by the fuel may increase as detailed in this Chapter. Use oil analysis to monitor the condition of the engine oil. Oil analysis will also help determine the oil change interval that is optimum. Use of analysis is strongly recommended for up to B20 biodiesel blends and required for blends >B20.

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

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

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

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

5. Neat biodiesel (B100) typically provides less energy per gallon compared to diesel fuels. The energy content of B100 is 5 percent to 8 percent lower than No. 2 diesel fuel. The energy content of B20 (and B35 where mandated) is 1 percent to 2 percent lower than No. 2 diesel fuel, which is not significant. Do NOT attempt to change the engine rating to compensate for the power loss. Any adjustments to the engine in service may result in violation of emissions regulations such as the U.S. EPA anti- tampering provisions. Also, if any tempering with the engine ratings occurs, problems may occur when the engine is converted back to 100 percent distillate diesel fuel.

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

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

7. Nitrile hoses typically used in some fuel transfer lines are not compatible with biodiesel. Hoses exposed to biodiesel and biodiesel blends may soften and may show some beading of fluid on the outside of the hose. Monitor the condition of the hoses and confirm with the hose manufacturer that the hoses are compatible with the biodiesel blend used. If necessary, replace with hoses of compatible materials. Consult with Perkins distributor for appropriate hose materials.

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

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

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

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

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

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

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

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

11. Due to limited oxidation stability and other potential issues, engines with limited operational time and seasonal use should either not use biodiesel/ biodiesel blends or, while accepting some risk, limit biodiesel to a maximum of B5. Examples of applications that should limit the use of biodiesel are the following: Standby Generator sets and certain emergency vehicles, school buses, farm machinery, etc. For more information, refer to the “Seasonal Operation” section.

a. For standby generator sets and emergency vehicles that use biodiesel, sample the fuel in the engine tank monthly. Test the fuel for acid number and oxidation stability. If the test results show that the fuel is degraded and not in specification (provided in Special Publication, “Biodiesel Fuel Specifications" in this “Alternative Fuels” section), drain the tank, and flush the engine by running with high-quality fuel.

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

12. Biodiesel is prone to microbial contamination and growth due to the chemical nature. Microbial contamination and growth can cause corrosion in the fuel system and premature plugging of the fuel filter. Consult your supplier of fuel and additive for assistance in selecting appropriate anti-microbial additives. Use anti-microbial additives at the first sign of detection. The cleaning process will be more effective if the biocide is used before extensive growth of microorganisms.

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

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

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

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

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

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Biodiesel Fuel Specifications

Specifications

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

The final blend of biodiesel as used in the engine must meet the requirements that are stated in table 6 in this Biodiesel section.

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

Table 6

Specification for Neat (B100) Biodiesel Blending Fuel				
Property	**Test Method, United States**	**Test Method, International**	**Units**	**Limits, B100 Blending Fuel**
Density at 15°C	“ASTM D1298”	“ISO 3675”	g/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	-	-	-	6 °C (10 °F) minimum below ambient temperature
- Summer	“ASTM D97”	“ISO 3016”	°C	
- Winter				
Cloud Point	“ASTM D2500”	-	°C	Report
Sulfur Content(1)	“ASTM D5453”	“ISO 20846” “ISO 20884”	Percent weight	0.0015(2) maximum
Distillation	-	-	-	-
T90	“ASTM D86”	“ISO 3924”	°C	360
Cetane Number	“ASTM D613”	“ISO 5165”	Percent evaporation	45 minimum
Sulfated Ash	“ASTM D874” or	“ISO 3987” or “ISO 6245”	percent weight	0.02 maximum
Water and Sediment	“ASTM D2709”	“ISO 12937”	percent volume	0.050 maximum
Water	“ASTM D1796”	“ISO 12937”	percent m/m	0.050 maximum
Copper Corrosion, 3 hours at 50°C	“ASTM D130”	“ISO 2160”		No. 1
Oxidation Stability	“EN 14112” or “EN 15751”	“EN 14112” or “EN 15751”	hours	3 minimum
Ramsbottom Carbon Residue on 10% bottoms	“ASTM D524”	“EN 10370”	percent m/m	0.30 maximum
Carbon Residue, Conradson (CCR)	“ASTM D4530”	“EN 10370”	percent weight	0.05 maximum
Esterification	“ASTM D7371” or “"ASTM D7806"”	“EN 14103”	percent volume	97.5 minimum
Total Acid Number	“ASTM D664”	“EN 14104”	mg KOH/g	0.5 maximum
Methanol Content	“EN 14110”	“EN 14110”	percent weight	0.2 maximum
Monoglycerides	“ASTM D6584”	“EN 14105”	percent weight	0.8 maximum
Diglycerides	“ASTM D6584”	“EN 14105”	percent weight	0.2 maximum
Triglycerides	“ASTM D6584”	“EN 14105”	percent weight	0.2 maximum
Free Glycerin	“ASTM D6584”	“EN 14105”	percent weight	0.02 maximum
Total Glycerin	“ASTM D6584”	“EN 14105”	percent weight	0.240 maximum
Phosphorus Content	“ASTM D4951”	“EN 14107”	percent weight	0.001 maximum
Calcium plus Magnesium	“EN 14538”	“EN 14538”	ppm	5 maximum
Sodium plus Potassium	“EN 14538”	“EN 14538”	ppm	5 maximum
Cold Soak Filterability	“ASTM D7501”	–	seconds	360 maximum
Cleanliness	“ASTM D7619”	“ISO 4406”	–	(3)

(continued)

(Table 6, contd)

Specification for Neat (B100) Biodiesel Blending Fuel				
Property	**Test Method, United States**	**Test Method, International**	**Units**	**Limits, B100 Blending Fuel**
Total contamination	“"EN 12662"”	“EN 14104”	mg / kg	24 maximum
Appearance	“"ASTM D4176"”			Clear and Bright

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

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

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

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Biodiesel Fuel Application

Non-Road Engine Applications

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

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

Understand that some Perkins engines that are certified per EU Stage V can use up to B20 biodiesel blends. Refer to the engine or product-specific Operation and Maintenance Manual and to the information specified within this Perkins Diesel Engines Fluids Recommendations.

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

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

The biodiesel blend levels acceptable for use in Perkins engines in various machines, marine, and locomotive commercial applications are given in Table 7 and Table 8 . Consult your Perkins dealer for further information on compatibility of non-metallic materials such as fuel lines, and other connections to the engine.

Biodiesel fuel must be per the quality recommendations given in this Perkins Diesel Engines Fluids Recommendations, “Biodiesel Fuel Specifications”. Otherwise, the fuel may result in performance issues and engine downtime.

Tier 4 / EU Stage IIIB / China NR4 or Later Emissions Regulations

Table 7 details biodiesel blend levels acceptable for use in Perkins engines for Tier 4, EU Stage IIIB, China NR4, or later emissions regulations. This includes the regional equivalencies to these advanced emissions regulations.

Table 7

Biodiesel Acceptability in Perkins Nonroad Engines for Tier 4 / EU Stage IIIB / China NR4 or Later Emissions Regulations[1]		
Engine Models	**Model Specific**	**Biodiesel Acceptable Blend Levels**
Perkins engine models: 1700 Series2200 Series, 2300 Series, 2400 Series,2500 Series, 2600 Series, and 2800 Series	Engine models with aftertreatment devices	Up to B20 [2]
Perkins 400 Series through 1100 Series (Mechanical Pump Line Nozzle (PLN) Fuel System)	400J Series <19kW engine models without aftertreatment devices	Up to B20 [2] [3]
	400F-E Series, 854 Series, 904EA-E Series, 904J-E Series[3], 1200E- E Series, 1200EA Series, 1200F-E Series, engine models with aftertreatment devices	

[1] Includes the regional equivalencies to Tier 4, EU Stage IIIB, China NR4, or later emissions regulations.
[2] Maximum Biodiesel blend, for which Stage V Type-Approval has been obtained.
[3] 904J-E Series - 106 kW rating may only be operated on ULSD blended with up to 8 percent FAME biodiesel in areas where EU Stage V applies.

Tier 3 / EU Stage IIIA / China NR3 or Earlier Emissions

Table 8 details biodiesel blend levels acceptable for use in Perkins engines for Tier 3, EU Stage IIIA, China NR3, or earlier emissions regulations. This includes the regional equivalencies to these emissions regulations.

Table 8

Biodiesel Acceptability in Perkins Nonroad Engines for Tier 3/ EU Stage IIIA / China NR3 or Earlier Emissions Regulations[1]		
Engine Models	**Model Specific**	**Biodiesel Acceptable Blend Levels**
Perkins engine models: 1300 Series1600 Series, 4000 Series, and 5000 Series	Engine models without aftertreatment devices	Up to B20 [2]
Perkins engine models: 1500 Series, 1700 Series, 2200 Series, 2300 Series, 2400 Series, 2500 Series, and 2800 Series	Engine models without aftertreatment devices	Up to B100 (for use of blends higher than B20, ensure that the fuel is per specification. [3] Consult with your Perkins distributor or Perkins Engines Company Limited for further guidance.
Perkins engine models: 100 Series, 500 Series, 700 Series, 900 Series (3cyl), 1000 Series, New 1000 Series, 3.152 Series, 4.108 Series, 4.154 Series, 4.165 Series, 4.203 Series, 4.236 Series, 4.318 Series, 6.247 Series, 6.354 Series, V8.540 Series, and V8.640 Series	All engine models	Up to B8
Perkins 400 Series through 1100 Series (Mechanical Pump Line Nozzle (PLN) Fuel System)	400C Series, 800C Series, 1103A Series, 1104A Series,1100C Series engine models: Tier 2 / EU Stage II / China NR2 or earlier Emissions Regulation, without aftertreatment devices.	Up to B8
	400A Series, 400D Series, 400F Series, 800D Series, 1106A Series, 1100D Series engine models Tier 3 / EU Stage IIIA / China NR3 Emissions Regulation, without aftertreatment devices	Up to B20 [4]

(continued)

(Table 8, contd)

Perkins engine models: 400 Series through 1200 Series High-Pressure Common-Rail (HPCR) Fuel System	904D-E Series,1100D-E Series, 1200A-E Series, 1200D-E Series engine models without aftertreatment devices	Up to B20 (4)
Perkins engines models: 1104D-E, 1106C-E, and 1106D-E, models NH, NJ, PK, and PJ with a High-Pressure Common-Rail (HPCR) Fuel System	1104D-E engines, models NH, and NJ with engine serial numbers up to N———— U022407S	Up to B8
	1106C-E and 1106D-E models PK, and PJ with engine serial numbers up to N———— U013752S	Up to B8
	1104D-E engines, models NH, and NJ with engine serial numbers from N———— U022408S	Up to B20 (4)

(1) Includes the regional equivalencies to Tier 3, EU Stage IIIA, China NR3, or earlier emissions regulations.
(2) Higher blends, up to B40, where mandated can be used in these engines.
(3) More frequent monitoring of the fuel and engine oil is required to reduce the risk of engine deterioration. Refer to Table 14.
(4) Higher blends, up to B50, where mandated can be used in these engines.

Renewable Diesel

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Renewable Diesel/Hydrotreated Vegetable Oil (HVO)

Table 9

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

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

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

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

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

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

To be applicable in the engine, Perkins recommends that renewable diesel must be per the latest version of any of the following specification:

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

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

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

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

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

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

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

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

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

Synthetic Fuels

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

Table 10

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

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

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

Note: Synthetic fuels covered in this section are different than biodiesel fuel. Biodiesel fuel information is covered in this Perkins Diesel Engines Fluids Recommendations, Biodiesel Fuel section.

To be applicable in the engine, Perkins recommends that renewable and synthetic fuels must be per the latest version of any of the following specification:

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

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

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

Note: Biodiesel (FAME) can be blended with renewable and synthetic fuels to the same equivalent blend level of standard diesel. Refer to the Perkins Diesel Engines Fluids Recommendations, Biodiesel Fuel section for acceptable levels of a specific product.

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

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

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

- No specific conversion process is needed when these fuels are used for the first time or thereafter.
- May reduce the power output of engines due to their low density. up to 5% reduction can be expected at 100%.
- Compatible with aftertreatment technologies such as DPF, DOC, and SCR.

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

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

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Pyrolysis

Pyrolysis Fuels

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

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

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

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

Upgraded pyrolysis fuels that meet Perkins Diesel Fuel specification (Perkins Specification for Distillate Fuel for Nonroad Diesel Engines table), “ASTM D975” and/or “EN 590” specifications can be considered for use in Perkins diesel engines. Refer to this Perkins Diesel Engines Fluids Recommendations for guidelines and requirements for fuels acceptable in Perkins engines. Refer to your Perkins distributor for further information.

Other Fuels

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Heavy Fuel Oil/Residual Fuel/ Blended Fuel

NOTICE

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

Engine Oil Section

Diesel Engine Oil (DEO)

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Diesel Engine Oil (DEO) General Information

NOTICE
These recommendations are subject to change without notice. Consult your local Perkins distributor for the most up-to-date recommendations.

Failure to follow the recommendations found in this Perkins Diesel Engines Fluids Recommendations can cause engine failures, shortened engine service life, and reduced engine performance.

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

- Provide lubrication to the moving components of the engine under a wide range of temperatures and pressures
- Keep the engine components clean and remove wear debris
- Remove heat from the lubricated components
- Neutralize acidic products due to combustion process
- Protect the engine from cavitation and foaming
- Protect the engine from corrosion and rust
- Control Oil Consumption
- Disperse/Solubilize Contaminants (soot)
- Support the regulated engine emissions limits

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

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

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

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

To obtain additional information on Perkins designed and produced filtration products, refer to your Perkins distributor for guidance. Consult your Perkins distributor for assistance with filtration recommendations for your Perkins machine.

Note: To help ensure the maximum expected engine performance and life, use a fluid that meets Perkins highest level of fluid performance as described in this “Perkins Diesel Engines Fluids Recommendations” for the engine. Using a fluid that is considered an acceptable, but lower performing option for typical applications, will provide lower performance.

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

Perkins Fluids

To avoid potential damage to your Perkins engine, only purchase Perkins fluids and Perkins filters through your Perkins distributor or Perkins authorized outlets. For a list of authorized Perkins parts outlets in your area, consult your Perkins distributor.

If you purchase what appear to be Perkins fluids and/or Perkins 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 Perkins product. The product performance and internal quality will typically be very low.

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

Perkins diesel engine oils have been developed and tested by Perkins to increase the performance and the life of Perkins components. The quality of finished oil depends on the quality of the base stock, the quality of the additives and the compatibility of the base stock and additives. Perkins diesel engine oils are formulated of high-quality refined oil base stocks and additives of optimal chemistry and quantity to provide high performance in engines and machine components.

Perkins recommends the use of the following Perkins fluids. The fluids listed below are approved by Perkins, but may not be suited best for every machine application. For information on what fluids best suit a given application, refer to this Perkins Diesel Engines Fluids Recommendations, “Lubricant Viscosities” section for more information.

Table 11

Perkins Lubricants		Viscosity Grade
Diesel Engine Oil-Ultra Low Sulfur (1) (API CK-4)	DEO-ULS	SAE 15W-40
		SAE 10W-30
Diesel Engine Oil (1) (API CI-4/API CI-4PLUS)	DEO	SAE 15W-40
		SAE 10W-30
Diesel Engine Oil (DEO) - Ultra Low Sulfur (ULS) (API CK-4) (2)	DEO-ULS	SAE 15W-40
Diesel Engine Oil (DEO) (API CI-4 / API CI-4PLUS)	DEO	SAE 15W-40

(1) Perkins engine oils exceed the performance requirements of the respective API categories
(2) These oils have changed from API CJ-4 to API CK-4 in early 2017.

Note: More Perkins engine oils may be available.

Note: Perkins engine oil availability will vary by region.

Always consult your Perkins distributor to ensure that you have the current revision level of the publication.

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

Determining Optimum Oil Change Intervals

This Perkins Diesel Engines Fluids Recommendations does not address recommended oil drain intervals. Refer to your engine Operation and Maintenance Manual, and consult your Perkins distributor for additional guidance, including but not limited to guidance on establishing optimized and/or acceptable oil drain intervals.

- Using recommended oils
- Using good fuel
- Using recommended filters
- Using industry standard good maintenance practices
- Following maintenance intervals as detailed in engine Operation and Maintenance Manual

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

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

- Use of Perkins lubricants
- Use of Perkins filters
- Use of oil analysis

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

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

Lubricants for Extended Oil Drains

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

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Diesel Engine Oil (DEO) Characteristics

Selecting the Viscosity

Ambient temperature is the temperature of the air in the immediate vicinity of the engine. This temperature may differ due to the engine application from the generic ambient temperature for a geographic region. When selecting the correct oil viscosity for use, review both the regional ambient temperature and the potential ambient temperature for a given engine application. Generally, use the higher temperature as the criterion for the selection of the oil viscosity. Generally, use the highest oil viscosity that is allowed for the ambient temperature when you start the engine. Refer to the “Lubricant Viscosities for Ambient Temperatures for Perkins Diesel Engines” table 12 for guidance. In cold-weather applications, the preferred method is to use properly sized engine compartment heaters and a higher viscosity grade oil. Thermostatically controlled heaters that circulate the oil are preferred.

The correct oil viscosity grade is determined by the minimum ambient temperature (the air in the immediate vicinity of the engine). To determine the correct oil viscosity grade, refer to the “Min” column in the “Lubricant Viscosities for Ambient Temperatures for Perkins Diesel Engines” table 12 . This information reflects the coldest ambient temperature condition for starting a cold engine and for operating a cold engine. Refer to the “Max” column in the “Lubricant Viscosities for Ambient Temperatures for Perkins Diesel Engines” table 12 to select the oil viscosity grade for operating the engine at the highest temperature that is anticipated. Unless specified otherwise in the tables, use the highest oil viscosity that is allowed for the ambient temperature when you start the engine.

Engines that are operated continuously should use oils that have the highest recommended viscosity. The oils that have the higher oil viscosity will maintain the highest possible oil film thickness. Refer to this Perkins Diesel Engines Fluids Recommendations, “Diesel Engine Oil General Information” section, Perkins Diesel Engines Fluids Recommendations, “Diesel Engine Oil Specifications” section, table 12 , and any associated footnotes. Consult your Perkins distributor if additional information is needed.

Note: SAE 0W and SAE 5W oils, are not recommended for use in engines that are operated continuously and/or are heavily loaded. Refer to the “Lubricant Viscosities for Ambient Temperatures for Perkins Diesel Engines” table 12 for guidance. The oils that have the higher oil viscosity will maintain the highest possible oil film thickness. Consult your Perkins distributor if additional information is needed.

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

Proper oil viscosity AND oil type/specification are required to maximize engine performance and life. Do NOT use only oil viscosity, or only oil type to determine the engine oil selection. Using only the oil viscosity or only the oil type to determine the engine oil selection can lead to reduced performance and engine failure. Refer to the applicable “Lubricant Viscosities for Ambient Temperatures” tables 12 and to ALL of the associated footnotes.

In colder ambient conditions an engine warmup procedure and/or supplemental engine fluid compartment heat may be required. Engine warmup procedures can typically be found in the Operation and Maintenance Manual for the engine. The “Lubricant Viscosities for Ambient Temperatures” tables 12 in this Perkins Diesel Engines Fluids Recommendations include footnotes that address engine warmup.

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

Refer to the minimum temperature in table 12 to determine the required oil viscosity for starting a cold engine. Refer to the maximum temperature to select the oil viscosity for engine operation at the highest ambient temperature that is anticipated.

Refer to this PerkinsDiesel Engines Fluids Recommendations, “Diesel Engine Oil General Information” section for important lubricant information.

Supplemental heat is recommended for cold-soaked starts below the minimum ambient temperature. Supplemental heat may be required for cold-soaked starts that are above the minimum temperature that is stated, depending on the parasitic load and other factors. Cold-soaked starts occur when the engine has not been operated for a time, allowing the oil to become more viscous in cooler ambient temperatures.

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

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

Note: 10W-30 is the preferred viscosity grade for the following diesel engines when the ambient temperature is above −18° C (0° F) and below 40° C (104° F).

- 1300 Series
- 1500 Series
- 1600 Series

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

Table 12

Lubricant Viscosities for Ambient Temperatures for Perkins Diesel Engines[1][2]					
Engine Type	Viscosity Grade	°C		°F	
		Min	Max	Min	Max
Direct Injection (DI) and Pre Combustion (PC)	SAE 0W-40	−40	40	−40	104
	SAE 5W-40	−30	50	−22	122
	SAE 10W-30	−18	40	0	104
	SAE 15W-40	−10	50	14	122

(1) Refer to “Engine Oil”, for information on the recommended and required engine oils for Tier 4 emissions certified engines.
(2) Commercial oils of viscosity grades that are not included in this table may be used, if they are per ECF specifications. Refer to the “Perkins Engine Crankcase Fluids (ECF) Definitions” table in this Perkins Diesel Engines Fluids Recommendations, “Diesel Engine Oil (DEO) Specifications” for more information. Commercial oils are second choice.

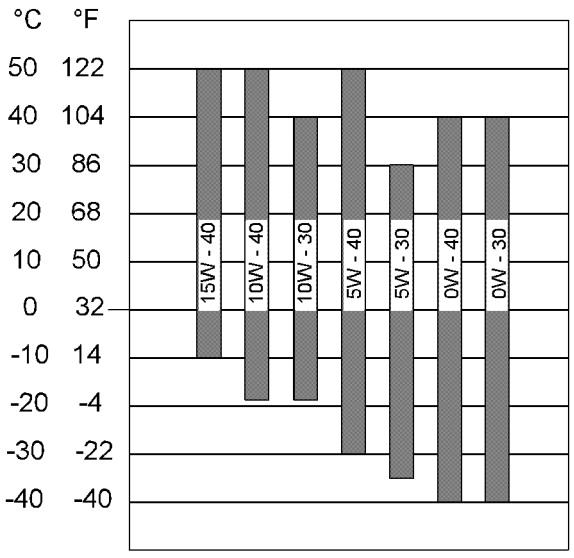


Illustration 2 g06509990

Typical example of Lubricant Viscosities for Ambient Temperatures

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

Refer to this PerkinsDiesel Engines Fluids Recommendations, “Lubricant Viscosities” and “Cold-Weather Lubricants” for additional lubricant information.

Synthetic Basestock Oils

Synthetic base oils are acceptable for use in Perkins engines. **If these oils meet the performance requirements that are specified by Perkins for the engine compartment.**. Each compartment has specific lubrication specifications to ensure proper lubrication and life of the system.

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

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

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

Oil drain intervals for Perkins diesel engines can only be adjusted after an oil analysis program that contains the following data:

- Oil condition, oil contamination, and wear metal analysis (Oil Analysis)
- Trend analysis
- Fuel consumption
- Oil consumption

Refined Basestock Oils

Re-refined basestock oils are acceptable for use in Perkins engines **IF these oils meet the performance requirements that are specified by Perkins.**

Re-refined basestock oils can be used exclusively in finished oil or in a combination with new basestock oils. The US military specifications and the specifications of other heavy equipment manufacturers also allow the use of re-refined basestock oils that meet the same criteria.

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

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

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Diesel Engine Oil (DEO) Specifications

Perkins Diesel Engine Oils Recommendations

Perkins DEO-ULS and Perkins DEO multigrade oils are the preferred oils for use in ALL Perkins diesel engines that are covered by this “Perkins Diesel Engines Fluids Recommendations”. Commercial alternative diesel engine oils are, as a group, acceptable oils.

NOTICE
Perkins 5000 Series engines require the use of API CI-4 engine oil. Failure to use the appropriate specification of engine oil will reduce the life of your engine. It is recommended to use API CI-4 engine oil, otherwise damage to the engine may occur.

Refer to table 13 below for information.

Table 13

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

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

Note: Perkins DEO-ULS (API CK-4) oil is backwards compatible and can be used in all engines with some restrictions related to fuel sulfur level, refer to Table 13 . Perkins DEO (API CI-4/API CI-4 PLUS) can be used in engines that are Tier 3 emissions certified and prior, and in engines that do not use aftertreatment devices.

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

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

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

Note: Each of the ECF specifications provides increased performance over lower ECF specifications. For example, ECF-3 provides higher performance than ECF-2 and ECF-3 provides much higher performance than ECF-1-a. Refer to table 14 for details.

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

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

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

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

Perkins DEO exceeds the limits of API CI-4/CI-4PLUS and API CH-4. Perkins DEO-ULS and Perkins DEO are rigorously tested with full-scale proprietary Perkins engine tests to ensure optimal protection of Perkins diesel engines. The tests include the following:

- Sticking of the piston rings
- Piston deposits
- Oil control tests
- Wear tests
- Soot tests

Proprietary tests help ensure that Perkins oils provide superior performance in Perkins diesel engines.

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

Use appropriate lubricating oils that are compatible with the engine certification and aftertreatment system and with the fuel sulfur levels. Refer to the table, to “Diesel Fuel Sulfur Impacts” section in Characteristics of Diesel Fuel and to Lubricant Information section of this Perkins Diesel Engines Fluids Recommendations.

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

Also, refer to the datasheets for the product for technical details.

Perkins DEO-ULS and Perkins DEO are recommended for all pre-Tier 4 engines that use Ultra Low Sulfur Diesel (ULSD) or Low Sulfur Diesel (LSD) fuels. Perkins DEO / API CI-4 is recommended for engines using fuels of sulfur levels that exceed 0.2 percent (2000 ppm). Perkins DEO-ULS may be used in these applications if an oil analysis program is followed. The oil change interval may be affected by the fuel sulfur level. Refer to table in this section for details.

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

Note: API oil category CF is obsolete. The API (American Petroleum Institute) does not license this category effective end of 2010. API does not validate the quality of API CF oils and does not allow the display of API symbol (also referred to as API doughnut) with CF as highest claim on the oil container.

Consult your Perkins distributor for part numbers and for available sizes of containers.

Commercial Engine Oil

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

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

Note: Commercial oils are, as a group, second choice oils. Within this grouping of second choice oils there are tiered levels of performance.

NOTICE
Perkins does not warrant the quality or performance of nonPerkins fluids.

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

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

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

When fluids made by other manufacturers are used on Perkins products, the Perkins warranty is not affected simply because of such use. Failures that result from the installation or usage of other manufacturer fluids, however, are not Perkins factory defects and therefore are NOT covered by the Perkins warranty. Perkins is not in a position to evaluate the many fluids promoted by other manufacturers and the effect on Perkins products. Installation or use of such items is at the discretion of the customer who assumes ALL risks for the effects that result from this usage.

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

There are significant variations in the quality and performance of commercially available oils. For this reason, Perkins recommends the oils listed in Tables 1 and 3.

When the preferred Perkins diesel engine oils are not used, commercial oils that are API CK-4 licensed and/or meet the requirements of the ECF-1-a, ECF-2, and/or the ECF-3 specification are acceptable for use in Perkins diesel engine, with aftertreatment devices or non-aftertreatment engines using ULSD / LSD fuels.

Oils that are API CJ-4, API CI-4/CI-4 PLUS / ACEA E7 / ACEA E11 and API CH-4, and do not meet any ECF specification are, as a group adequate but **may cause reduced engine life**.

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

Refer to “Perkins Engine Lubricants Recommendations/Requirements” Table 13 for guidance on commercial lubricant usage in Perkins diesel engines

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

API CK-4 oils exceed the performance requirements of prior API categories. Perkins developed the Engine Crankcase Fluid (ECF) specifications to ensure the availability of minimum acceptable performance commercial diesel engine oils. The three ECF specifications: ECF-1-a, ECF-2, and ECF-3 are described in Table 14 . These specifications require more engine tests than the corresponding API categories.

Each higher ECF specification provides increased performance over lower ECF specifications. For example, ECF-3 provides higher performance than ECF-2 and ECF-3 provides much higher performance than ECF-1-a. Refer to table 14 for details.

Table 14 below provides details of Perkins Engine Crankcase Fluids (ECF) specifications.

Table 14

Perkins Engine Crankcase Fluids (ECF) Definitions	
Minimum Performance Requirements for Commercial Oils	**ECF Specifications Requirements[1]**
[2]	API CK-4 Oil Category performance requirements
ECF-3	API CJ-4 Oil Category performance requirements
ECF-2	API CI-4 / CI-4 PLUS Oil Category performance requirements and Passing standard Perkins 2206 engine test per API requirements and Oils of sulfated ash > 1.50 percent are not allowed
ECF-1-a	API CH-4 Oil category performance requirements and for oils that are between 1.30 percent and 1.50 percent sulfated ash, passing one additional (“ASTM D6681”) is required and Oils of sulfated ash > 1.50 percent are not allowed

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

Refer to “Commercial Engine Oil Recommendations” and “The Current American Petroleum Institute (API) Oil Categories” sections of this chapter for information on the API categories and corresponding Perkins engine oils.

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

For engines using fuels of sulfur levels that exceed 0.2 percent (2000 ppm), Perkins recommends Perkins DEO engine oils. However, commercial oils that meet ECF- 2 or ECF-1-a specifications are acceptable. Commercial oils that meet ECF- 3 specifications may be used in these applications if an oil analysis program is followed. The oil change interval is affected by the fuel sulfur level. Refer to table of this Perkins Diesel Engines Fluids Recommendations.

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

To make the correct diesel engine oil viscosity grade choice, refer to “Lubricant Viscosities for Ambient Temperatures” table in the “Diesel Engine Oil Specifications” section of this Perkins Diesel Engines Fluids Recommendations.

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

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

The current licensed oils are:

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

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

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

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

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

To help protect your engine, and to help optimize oil drain intervals for engine applications and duty cycles, use oil analysis. Refer to the section below and to the section on analysis later in this Perkins Diesel Engines Fluids Recommendations.

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

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Diesel Engine Oil (DEO) Applications

Recommendation for US EPA Tier 4 / EU Stage IIIb/IV Certified Nonroad Engines

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

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

- China Nonroad Stage IV

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

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

Note: Note that ACEA E11 oils are validated using some but not all ECF-3 and API CJ-4 standard engine performance tests. Consult your oil supplier when considering use of an oil that is not API CK-4, ECF-3, or API CJ-4 qualified.

The chemical limits are detailed in the “Diesel Engine Oil Specifications” section of this “Perkins Diesel Engines Fluids Recommendations”.

Diesel Fuels

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

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

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

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

The fuels listed above have to meet the performance levels detailed in the Fuel Information for Diesel Engines chapter in this Publication. The Fuel Information for Diesel Engines Chapter also includes the pertinent recommendations for biodiesel fuels in the engines certified to non-road emissions standards listed above.

Recommendation for Europe Stage V Certified Nonroad Engines

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

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

- The sulfur content should not be greater than 10 mg/kg (20 mg/kg) at point of final distribution
- The Cetane number should not be less than 45
- The biodiesel (also called Fatty Acid Methyl Ester (FAME)) content should not be greater than 8 % volume/volume

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

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

Fuel Sulfur Impact on Engine Oil

The use of oil analysis is recommended for determining oil life.

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

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

- Recommended normally
- For fuel sulfur level up to 0.05 percent (500 ppm), no additional sampling is required. Follow the recommended oil sampling in the machine OMM

- For fuel sulfur level of > 0.05 percent to 0.5 percent (500 ppm to 5000 ppm), oil analysis isstrongly recommended to determine oil drain intervals. Sample the oil every 250 hours until a trend is established, then sample as needed.
- For fuel sulfur level of > 0.50 percent (>5000 ppm), oil analysis is required to determine oil drain intervals. Sample oil every 125 hours until a trend is established, then sample as needed.

These recommendations apply for DEO-ULS and DEO oils.

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

The engine oil Total Base Number (TBN) and ash content can impact the oil performance and the oil service interval. Excessive piston deposits can be produced by oil with a high TBN and/or high ash. These deposits can lead to a loss of control of the oil consumption and to the polishing of the cylinder bore. The engine oil TBN can be measured upon special request. However, analysis of used oil for parameters such as oxidation, wear metals, and other typical analysis are strong indicators of the condition of the oil and impacts of fuel sulfur level on its degradation.

Refer to Severe Operation Conditions in this Section of this Perkins Diesel Engines Fluids Recommendations.

Consult a trained analyst when making oil drain decisions based on oil sample results.

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

This Perkins Diesel Engines Fluids Recommendations does not address recommended oil drain intervals, but rather provides guidance that should be used with your specific engine/machine Operation and Maintenance Manuals in determining acceptable oil drain intervals.

Consult your engine/machine Operation and Maintenance Manuals, and consult your Perkin distributor for additional guidance, including but not limited to guidance on establishing optimized and/or acceptable oil drain intervals.

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

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

Severe Applications

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

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

- Reliability
- Service life

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

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

To help ensure the maximum expected engine performance and life, higher performing fluids as described in this Perkins Diesel Engines Fluids Recommendations may be required. Fluids that meet only the minimum performance levels may be allowed for typical applications, but maintenance intervals must be reduced. For the maximum expected engine performance and life and where LSD or ULSD fuels are available, oils meeting the API CK-4 or ECF-3 specification must be used.

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

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

Severe Environmental Factors

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

Severe Operating Conditions

- Frequent operation with inlet air which has a corrosive content
- Operation with inlet air which has a combustible content
- Operation which is outside of the intended application
- Operation with a plugged fuel filter
- Extended operation at low idle (more than 20% of hours)
- Frequent cold starts at temperatures below 0° C (32° F)
- Frequent dry starts (starting after more than 72 hours of shutdown)
- Frequent hot shutdowns (shutting down the engine without the minimum of 2 minutes to 5 minutes of cool down time)
- Operation above the engine rated speed
- Operation below the peak torque speed
- Operating with fuel which does not meet the standards for distillate diesel fuel as stated in Perkins Diesel Engines Fluids Recommendations, “Fuel Recommendations”.
- Operating with a blend of distillate fuel which contains more than 20 percent biodiesel

Fuel Sulfur Impact on Engine Oil

Follow the recommendations given in the "Fuel Sulfur Impact on Engine Oil" section given earlier in this Perkins Diesel Engines Fluids Recommendations in the Engine Oil section.

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

NOTICE
Depending on application severity and localized environmental conditions, and also depending on maintenance practices, operating Direct Injection (DI) diesel engines and operating PC (Precombustion Chamber) diesel engines on fuel with sulfur levels over 0.1 percent (1000 ppm) may require shortened oil change intervals to help maintain adequate wear protection. Refer to this Perkins Diesel Engines Fluids Recommendations, “Diesel Fuel Specifications” section for additional information.

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

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

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

- Inadequate maintenance of fuel storage tanks from causes such as excessive water, sediment, and microorganism growth.
- Extending maintenance intervals beyond the recommended intervals
- Using fluids which are not recommended in Perkins Diesel Engines Fluids Recommendations, M0113102
- Extending maintenance intervals for changing the engine oil and engine coolant without a fluid sampling program
- Extending maintenance intervals for changing air filters, oil filters, and fuel filters
- Failure to use a water separator
- Using non-recommended filters
- Storing the engine for more than 3 months but less than 1 year

For fuel and coolant analysis , refer to the “Distillate Fuel” and “Coolant” section in this Perkins Diesel Engines Fluids Recommendations.

Cold-Weather Applications

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

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

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

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

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

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

Various starting aids are available to assist with cold engine starts in low temperature conditions. Follow the recommendations that are provided by the manufacturer of the starting aid. Refer to the “Aftermarket Products and Warranty” article in the “ Warranty Information” section of this Perkins Diesel Engines Fluids Recommendations.

Additionally, for more information on cold-weather operation, refer to this Perkins Diesel Engines Fluids Recommendations, “Diesel Fuel Specifications” section. Also refer to this Perkins Diesel Engines Fluids Recommendations, “Coolant Specifications”.

Before attempting to start the engine, make sure that the oil in the engine is fluid enough to flow. Check the oil by removing the oil level gauge. If the oil will drip from the oil level gauge, then the oil should be fluid enough to allow the engine to start. Do not use oil that has been diluted with kerosene. Kerosene will evaporate in the engine. Evaporation will cause the oil to thicken. Kerosene will cause swelling and softening of the silicone seals. Kerosene will dilute the oil additives. Dilution of the oil additives will reduce the oil performance, and reduce the engine protection that the additives provide. If your machine is equipped with a gasoline starting engine (earlier machine), make sure that the oil is fluid enough to flow.

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

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

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

Note: Use the highest oil viscosity grade that is allowed for the ambient temperature when you start the engine. If a different oil viscosity grade is specified in “Lubricant Viscosities for Ambient Temperatures”, use the viscosity grade that is specified in the table. **In arctic applications, a properly sized engine compartment heater is recommended and use of a higher viscosity grade oil.** Refer to the “Diesel Engine Oil Specifications” article in this Perkins Diesel Engines Fluids Recommendations for further details.

Note: Cold-soaked starts occur when the engine has not been operated for a time. The oil becomes more viscous due to cooler ambient temperatures. Supplemental heat is recommended for cold-soaked starts that are below the minimum ambient temperatures listed in the “Lubricant Viscosities for Ambient Temperatures” tables. Supplemental heat may be required for cold-soaked starts that are above the minimum temperature that is stated, depending on the parasitic load and other factors.

NOTICE

Engines that use fluid or pan heaters, or heated enclosures, or are kept running under load, etc. can, and generally should use higher viscosity oil. The “Lubricant Viscosities for Ambient Temperatures” tables (Maintenance Section) **Minimum** viscosity for ambient temperature recommendations are for cold-soaked conditions. Use the highest viscosity oil that is allowed for the ambient temperature at startup. **BUT, under continuous usage (multiple shifts per day),** and/or when using **fluid or pan heaters**, use a higher viscosity oil than the minimum recommended viscosity for cold-soaked starting conditions. The higher viscosity oil will maintain the highest possible oil film thickness. Refer to the “Lubricant Viscosities for Ambient Temperatures” tables and the table footnotes for exceptions.

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

NOTICE

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

Warmup Procedures for Machines that are used in Cold Weather (Generic)

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

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

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

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

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

To reduce the total warmup time, start exercising the entire machine before you complete the hydraulic warmup time.

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

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

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

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

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

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

Coolant Section

Engine Coolant

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Coolant General Information

⚠ WARNING

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

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

Avoid contact with coolant.

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

The information provided are the latest recommendations for the Perkins diesel engines that are covered by this Perkins Diesel Engines Fluids Recommendations. This information supersedes all previous recommendations which have been published for the Perkins diesel engines that are covered by this Perkins Diesel Engines Fluids Recommendations. Special fluids are required for some engines and continued use of these special products will be necessary. Refer to the applicable engine Operation and Maintenance Manual for more information.

This publication is a supplement to the engine Operation and Maintenance Manual. This publication does not replace the engine-specific Operation and Maintenance Manuals for the recommended maintenance intervals.

NOTICE
These recommendations are subject to change without notice. Consult your nearest Perkins distributor for the most up-to-date recommendations.

NOTICE
To avoid potential damage to your Perkins engine, only purchase Perkins fluids and Perkins filters through your Perkins distributor or Perkins authorized outlets. For a list of authorized Perkins parts outlets in your area, consult your Perkins distributor.

If you purchase what appear to be Perkins fluids and/or Perkins 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 Perkins product, but the product performance and internal quality will typically be very low.

NOTICE
Commercial products that make generic claims of meeting Perkins requirements without listing the specific Perkins recommendations and requirements that are met, may not provide acceptable performance. Commercial products may cause reduced engine and/or application fluid compartment life. Refer to this Perkins Diesel Engines Fluids Recommendations for Perkins fluids recommendations and requirements. Refer to product-specific Operation and Maintenance Manual for Perkins fluids recommendations and requirements.

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

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

NOTICE
Frequently check the specific gravity of the coolant for proper freeze protection or for anti-boil protection.

Clean the cooling system for the following reasons:

- Contamination of the cooling system
- Overheating of the engine
- Foaming of the coolant

NOTICE
Never operate an engine without water temperature regulators in the cooling system. Water temperature regulators help to maintain the engine coolant at the proper operating temperature. Cooling system problems can develop without water temperature regulators.

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

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

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

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

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

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

Coolant is normally composed of the following elements:

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

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

Coolant Terminology

Extended Life Coolant (ELC) – A coolant that relies largely on organic inhibitors for corrosion and cavitation protection. Carboxylate is an example of organic corrosion and cavitation inhibitors. Perkins ELC, Perkins ELC Advanced, and Perkins ELI in water are extended life coolants that also include nitrites and molybdates for increased cavitation protection.

- Commercial extended life coolants containing silicate do not meet the additional requirements set in this Special Publication for coolants claiming to meet Perkins EC-1 specification.
- Do not use commercial extended life coolants with more than 125 ppm silicon (present in the coolant in the form of silicate).
- Extended life coolants that meet “ASTM D6210-06” may be used at the recommended maximum coolant service life intervals stated in this publication for coolants that meet the ASTM specifications.

Conventional coolant – A coolant that relies largely on inorganic inhibitors for corrosion and cavitation protection. Silicates and nitrites are examples of inorganic inhibitors. Conventional coolants are also referred to as heavy-duty coolants, heavy-duty fully formulated coolants, or traditional coolants. In order to be used in most Perkins cooling systems, conventional coolants must meet “ASTM D6210-06”.

Supplemental Coolant Additive (SCA) – SCA is a general term for a concentrated inorganic inhibitor package. SCA is used for three different purposes:

- To precharge a new conventional coolant that is not fully formulated.
- To provide corrosion protection in water/SCA cooling systems.
- To recharge an in service conventional coolant on a maintenance basis to maintain proper inhibitor levels.

Hybrid Coolant – A coolant in which the corrosion and cavitation protection is based on a mixture of organic and inorganic inhibitors.

Extender – An inhibitor package that is added to extended life coolants, to recharge an in-service coolant. Extenders, typically, only should be added at one half the service life of the coolant.

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Coolant Characteristics

Water

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

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

NOTICE
All Perkins engines that are equipped with a Perkins NOx Reduction System will require a minimum of 50 percent glycol to help prevent cavitation damage and boiling of the engine coolant. These engines include Tier 4 / Stage IIIb / IV / V engines.

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

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

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

If distilled water or deionized water is not available, use water that meets or exceeds the minimum acceptable water requirements that are listed in Table 15 .

Table 15

Perkins Minimum Acceptable Water Requirements		
Property	**Maximum Limit**	**ASTM Test**
Chloride (Cl)	40 mg/L (2.4 grains/US gal)	“D4327”
Sulfate (SO_4)	100 mg/L (5.9 grains/US gal)	“D4327”
Total Hardness	170 mg/L (10 grains/US gal)	“D1126”
Total Solids	340 mg/L (20 grains/US gal)	“Federal Method 2540B”(1)
Acidity	pH of 5.5 to 9.0	“D1293”

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

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

- Local water utility company
- Agricultural agent
- Independent laboratory

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

Additives

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

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

Many additives are depleted during engine operation. These additives must be replaced periodically.

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

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

Glycol

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

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

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

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

Most conventional heavy-duty coolant/antifreezes use ethylene glycol. Propylene glycol may also be used. In a 50 percent by volume of glycol in the finished coolant, ethylene and propylene glycol provide similar protection against freezing and boiling. Refer to tables 16 and 17 .

Note: 100 percent pure glycol will freeze at a temperature of −13 °C (8.6 °F).

Table 16

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

(1) Boiling protection is increased with the use of a pressurized radiator. A system with a 1 bar (14.5 psi) pressure cap at sea level, will increase the final boiling point of 50 percent coolant to 130° C (266° F).

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

Table 17

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

(1) Boiling protection is increased with the use of a pressurized radiator. A system with a 1 bar (14.5 psi) pressure cap at sea level, will increase the final boiling point of 50 percent coolant to 130° C (266° F).

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

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

Testing the Concentration of Glycol

To check the concentration of glycol in the coolant, measure the specific gravity of the coolant.

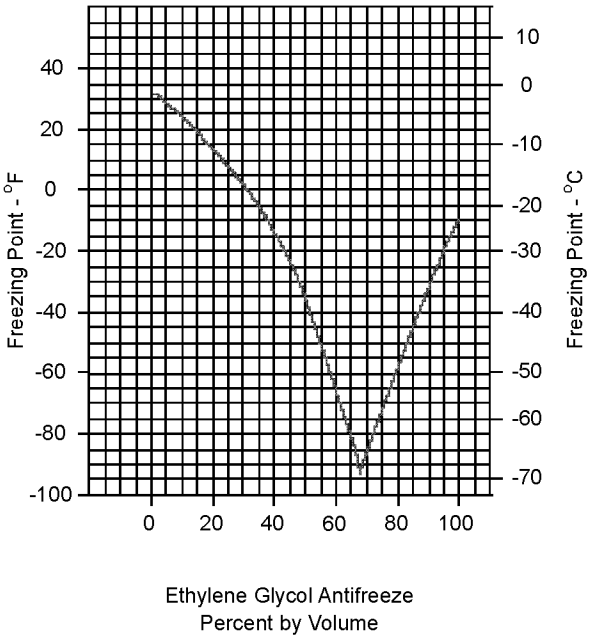


Illustration 3 g01189253

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

Table 18

Freeze Protection for Antifreeze Concentrations[1]	
Protection to:	**Concentration**
−8° C (18° F)	20% glycol 80% water
−15 °C (5 °F)	30% glycol 70% water
−24 °C (−12 °F)	40% glycol 60% water
−37 °C (−34 °F)	50% glycol 50% water
−52 °C (−62 °F)	60% glycol 40% water

(1) Ethylene glycol-based antifreeze.

Alternative products that are used to protect from boiling or freezing of the engine coolant include:

- “1,3 propandiol” (PDO)
- glycerin
- mixtures of these alternative products with glycol

Some commercially available coolants are based on alternative fluids, such as 1, 3-propanediol (beta-propylene glycol, PDO), glycerin (glycerol), or mixtures of these alternatives with ethylene/propylene glycols. At the time of publication of this document no industry standard exists for coolants based on these chemicals. **Until such standard/specifications are published and evaluated, use of PDO, glycerine, or other alternative coolants are not recommended in Perkins engines.**

Embitterment

Ethylene glycol is a toxic chemical with a naturally sweet taste. To avoid accidental excessive ingestion by humans or animals, coolants may contain embittering agents that make the coolant taste bad. **All glycol containing coolants are embittered.** Embittering agents have no beneficial or detrimental effect on coolant performance or characteristics.

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Coolant Specifications

The following three glycol-based coolants are recommended for use in Perkins diesel engines:

Preferred – Perkins ELC Advanced or Perkins ELC

Acceptable – A commercial heavy-duty antifreeze that meets “ASTM D6210” specifications. Must be replaced after 2 years.

Adequate – A commercial heavy-duty antifreeze that meets “ASTM D4985” specifications. Must be replaced after 1 year.

NOTICE
The Perkins engines, where equipped with NOx reduction system must be operated with a 50 percent glycol concentration. This concentration allows the NOx reduction system to operate correctly with the high gas temperatures seen during operation.

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

NOTICE
A commercial heavy-duty antifreeze that meets “ASTM D4985” specification requires a treatment with an SCA at the initial fill. Read the label or the instructions that are provided by the manufacturer of the product.

NOTICE
A commercial heavy-duty antifreeze that meets either “ASTM D4985” or “ASTM D6210” specification requires the SCA concentration to be checked at 500-hour service intervals.

Perkins recommends a 50 percent volume (1:1) glycol and distilled or deionized water of the correct specification. This mixture will provide optimum performance as a coolant/antifreeze. This ratio can be increased to 60 percent volume ethylene glycol to water if extra freezing protection is required.

For applications not requiring freeze protection, the following can be used:

Preferred – Perkins ELI

Acceptable – A commercial supplemental coolant additive (SCA) that meets “ASTM D5752” specifications.

A mixture of SCA inhibitor and distilled or deionized water is acceptable but will not provide the same level of corrosion, boiling, and freezing protection as ELC or ELI. Perkins recommends a 6 percent to 8 percent concentration of SCA in those cooling systems. Distilled water or deionized water is preferred. Water which has the recommended properties may be used.

The finished coolants that are recommended or acceptable for use in Perkins diesel engines are given in Table 19 below:

Table 19

Recommendations for Finished Coolants Service Life for use in Perkins engines				
Coolant Type	**Recommendations**	**Product**	**Service Hours (1)(2)**	**Required Maintenance (3)**
Perkins ELC Advanced Perkins ELC, Perkins ELI, or Commercial Long-life coolant that meets “ASTM D6210”	Preferred	Perkins ELC Advanced	6000 Service Hours or 3 Years	-
		Perkins ELC	6000 Service Hours or 3 Years	-
		Perkins ELI (4)	6000 Service Hours or 3 Years	-
	Minimum requirements	“ASTM D6210” and Organic Additive Technology (OAT) based on a combination of a monocarboxylic acid and a dicarboxylic acid. Phosphate, borate, and silicate free. Tolyltriazole: minimum typical concentration of 900 ppm Nitrite (5) (as NO2): minimum typical concentration of 500 ppm in new coolants.	6000 Service Hours or 6 Years (6)	Add Extender at 3000 service hours or one half of service life(6)
Conventional Coolants and Commercial Extended Life Coolants that do NOT meet the Perkins minimum requirements	Acceptable Minimum requirements for fully formulated Heavy-Duty Commercial coolants	Commercial Heavy-Duty Antifreeze that meets “ASTM D6210” specifications and the following: Nitrite(5) (as NO2) concentration: Minimum of 1200ppm and maximum of 2400ppm. Silicate concentration: Minimum of 100ppm and Maximum of 275ppm.	3000 Service Hours or 2 Years	SCA at maintenance intervals
	Adequate Minimum requirements for fully formulated Heavy-Duty Commercial coolants requiring SCA pre-charge	A Commercial Heavy-Duty Antifreeze that meets “ASTM D4985” specifications and the following: Nitrite(5) (as NO2) concentration: Minimum of 1200ppm and maximum of 2400ppm. Silicate concentration: Minimum of 100ppm and Maximum of 275ppm.	3000 Service Hours or 1 Year	SCA at initial fill and SCA at maintenance intervals per manufacturer recommendations
	Acceptable - Minimum requirements for SCA and water(4) (7)	A commercial Supplemental Coolant Additive (SCA)(4) that meets “ASTM D5752” specifications and water having Nitrite(5) (as NO2) concentration: Minimum of 1200ppm and maximum of 2400ppm. Silicate concentration: Minimum of 100ppm and Maximum of 275ppm.	3000 Service Hours or 1 Year	SCA at maintenance intervals per manufacturer recommendations

(1) New Coolants at 50 volume percent diluted. Coolants that are prediluted at the coolant manufacturer must be diluted with water that meets “Reagent 4” “ASTM D1193” requirements.

(2) Use the interval that occurs first. Flush the cooling system at this point. These service lives can only be met if regular coolant sampling, analysis, and proper maintenance are carried out, with the engine in normal service.

(continued)

(Table 19, contd)

(3) For appropriate maintenance procedures, refer to the details given in this section. For applications that allow the use of Perkins ELI in water, a minimum of 7.5 percent of Perkins ELI is recommended. For applications that allow the use of SCA and water, a minimum of 6 percent to a maximum of 8 percent concentration of SCA are recommended.

(4) Water-based coolants are not allowed for use in machines that have NOx reduction aftertreatment devices, where the minimum glycol concentration is 50 percent, in engines that have ATAAC where the minimum glycol concentration is 30 percent.

(5) Nitrite concentration is required for cavitation protection in wet sleeve liner engines (typically in Perkins engines >7.2 L); Nitrite free coolant formulation can be used in none wet sleeve liner engines (typically inPerkins engines <7.2 L).

(6) For Commercial Long-Life Coolant (LLC) that meets the Perkins minimum specification, the recommended service hours and required maintenance should be confirmed with the coolant manufacturer/supplier and should be maintained through regular coolant sampling and analysis.

(7) There are currently no industry standards to define the quality of water-based conventional coolants. To control the quality of SCA and water coolants, the commercial SCA additive package should meet the requirements of “ASTM D6210” and/or “ASTM D4985” when this package is used in a glycol-based coolant. Do not use a commercial SCA additive package that only meets the ASTM D3306 or equivalent specification when used in a glycol-based coolant.

When referring to the Service Life in table 19 , use the interval that occurs first. These coolant change intervals are only achievable with annual Level 2 coolant sampling analysis.

Refer to the engine Operation and Maintenance Manual for the correct interval for replacement of the cooling system water temperature regulator.

Extended life coolants require the one time maintenance addition of an extender at coolant service mid-life. For commercial coolants, do NOT use an extender with a coolant unless the extender has been approved by the coolant manufacturer for use with the coolant. The coolant manufacturer is responsible for ensuring the compatibility and acceptable performance of the coolant. Failure to follow these recommendations can result in shortened cooling system component life.

Conventional coolants require the maintenance addition of SCA throughout the expected life. For commercial coolants, do NOT use a SCA unless approved by the coolant supplier for use with the coolant. The coolant manufacturer is responsible to ensure compatibility and acceptable performance.

“ASTM D4985” and “ASTM D6210” require coolants that are properly dosed with SCA and that are in a properly maintained cooling system in normal service to be suitable for use for a maximum of 1 year (“ASTM D4985”) and 2 years (“ASTM D6210”). **The suitability for use requirement is the direct responsibility of the coolant manufacturer and SCA manufacturer.** Consult with the coolant and/or SCA manufacturer concerning the suitability of the products for use in a given application.

A commercial heavy-duty coolant/antifreeze that only meets “ASTM D4985”, WILL require a treatment with a SCA at the initial fill and has to fulfill all the requirements listed in the “Technical Requirements for Commercial Extended Life Coolants” table. The user and the coolant manufacturer are responsible for ensuring the SCA is compatible. Compatibility is based on the recommendations provided by the coolant manufacturer and SCA manufacturer. For example, an extended life coolant that meets the “ASTM D4985” technical specification may not be compatible with a SCA designed for use with conventional coolants. The coolant manufacturer is responsible to provide sources of compatible SCAs. The coolant manufacturer and SCA manufacturer are responsible to demonstrate a positive influence on reducing cavitation corrosion in an operating diesel engine.

Read the label or the instructions that are provided by the manufacturer of the commercial heavy-duty coolant/antifreeze.

When adding SCA at initial fill to a coolant/antifreeze that only meets “ASTM D4985” specification, the user, and the coolant manufacturer must ensure that the SCA is compatible with the antifreeze/coolant. The addition must be based on the recommendations provided by the coolant manufacturer and SCA manufacturer. One of the test methods required to be used to help ensure SCA compatibility with the antifreeze/coolant concentrate is “ASTM D5828-97”. Follow the test procedure using the antifreeze/coolant of interest to compare the SCA of interest with the reference SCA. The ratio of insoluble for SCA to reference SCA must be < 1. Total insoluble should not exceed 4 mL (0.136 oz) for a 6% SCA mixture. The SCA manufacturer is responsible for ensuring the SCA is compatible with water meeting the “Perkins Minimum Acceptable Water Quality Requirements” as found in “Perkins Diesel Engines Fluids Recommendations”, and is found in “ASTM D6210”, Table X1.1.

The coolant manufacturer and the SCA manufacturer are responsible to ensure that the products will not cause cooling system harm.

In stationary engine applications that do not require protection from boiling or freezing, except as noted in Table 19 , Perkins ELI in water or SCA and water are acceptable. Perkins **recommends a minimum of 7.5 percent concentration of Perkins ELI in those cooling systems using Perkins ELI. Perkins recommends a minimum of 6 percent to a maximum of 8 percent concentration of SCA in those cooling systems using SCA** and water. Distilled water or deionized water is preferred in those systems. If distilled or deionized water is not available, use water that meets or exceeds the minimum acceptable water requirements that are listed in this Perkins Diesel Engines Fluids Recommendations, “General Coolant Information” section.

After the addition of water and proper mixing, the concentration of Perkins ELI can be determined using a suitable refractometer. The concentration of a sample of in-use Perkins ELI taken from the cooling system can also be determined using a suitable refractometer

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

NOTICE
Do not use a commercial coolant/antifreeze that only meets the ASTM “D3306” or equivalent specification. This type of coolant/antifreeze is made for light-duty automotive applications. Use only the recommended coolant/antifreeze.

Perkins recommends a 50 volume percent glycol and water that meets or exceeds the minimum acceptable water requirements that are listed in this Perkins Diesel Engines Fluids Recommendations, “General Coolant Information” section. This mixture will provide optimum heavy-duty performance as a coolant/antifreeze.

Maintain a concentration level of nitrites in the cooling system that is between 1200 ppm (70grains/US gal) and 2400 ppm (140 grains/US gal). Coolant sample analysis is the preferred method to check SCA concentration. Alternatively, nitrite levels can be tested with suitable nitrite level test strips.

Frequently check the concentration of glycol in glycol-based coolant to ensure adequate protection against boiling or freezing. Perkins recommends the use of a refractometer for checking the glycol concentration. Do not use a hydrometer.

Maintain the correct concentrations of glycol and additives in the coolant. Lowering the concentration of glycol or additives will lower the ability of the coolant to protect the system from pitting, from cavitation, from erosion, and from deposits.

Do not top off the cooling system with water unless there is a specific need to adjust the water/glycol ratio. Compatible 50/50 (water/glycol) coolant is typically used and recommended when cooling system top off is required.

Clean the cooling system for the following reasons:

- Contamination of the cooling system
- Overheating of the engine
- Foaming of the coolant
- Changing from conventional heavy-duty coolant/antifreeze to Perkins ELC Advanced, Perkins ELC or a commercial long-life coolant that meets the Perkins Technical specification requirements.

Note: Air pockets can form in the cooling system if the cooling system is filled at a rate that is greater than 20 L (5.3 US gal) per minute. The maximum recommended cooling system fill rate for some smaller engine models will be less. Refer to the engine Operation and Maintenance Manual for exceptions.

After you drain the cooling system and refill the cooling system, operate the engine. Operate the engine without the filler cap until the coolant level stabilizes. Ensure that the coolant is maintained to the correct level.

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Coolant Applications

Perkins Extended Life Coolant (ELC) and Perkins ELC Advanced

Perkins provides Perkins ELC and Perkins ELC Advanced for use in the following applications:

- Heavy-duty diesel engines
- Automotive applications

NOTICE
Perkins 1300 Series engines are supplied with a coolant filter/coolant canister. The canister contains a SCA described as a complete chemical protection package containing phosphate, molybdate, and nitrates to prevent corrosion and cylinder liner pitting/cavitation.

Perkins ELC or Perkins ELC Advanced is NOT recommended for use in the Perkins 1300 Series engines.

The anti-corrosion package for Perkins ELC and Perkins ELC Advanced is different from anti-corrosion package for other coolants. Perkins ELC and Perkins ELC Advanced have been formulated with the correct amounts of additives. Superior corrosion protection is provided for all metals that are in engine cooling systems. Perkins ELC and Perkins ELC Advanced are an ethylene glycol base coolant. However, ELC contains organic corrosion inhibitors and antifoam agents with low amounts of nitrite. Perkins ELC and Perkins ELC Advanced have been formulated with the correct amount of these additives to provide superior corrosion protection for all metals in engine cooling systems.

Perkins ELC and Perkins ELC Advanced are available in a premixed cooling solution with distilled water. Perkins ELC and Perkins ELC Advanced is a 50 percent by volume of glycol mixture. The premixed Perkins ELC and Perkins ELC Advanced provides freeze protection to −37 °C (−34 °F). The premixed Perkins ELC and Perkins ELC Advanced are recommended for the initial fill of the cooling system. The premixed Perkins ELC and Perkins ELC Advanced is also recommended for topping off the cooling system.

Containers of several sizes are available. Consult your Perkins distributor for the part numbers.

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

Commercial Extended Life Coolant

NOTICE
The engine should use the correct specification of fluids. Failure to use the correct specification of fluids could affect your warranty.

To use a commercial extended life coolant in Perkins diesel engine cooling systems at the published service intervals, select a commercial extended life coolant that meets all the requirements given in table 20 in this “Perkins Diesel Engines Fluids Recommendations”.

Table 20

Technical Requirements for Commercial Extended Life Coolants	
Specifications	"ASTM D6210"
Additional Requirements	Organic Additive Technology (OAT) based on a combination of a monocarboxylic acid and a dicarboxylic acid
	Phosphate, borate, and silicate free
	Minimum typical Tolyltriazole level of 900 ppm for new coolants
	Minimum typical nitrite level of 500 ppm in new coolants
Maintenance (1)	One time addition of an extender at the mid-life of the coolant to maintain the coolant nitrite level between 300 - 600 ppm

(1) Nitrite concentration is required for cavitation protection in wet sleeve liner engines (typically in Perkins engines >7.2 L), Nitrite free coolant formulation can be used in none wet sleeve liner engines (typically in Perkins engines <7.2 L).

Note: The Perkins specification describes the minimum requirements for extended life coolants.

Use an extender that is recommended by the Perkins technical specification requirements and coolant supplier at mid-life of the coolant.

Commercial coolants that do not meet the minimum requirements defined in this "Perkins Diesel Engines Fluids Recommendations" are not allowed for use in Perkins engines.

Commercial extended life coolant used in Perkins engines must meet all requirements given in table 20 . If the ELC does meet the requirements, the service interval listed in this "Perkins Diesel Engines Fluids Recommendations" may not be used. Follow the maintenance guidelines for the coolant from the supplier of the commercial extended life coolant. Follow the Perkins guidelines for the quality of water and the specified coolant change interval.

Note: Coolants must be tested against the Perkins technical specification requirements. Coolants that only claim to meet the performance requirements of the Perkins technical specification requirements, may not meet all the minimum requirements.

To be marketed as a product that meets Perkins technical specification requirements, all Perkins technical specification requirements must be met. Requirements include, but are not limited to the following:

- Physical and Chemical Properties
- Compatibility Characteristics
- Bench Testing
- Field Testing

The field test includes the use of the following requirements:

- Radiator types
- Minimum field test duration
- Minimum number of diesel engines
- Perkins diesel engine models of the required minimum power rating

Extended Life Coolant Cooling System Maintenance

Correct Additions to the Perkins Extended Life Coolant (ELC) and Perkins Extended Life Coolant (ELC) Advanced

NOTICE

Use only Perkins products or commercial products that meet the requirements covered in this publication for pre-mixed or concentrated coolants.

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

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

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

To maintain the correct balance between the antifreeze and the additives, you must maintain the recommended concentration of Perkins ELC or Perkins ELC Advanced. Lowering the proportion of antifreeze lowers the proportion of additive. Lowering the ability of the coolant to protect the system will form pitting, from cavitation, from erosion, and from deposits.

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

Do not use standard Supplemental Coolant Additive (SCA).

Do not use ELC in systems with standard SCA / SCA filters. When switching from conventional coolant to ELC in a system equipped with SCA filter, remove the filter from the system to prevent ELC contamination and filter corrosion and leaks.

Perkins ELC and Perkins ELC Advanced Cooling System Maintenance

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

Distilled or deionized water is the only cleaning agent that is required when Perkins ELC or Perkins ELC Advanced is drained from the cooling system.

Before the cooling system is filled, the cabin heater control (if equipped) must be set to the HOT position. Refer to the OEM to set the cabin heater control. After the cooling system is drained and the cooling system is refilled, operate the engine until the coolant level reaches the normal operating temperature and until the coolant level stabilizes. As needed, add the coolant mixture to fill the system to the specified level.

Recycling Perkins ELC and Perkins ELC Advanced

Perkins ELC can be recycled into conventional coolants. The drained coolant mixture can be distilled to remove the ethylene glycol and the water. The ethylene glycol and the water can be reused. The distilled material does not contain the additives that are classified as Perkins ELC or Perkins ELC Advanced. Consult your Perkins distributor for more information. Recycled coolants should meet the most current revision level of “ASTM D6210”.

Changing to Perkins ELC and Perkins ELC Advanced

To change from heavy-duty antifreeze to Perkins ELC or Perkins ELC Advanced, perform the following steps:

NOTICE
Care must be taken to ensure that all fluids are contained during performance of inspection, maintenance, testing, adjusting and the repair of the product. Be prepared to collect the fluid with suitable containers before opening any compartment or disassembling any component containing fluids.

Dispose of all fluids according to local regulations and mandates.

1. Drain the coolant into a suitable container.
2. Dispose of the coolant according to local regulations.
3. Flush the system with distilled or deionized water to remove any debris.
4. Use an appropriate cleaner to clean the system. Follow the instruction on the label.
5. Drain the cleaner into a suitable container. Flush the cooling system with distilled or deionized water.
6. Fill the cooling system with distilled or deionized water and operate the engine until the engine is warmed to 49° to 66°C (120° to 150°F).

NOTICE
Incorrect or incomplete flushing of the cooling system can result in damage to copper and other metal components.

To avoid damage to the cooling system, make sure that the cooling system is completely flushed with distilled or deionized water. Continue to flush the system until all signs of the cleaning agent are gone.

Most commercial cooling system cleaning agents are corrosive and their use is not recommended by Perkins. If these agents have to be used to remove heavy deposits, then the cleaning agents should not be left in the system any longer then recommended by the agent manufacturer and engine temperature should not exceed 30 °C. The system must be thoroughly flushed with distilled or deionized water after use of these cleaning agents.

7. Drain the cooling system into a suitable container and flush the cooling system with distilled or deionized water.

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

8. Repeat Steps 6 and 7 until the system is completely clean.

9. Fill the cooling system with the Perkins Premixed ELC or ELC Advanced.

Perkins ELC and Perkins ELC Advanced Cooling System Contamination

NOTICE
Mixing Perkins ELC or Perkins ELC Advanced with other products reduces the effectiveness of Perkins ELC or Perkins ELC Advanced and shortens the Perkins ELC or Perkins ELC Advanced service life. Failure to follow these recommendations can result in shortened cooling system component life.

Do not mix types and specifications of coolant.

Do not mix types and specifications of SCAs.

ELC cooling systems can withstand contamination to a maximum of 10 percent of conventional heavy-duty antifreeze or SCA. If the contamination exceeds 10 percent of the total system capacity, perform ONE of the following procedures:

- Drain the cooling system into a suitable container. Dispose of the coolant according to local regulations. Flush the system with a 5 to 10 percent solution of Perkins ELC or Perkins ELC Advanced. Fill the system with the Perkins ELC or Perkins ELC Advanced.
- Drain a portion of the cooling system into a suitable container according to local regulations. Then, fill the cooling system with premixed Perkins ELC or Perkins ELC Advanced. This procedure should lower the contamination to less than 10 percent.
- Maintain the system as a conventional Heavy-Duty Coolant. Treat the system with an SCA. Change the coolant at the interval that is recommended for the conventional Heavy-Duty Coolant.

Extended Life Inhibitor (ELI)

NOTICE
Do NOT use commercial SCA/ELI with Perkins ELI. Mixing Perkins ELI with commercial coolants and/or commercial SCA reduces the Perkins ELI service life.

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

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

NOTICE
Perkins 1300 Series engines are supplied with a coolant filter/coolant canister. The canister contains a SCA described as a complete chemical protection package containing phosphate, molybdate, and nitrates to prevent corrosion and liner pitting/cavitation.

Perkins ELI is NOT recommended for use in the Perkins 1300 Series engines.

Perkins Extended Life Inhibitor (ELI) is water-based coolant that does not contain glycol. Perkins ELI is for applications that do not require freeze protection. Exceptions are listed here. Failure to follow these recommendations can or will result in failures.

Perkins ELI is a corrosion inhibitor concentrate that is mixed to approximately 7.5 % by volume with water. Perkins ELI has the following characteristics:

- Based on the same organic additive technology that is used in Perkins Extended Life Coolant (ELC)
- Does not contain glycol. Designed for use in applications that do not require freeze protection.
- Provides superior corrosion and cavitation protection compared to SCA mixed with water.
- Provides an extended drain interval of up to 3 years or 6,000 hours. The drain interval may be longer as determined by using coolant sample analysis program.
- Requires little maintenance compared to conventional SCA mixed with water.

In engine applications that do not require freeze protection,Perkins ELI can replace SCA/Water coolant

Additional information is available from your Perkins distributor. Refer to table 21 for information about Perkins ELI.

Table 21

Part Number	Container Size	Volume of Finished Coolant Produced
T402623	1.0 L (1.06 qt)	13.3 L (3.5 US gal)

Mixing Perkins ELI

The recommended water for mixing with Perkins ELI concentrate is distilled or deionized water. Water must meet requirements of ASTM 1193, “Type IV Reagent Water Specification”. If distilled or deionized water is not available, water should meet the “Perkins Minimum Acceptable Water Requirements” table in “General Coolant Information” section in this Perkins Diesel Engines Fluids Recommendations.

To ensure a correct concentration, the preferred method is to mix Perkins ELI concentrate with water. Then, add the mixed coolant to the engine cooling system. Add the correct amount of water and Perkins ELI into a clean container and mix thoroughly by manual stirring or mechanical agitation.

If the preferred method cannot be performed, a Perkins ELI mixture can be made by adding Perkins ELI concentrate directly into engine cooling system. Add good quality water until the dilution level is approximately 7.5%. Adequate mixing is attained by operating the engine for at least 30 minutes.

Appropriate mixing rates for available ELI container sizes are provided in table 21 .

After the addition of water and proper mixing, the concentration of Perkins ELI can be determined using a suitable Refractometer.

Changing to Perkins ELI

For cooling systems previously running Perkins ELC or an extended life coolant that meets Perkins technical specification requirements, drain the cooling system and flush with water. Then refill the cooling system with a mixture of 7.5% Perkins ELI in water that meets the “Perkins Minimum Acceptable Water Requirements” table in “General Coolant Information”section in this Perkins Diesel Engines Fluids Recommendations.

For cooling systems previously running a conventional heavy-duty coolant or a water/SCA mixture, follow the steps listed in this Perkins Diesel Engines Fluids Recommendations, “Changing to Perkins ELC”. Then refill the cooling system with a mixture of 7.5% Perkins ELI in water that meets the “Perkins Minimum Acceptable Water Requirements” table in “General Coolant Information” section in this PerkinsDiesel Engines Fluids Recommendations.

Perkins ELI Maintenance

Maintenance of Perkins ELI is similar to Perkins ELC. A coolant sample should be submitted for “Level 2 Coolant Analysis” after the first 500 hours of operation and then annually thereafter.

Analysis and interpretation of Perkins ELI coolant sample analysis results is similar to the analysis and interpretation of Perkins ELC. There will be no glycol and glycol oxidation products, which do not apply to Perkins ELI.

The concentration of a sample of in-use Perkins ELI taken from the cooling system can also be determined using a suitable Refractometer.

Note: Clean water is the only flushing agent that is required when Perkins ELI is drained from a properly maintained cooling system.

Mixing Perkins ELI with Perkins ELC or Perkins ELC Adanced

Since Perkins ELI, Perkins ELC, and Perkins ELC Advanced are based on the same corrosion inhibitor technology, Perkins ELI can be mixed with Perkins ELC or Perkins ELC Advanced. Mixing may be desired when only low level of freeze protection is required. Consult your local Perkins distributor to ensure correct mixing of the products to provide adequate freeze protection and corrosion protection.

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

NOTICE
The engine should use the correct specification of fluids. Failure to use the correct specification of fluids could affect your warranty.

NOTICE
Do NOT mix brands or types of SCA. Do NOT mix SCAs and commercial extenders.

Failure to follow the recommendations can result in shortened cooling system component life.

NOTICE

Use Only Approved SCAs. Conventional coolants require the maintenance addition of SCA throughout their expected life. Do NOT use an SCA with a coolant unless specifically approved by the coolant supplier for use with their coolant. It is the responsibility of the coolant manufacturer to ensure compatibility and acceptable performance.

Failure to follow the recommendations can result in shortened cooling system component life.

NOTICE

Perkins 1300 Series engines are supplied with a coolant filter/coolant canister. The canister contains a SCA described as a complete chemical protection package containing phosphate, molybdate, and nitrates to prevent corrosion and liner pitting/cavitation. The coolant or antifreeze specified must be compatible with this SCA system. An Ethylene or Propylene Heavy-Duty commercial coolant is required and only coolant that meets the “ASTM D4985””specification is acceptable.

The canister and coolant should be changed together.

Perkins ELC, Perkins ELC Advanced/ Perkins ELI is NOT recommended for use in the Perkins 1300 Series engines.

Follow the maintenance information provided in the Coolant Recommendations (General Maintenance) section in this Perkins Diesel Engines Fluids Recommendations.

Select a commercial diesel engine antifreeze coolant that meets all the requirements given in Table 22 . The table contains the requirements for coolant to meet the published service intervals.

The provided requirements are applicable to finished coolants and not for the concentrates. When concentrated coolant/antifreeze is mixed, Perkins recommends mixing the concentrate with distilled water or with deionized water. If distilled water or deionized water is not available, water which has the required properties may be used. For the water properties, refer to this Perkins Diesel Engines Fluids Recommendations, “General Coolant Information” article.

Coolant/antifreezes for heavy-duty applications that meet “ASTM D6210” do not require treatment with SCA at the initial fill. Use the recommended 1:1 or higher concentration with recommended water. Treatment with SCA is required on a maintenance basis.

Coolant/antifreezes for heavy-duty applications that meet “ASTM D4985” do not require treatment with SCA at the initial fill. Use the recommended 1:1 or higher concentration with recommended water. Treatment with SCA is required on a maintenance basis.

The SCA manufacturer is responsible for ensuring the SCA is compatible with water meeting the “Perkins Minimum Acceptable Water Requirements” as found in this Perkins Diesel Engines Fluids Recommendations, and “ASTM D6210-08, Table X1.1”. The coolant manufacturer and the SCA manufacturer are responsible to ensure that the products will not cause cooling system harm.

Do not mix brands or types of coolants with different brands or types of SCA or extender.

If using non Perkins coolants, refer to the coolant manufacturer for information on a compatible SCA.

Treat the compatible commercial coolant with 3 to 6 percent SCA by volume. Maintain a 3 to 6 percent concentration level of SCA in the cooling system. For more information, refer to this Perkins Diesel Engines Fluids Recommendations, “Coolant Recommendations (General Maintenance)” article.

Table 22

Technical Requirements for Commercial Diesel Engine Antifreeze Coolants	
Specifications	“ASTM D6210”
Additional Requirements	Silicate: Minimum 100 ppm to maximum 275 ppm Nitrites(1): maintained at 1200ppm minimum to 2400 ppm maximum SCA at 3 to 6 percent
Maintenance	Add compatible SCA at maintenance intervals Clean and flush the cooling system at drain intervals

(1) Nitrite concentration is required for cavitation protection in wet sleeve liner engines (typically in Perkins engines >7.2 liters), Nitrite free coolant formulation can be used in none wet sleeve liner engines (typically in Perkins engines <7.2 liters)

Water/SCA (Supplemental Coolant Additive)

Commercial SCA can be added to water of the recommended quality to form a Water/SCA finished coolant. SCA/Water finished coolant is glycol free. SCA/Water finished coolant is for engine applications that do not require freeze protection.

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

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

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

If Commercial SCA is used, select a fully formulated commercial SCA. The commercial SCA must provide a minimum of 1200mg/L or 1200 ppm (70 grains/US gal) and a maximum of 2400 mg/L or 2400 ppm (140 grains/US gal) of nitrites in the final coolant mixture.

The quality of the water is an important factor in this type of cooling system. Distilled water or deionized water is recommended for use in cooling systems. If distilled water or deionized water is not available, use water that meets or exceeds the minimum requirements that are listed in the “Perkins Minimum Acceptable Water Requirements” table for recommended water properties in this Perkins Diesel Engines Fluids Recommendations, “General Coolant Information”.

A cooling system that uses a mixture of SCA and water only needs more SCA. The SCA concentration in a cooling system that uses SCA and water should be 6 to 8 percent by volume.

Maintain the SCA in the same way as you would maintain a cooling system that uses heavy-duty coolant/antifreeze. Adjust the maintenance for the amount of SCA that has been added.

Commercial Heavy-Duty Antifreeze/ Coolant (“ASTM D4985”and “ASTM D6210”) and SCA

NOTICE
Commercial Heavy-Duty Coolant which contains Amines as part of the corrosion protection system must not be used.

NOTICE
Never operate an engine without water temperature regulators in the cooling system. Water temperature regulators help to maintain the engine coolant at the correct operating temperature. Cooling system problems can develop without water temperature regulators.

Check the antifreeze (glycol concentration) to ensure adequate protection against boiling or freezing. Perkins recommends the use of a refractometer for checking the glycol concentration. Do not use a hydrometer.

NOTICE
Do not mix types and specifications of coolant.

Do not mix types and specifications of SCAs.

Do not mix SCAs and Extenders.

Only use SCAs or Extender approved by coolant manufacturer and are compatible with the coolant type used.

Perkins engine cooling systems should be tested at 500-hour intervals for the concentration of SCA.

Additions of SCA are based on the results of the test. SCA that is liquid may be needed at 500-hour intervals.

Adding the SCA to Water at the Initial Fill

Use the equation that is in this Perkins Diesel Engines Fluids Recommendations, “Adding SCA to Heavy-Duty Coolant (ASTM D4985) at the Initial Fill” to determine the amount of SCA that is required at the initial fill. This equation is for a mixture of only SCA and water.

Adding the SCA to Water for Maintenance

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

Commercial SCA test kits are available to test the concentration of SCA or a coolant sample can be sent for analysis, consult your Perkins Distributor for more information. Refer to this document section Perkins Diesel Engines Fluids Recommendations, “Coolan Analysis”.

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

Use the equation that is in this Perkins Diesel Engines Fluids Recommendations, “Adding SCA to Commercial Heavy-Duty Coolant (ASTM D4985 and ASTM D6210) for Maintenance” to determine the amount of SCA that is required for maintenance, if necessary.

Note: Specific engine applications may require maintenance practices to be periodically evaluated to maintain the engine cooling system properly.

Adding SCA to Heavy-Duty Coolant (“ASTM D4985”) at the Initial Fill

Use the equation that is in Table 23 to determine the amount of SCA that is required when the cooling system is initially filled.

Coolants that conform to “ASTM D4985” and do not conform to “ASTM D6210” will require addition of SCA at initial fill.

Table 23

Equation For Adding The SCA To The Heavy-Duty Coolant At The Initial Fill
V × 0.07 = X
V is the total volume of the cooling system.
X is the amount of SCA that is required.

Table 24 is an example for using the equation that is in Table 23 .

Table 24

Example Of The Equation For Adding The SCA To The Heavy-Duty Coolant At The Initial Fill		
Total Volume of the Cooling System (V)	**Multiplication Factor**	**Amount of SCA that is Required (X)**
15 L (4 US gal)	× 0.07	1.05 L (35.5 oz)

Adding SCA to Commercial Heavy-Duty Coolant (“ASTM D4985”and “ASTM D6210”) for Maintenance

Heavy-duty antifreezes of all types **REQUIRE** periodic additions of SCA.

Test the antifreeze periodically for the concentration of SCA. For the interval, refer to the Operation and Maintenance Manual, “Maintenance Interval Schedule” (Maintenance Section). Cooling System Supplemental Coolant Additive (SCA) Test/Add.

Additions of SCA are based on the results of the test. The size of the cooling system determines the amount of SCA that is needed.

Use the equation that is in Table 25 to determine the amount of SCA that is required, if necessary:

Table 25

Equation for Adding the SCA to the Commercial Heavy-Duty Coolant for Maintenance
V × 0.023 = X
V is the total volume of the cooling system.
X is the amount of SCA that is required.

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

Table 26

Example of the Equation for Adding the SCA to the Commercial Heavy-Duty Coolant for Maintenance		
Total Volume of the Cooling System (V)	**Multiplication Factor**	**Amount of SCA that is Required (X)**
15 L (4 US gal)	× 0.023	0.35 L (11.7 oz)

Cleaning the System of Heavy-Duty Coolant/Antifreeze

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

Suitable commercial Cooling System Cleaners, should be able to:

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

Standard Cooling System Cleaners are designed to clean the cooling system of harmful scale and corrosion without removing the engine from service. Some commercial cooling system cleaners can be Standard type and Quick Flush type, both types can be used in all Perkins engine cooling systems. Consult your Perkins distributor for further guidance.

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

Prior to performing a cleaning of the cooling system, take a 1.0 L (1.0 qt) sample of coolant from the engine while in operation into a clear container. Take the sample shortly after start-up while the coolant is not yet hot. The coolant should be adequately mixed by the water pump. Allow the sample to sit for 2 hours. If a visible oil layer is present, most commercial cooling system cleaners or the Standard or Quick Flush type will be fully effective. First, drain the coolant and then perform the procedure given below (using nonfoaming dish detergent).

Procedure for Cleaning an Oil Contaminated Cooling System

1. Drain the cooling system.

2. Fill the cooling system with acceptable water.

Note: Refer to the “Perkins Minimum Acceptable Water Quality Requirements” in this “Perkins Diesel Engines Fluids Recommendations”.

3. Start the engine and run the engine until the thermostat opens.

4. Add a non-foaming detergent containing tripolypentasodium phosphate (TSP) to equal approximately 2-3% cooling system capacity.

Note: Pre-dissolve the detergent in approximately 19 L (5.0 US gal) of acceptable quality water. Add this mixture directly to the cooling system and top off the cooling system with water.

5. Run the engine for at least 30 minutes. Stop the engine.

6. Remove a small sample of the detergent solution from the cooling system and then drain the cooling system. Allow the sample solution to sit for at least 30 minutes and check for signs of a visible oil layer on top. If oil is still present, repeat steps 2 to 6.

Note: Corrosion of the metal can occur if the detergent solution is left in the cooling system for longer than 1 hour.

7. Flush the cooling system, if there is no visible oil layer in the solution. Fill the cooling system with acceptable quality water. Run the engine for 20 minutes and then drain the water.

8. Perform the cleaning procedure using a suitable commercial cooling system cleaner, if more removal of scale, rust, and inhibitor deposits from the previous coolant is needed.

9. If further cleaning is not needed, refill the cooling system with new coolant.

Recycling Perkins Heavy-Duty Coolant/ Antifreeze

Perkins Heavy-Duty Coolant/Antifreeze can be recycled. The drained coolant mixture can be distilled to separate the ethylene glycol and water. The ethylene glycol and the water can be reused. The distilled material does not contain the additives that are classified as either Perkins ELC, Perkins ELC Advanced, or Perkins Heavy-Duty Coolant/ Antifreeze. Consult your Perkins distributor for more information.

When recycled coolants are used, use only coolants that have been recycled from extended life, heavy-duty, or automotive coolants. Use coolants that were originally manufactured from virgin ethylene or propylene glycol.

Recycled coolants should meet the latest revision of “ASTM D6210”.

Exhaust Aftertreatment Section

Diesel Exhaust Fluid (DEF)

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DEF General Information

General Information

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

Aftertreatment systems may include the following:

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

Other systems may apply.

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

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

Diesel Exhaust Fluid (DEF) is a liquid that is injected into the exhaust system of engines equipped with Selective Catalytic Reduction (SCR) systems. SCR reduces emissions of nitrogen oxides (NOx) in diesel engine exhaust.

Diesel Exhaust Fluid (DEF) is available in many brands, including those brands that carry the AdBlue or API certification. DEF is also generically referred to as urea.

In engines equipped with SCR emissions reduction system, DEF is injected in controlled amounts into the engine exhaust stream. At the elevated exhaust temperature, urea in DEF is converted to ammonia. The ammonia chemically reacts with NOx in diesel exhaust in the presence of the SCR catalyst. The reaction converts NOx into harmless nitrogen (N2) gas and water vapor (H2O).

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

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

DEF Recommendations for SCR Aftertreatment Systems

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

The caps of DEF tanks are typically blue as recommended by the “ISO 22241-4” Standard. Fill DEF, only in clearly marked DEF tanks that have the blue cap.

In North America, commercial DEF that is API approved and meets all the requirements defined in “ISO 22241-1” may be used in Perkins engines that are equipped with SCR systems.

Outside of North America, commercial DEF that meets all requirements defined in “ISO 22241-1” may be used in Perkins engines that are equipped with SCR systems.

The supplier should provide documentation to prove that the DEF is compliant with the requirements of “ISO 22241-1”.

NOTICE
The engine should use the correct specification of fluids. Failure to use the correct specification of fluids could affect your warranty.

NOTICE
Do not use agriculture grade urea solutions. Do not use any fluids that do not meet “ISO 22241-1” Requirements in SCR emissions reduction systems. Use of these fluids can result in numerous problems including damage to SCR equipment and a reduction in NOx conversion efficiency.

DEF is a solution of solid urea that is dissolved in deionized water to produce a final concentration of 32.5% urea. Most SCR systems are designed to operate only on DEF concentration of 32.5 percent. DEF solution of 32.5% urea has the lowest attainable freeze point of −11.5° C (11.3° F). DEF concentrations that are higher or lower than 32.5% have higher freeze points. DEF dosing systems and “ISO 22241-1” specifications are designed for a solution that is approximately 32.5%.

Perkins offers refractometers that can be used to measure DEF concentration. Refer to Table 27 for the part number. Follow the instructions provided with the instruments.

Table 27

Perkins DEF Refractometers		
Refractometer Part Numbers	T400195	Analog, specific to DEF, and requires a multi-step test procedure

DEF Guidelines

DEF solution is typically colorless and clear. Changes to color or clarity are indicators of quality issues. Quality of DEF can degrade when stored and handled inappropriately or if DEF is not protected from contamination. Details are provided below.

If quality issues are suspected, testing of DEF should focus on urea percentage, alkalinity as NH3 and biuret content. DEF that does not pass all these tests or the DEF is no longer clear must not be used.

Note: Perkins strongly recommends that customers purchase the pre-mixed DEF urea solution from a reputable supplier. The DEF must satisfy all the specifications of quality given in this chapter of this Perkins Diesel Engines Fluids Recommendations. Urea solutions that are not made of urea and water of the appropriate quality and cleanliness may damage the SCR system. Poor or questionable quality DEF can lead to additional repair and maintenance costs to the customer. Perkins warranties do not cover failures caused by or related to the use of out of specification urea solutions in Tier 4 Stage IIIB MLIT Step 4 products equipped with SCR systems.

Materials compatibility

DEF is corrosive. Due to the corrosion caused, DEF must be stored in tanks constructed of approved materials. Recommended storage materials:

Stainless Steels:

- 304 (S30400)
- 304L (S30403)
- 316 (S31600)
- 316L (S31603)

Alloys and metals:

- Chromium Nickel (CrNi)
- Chromium Nickel Molybdenum (CrNiMo)
- Titanium

Non-metallic materials:

- Polyethylene
- Polypropylene
- Polyisobutylene
- Teflon (PFA)
- Polyfluoroethylene (PFE)
- Polyvinylidene fluoride (PVDF)
- Polytetrafluoroethylene (PTFE)

Materials NOT compatible with DEF solutions include aluminum, copper, copper alloys, magnesium, zinc, nickel coatings, silver, and carbon steel and solders containing any of the above. Unexpected reactions may occur if DEF solutions come in contact with any non-compatible material or unknown materials.

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DEF Maintenance

Bulk storage

Follow all local regulations covering bulk storage tanks. Follow proper tank construction guidelines. Tank volume typically should be 110% of planned capacity. Appropriately vent indoor tanks. Plan for control of overflow of the tank. Heat tanks that dispense DEF in cold climates.

Bulk tank breathers should be fitted with filtration to keep airborne debris from entering the tank. Desiccant breathers are not be used because water will be absorbed, which potentially can alter DEF concentration.

Handling

Follow all local regulations covering transport and handling. DEF transport temperature is recommended to be −5° C (23° F) to 25° C (77° F). All transfer equipment and intermediate containers should be used exclusively for DEF. Containers are not be reused for any other fluids. Ensure that transfer equipment is made from DEF-compatible materials. Recommended materials for hoses and other non-metallic transfer equipment include:

- Nitrile Rubber (NBR)
- Fluoroelastomer (FKM)
- Ethylene Propylene Diene Monomer(EPDM)

The condition of hoses and other nonmetallic items that are used with DEF should be monitored for signs of degradation. DEF leaks are easily recognizable by white urea crystals that accumulate at the site of the leak. Solid urea can be corrosive to galvanized or unalloyed steel, aluminum, copper, and brass. Leaks should be repaired immediately to avoid damage to surrounding hardware.

Cleanliness

Contaminants can degrade the quality and life of DEF. The recommended DEF cleanliness target as dispensed into the machine or engine fill tank is ISO 18/16/13. Refer to the Contamination Control section in this Perkins Diesel Engines Fluids Recommendations.

Filtering DEF is recommended when dispensed into the DEF tank to achieve the recommended cleanliness targets. DEF filters should be compatible with DEF and should be used exclusively with DEF. Check with the filter supplier to confirm compatibility with DEF before using. Mesh type filters using compatible metals, such as stainless steel, can be used. Paper (cellulose) media and some synthetic filter media are not recommended because of degradation during use. The filter size must be appropriate for the DEF pump design, flow rate, expected pressures, and required filter life. Refer to table 28 below for filtration requirements for Perkins engines.

Care should be taken when filling DEF tanks or containers from bulk tanks to avoid cross contamination of the fluid with Hydro-carbons from oils, if contamination is suspected test the fluid before decanting in to the DEF tank using test strips from a suitable supplier or DEF supplier. The test strips should be able to detect fuel or oil contamination greater than 10ppm.

Care should be taken when dispensing DEF. Spills should be cleaned immediately. Machine or engine surfaces should be wiped clean and rinsed with water. Caution should be used when dispensing DEF near an engine that has recently been running.

Note: Spilling DEF onto hot components may cause the release of ammonia vapors. Do not breathe ammonia vapors. Do not clean up any spills with bleach.

Table 28

DEF Filtration Requirements For Bulk Tanks in Specific Applications		
DEF System	**Filter Requirements**	**Filter location**
All Perkins engines	Recommended: ≤ 5 microns (µm), Beta value ≥ 1000 Required: ≤ 10 microns (µm), Beta value ≥ 1000	Prior to the Inlet to DEF Tank / Pump Electronic Tank Unit (PETU)

Stability

Note: Do not store DEF in direct sunlight.

DEF fluid is stable when stored and handled properly. The quality of DEF rapidly degrades when stored at high temperatures. The ideal storage temperature for DEF is between −9° C (15.8° F) and 25° C (77° F). DEF that is stored above 35° C (95° F) for longer than 1 month must be tested before use. Testing should evaluate Urea Percentage, Alkalinity as NH3 and Biuret content.

The length of storage of DEF is listed in the following table:

Table 29

Storage Temperature	Expected DEF Life
Below 25° C (77° F)	18 months
25° C (77° F) to 30° C (86° F)	12 months
30° C (86° F) to 35° C (95° F)	6 months
Above 35° C (95° F)	test quality before use

Refer to “ISO 22241” document series for more information about DEF quality control.

Note: Dispose of all fluids according to applicable regulations and mandates.

DEF/Urea Solution Recommendations for Marine Engines

The US has adopted/approved NOx Emissions Control Area (ECA) regulations. Per ECAs, vessels that are 2016 and later models, or vessels that are modified to 2016 models, are required to meet Tier III NOx standards. These engines may require the use of Diesel Exhaust Fluid (DEF) and other urea solutions for engines equipped with Selective Catalytic Reduction (SCR) systems.

The crystallization temperature of 40 percent urea solution is 0° C (32° F). If urea solution ambient temperatures are routinely below 5° C (41° F) and supplemental heat is not applied to urea storage, then 32.5 percent solution should be used and maintained at a temperature above −10° C (14° F). Urea solutions should be maintained above the specified freezing temperature. Consult the urea supplier and follow the guidelines provided in this article for handling and recommendations.

Vessels that are traveling internationally and have on/off NOx controls that allow the vessels to meet ECA regulations must enable NOx controls prior to entering the ECA. For US flagged vessels, the SCR must be activated and deactivated automatically based on input from the Global Positioning System. For US flagged vessels, on/off NOx controls are allowed on engines **>** 30 liters/cylinder and are not allowed on engines < 30 liters/cylinder unless installed on a vessel with propulsion engines >30 liters/cylinder. Otherwise the NOx control systems on Category 1 and 2 engines must always be on. Foreign destinations should be reviewed for supply of ULSD fuel and DEF prior to departure. Exemptions for ULSD or DEF use due to fluid unavailability per “40 CFR part 1042.650(a)” by US flagged vessels operating outside of US waters may be requested from the US Environmental Protection Agency (EPA). The EPA can be contacted at the following address:

complianceinfo@epa.gov

When used in marine engines, DEF of 32.5 percent urea concentration must meet all the guidelines and quality recommendations given in this section.

When used in marine engines, urea solution of 40 percent urea concentration must follow all the DEF guidelines and quality recommendations given in this section and must meet the characteristics listed in Characteristics for Urea Solutions Table for 40 percent concentration. The supplier should provide documentation to prove that the urea solution is compliant with the characteristics published in Characteristics for Urea Solutions Table .

Refer to your engine Operation and Maintenance Manual to determine the concentration of urea solution allowed in your engine.

NOTICE
The engine should use the correct specification of fluids. Failure to use the correct specification of fluids could affect your warranty.

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DEF Specifications

General Characteristics of DEF

For detailed information on the requirements and characteristics of DEF, refer “ISO 22241”. For a quick reference, typical specifications of DEF are given in Table 30 .

Table 30

Characteristics for Urea Solutions			
Property	**Unit of measure**	**DEF 32.5 percent**	**Urea Solution 40 percent (1)**
Urea content		32.5 percent (2)	40 percent (3)
Alkalinity as NH_3	Percent	0.2	0.2
Density at 20° C (68° F)	g/L	1.087 - 1.093 (4)	1.108 - 1.114 (5)
Refractive Index at 25° C (77° F)		1.381 - 1.384 (6)	1.394-1.397 (7)
Biuret	Percent	0.3 max	
Aldehydes	mg/kg	5 max	
Insoluble Matter	mg/kg	20 max	
Aluminum	mg/kg	0.5 max	
Calcium	mg/kg	0.5 max	
Chromium	mg/kg	0.2 max	
Copper	mg/kg	0.2 max	
Iron	mg/kg	0.5 max	
Magnesium	mg/kg	0.5 max	
Nickel	mg/kg	0.2 max	
Phosphate (PO_4)	mg/kg	0.5 max	
Potassium	mg/kg	0.5 max	
Sodium	mg/kg	0.5 max	
Zinc	mg/kg	0.2 max	

(1) For use in marine engines only
(2) Acceptable range is 31.8 - 33.2 percent
(3) Acceptable range is 39-41 percent
(4) Target value is 1.090 g/L
(5) Target value is 1.112
(6) Target value is 1.382
(7) Target value is 1.3956

Fluid Sampling & Analysis Section

Analysis

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Perkins Fuel Analysis

Perkins Fuel Analysis

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

Fuel Analyses

A Fuel Analysis program provides testing of the fuel for the properties listed below. The actual analyses provided may vary depending on your requirements and reasons for testing. Consult your local Perkins distributor for complete information and assistance about a Fuel Analysis program.

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

The results are reported and appropriate recommendations are provided.

A properly administered Fuel Analysis program can reduce the repair costs and reduce the impact of down time. Fuel Analysis is a key component of this program and can ensure that your fuel is stored in a clean environment, meets government requirements, and can meet the expected guidelines for performance in your engine. Consult your Perkins distributor to determine your fuel testing needs and establish a regular testing interval based on those needs. Consult the “Perkins Specification for Distillate Fuel for Nonroad Diesel Engines” listed in table in section XXXX and the Contamination Controlsection of this Perkins Diesel Engines Fluids Recommendations for related details on fuel recommendations including cleanliness.

Obtaining Fuel Samples

Fuel sampling methods depend on the type of fuel tank to be sampled. Storage tanks may have an automatic sampling valve at different levels. Storage tanks without an automatic sampling valve require a tank sampling device (commonly known as a “Bacon Bomb” or “Sample Thief”). Fuel analysis sampling kits can be obtained from your local Perkins distributor. Size of fuel sample needed may be dependent upon the list of tests required.

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Perkins Coolant Analysis

Testing the engine coolant is important to ensure that the engine is protected from internal cavitation and corrosion. The analysis also tests the ability of the coolant to protect the engine from boiling and freezing. Coolant analysis is the best way to monitor the condition of your coolant and your cooling system and is based on periodic samples. Consult your local Perkins distributor for information and assistance about a Coolant Analysis program.

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

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

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

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

New Systems, Refilled Systems, and Converted Systems

Perform a Coolant analysis (Level 2) at the following maintenance intervals.

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

Perform this analysis at the interval that occurs first for new systems, for refilled systems, or for converted systems that use Perkins ELC (Extended Life Coolant). This 500 service hours check will also check for any residual cleaner that may have contaminated the system.

Recommended Interval for Coolant Sample

Table 31 contains the recommended sampling interval for all coolants that meet EC-1 (Engine Coolant specification - 1). These figures are also the recommended sampling interval for all conventional heavy-duty coolant/antifreeze.

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

Table 31

Recommended Interval		
Type of Coolant	**Level 1**	**Level 2**
Commercial Heavy-Duty Coolant/Antifreeze and SCA (Supplemental Coolant Additive)	Every 250 hours	Yearly
Perkins ELC and Commercial Extended Life Coolant (1)	Optional or every 500 hours	Yearly or every 500 hours

(1) Commercial Extended Life Coolant that meets the Perkins technical specification requirements

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

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

Coolant Analysis (Level 1)

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

The following properties of the coolant are tested:

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

The results are reported, and appropriate recommendations are made.

Coolant Analysis (Level 2)

A coolant analysis (Level 2) is a comprehensive chemical evaluation of the coolant. This analysis is also a check of the overall condition of the cooling system.

The coolant analysis (Level 2) has the following features:

- Full coolant analysis (Level 1)
- Identification of metal corrosion and of contaminants
- Identification of buildup of the impurities that cause corrosion
- Identification of buildup of the impurities that cause scaling
- Determination of the possibility of electrolysis within the cooling system of the engine

The results are reported, and appropriate recommendations are made.

For more information on coolant analysis, consult your Perkins distributor.

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Perkins Oil Analysis

NOTICE
These recommendations are subject to change without notice. Consult your local Perkins distributor for the most up-to-date recommendations.

Note: DO NOT USE ONLY THIS Perkins Diesel Engines Fluids Recommendations AS A BASIS FOR DETERMINING OIL DRAIN INTERVALS.

The use of an oil sampling maintenance tool service that evaluates oil degradation and detects signs of wear on internal components is recommended. Oil sampling analysis divides oil analysis into four categories:

- Component wear
- Oil condition
- Oil contamination
- Oil identification

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

Oil Condition analysis is used to determine if the oil has degraded. Tests are done to look at the oxidation, sulfation, and viscosity of the oil. An Analysis service uses established guidelines or trend analysis to determine if the oil has reached the useful life limit.

Oil Contamination tests are performed to determine if anything harmful has entered the oil. This analysis relies on the results from the following tests: elemental analysis, soot, particle count, fuel dilution, water, and glycol.

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

These four types of analysis are used to monitor the condition of your application, and to help identify potential problems. A properly administered oil analysis program will reduce repair costs and the program will lessen the impact of downtime.

An oil analysis program uses a wide range of tests to determine the condition of the oil and the condition of the lubricated compartment.

Guidelines that are based on experience and a correlation to failures have been established for these tests. A trained person at your Perkins distributor should make the final analysis.

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

Note: Cooling system problems will also reduce the life of engines. Coolant analysis and oil analysis provide a complete and accurate method for monitoring the health of all engine systems. Refer to the coolant analysis information in this Perkins Diesel Engines Fluids Recommendations. A properly administered sampling program will reduce repair costs and lessen the impact of downtime.

Refer to the Contamination Control section in this “Perkins Diesel Engines Fluids Recommendations” for recommended fluid cleanliness targets.

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

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

Consult your Perkins distributor for complete information and assistance about the oil analysis program.

Obtaining Oil Samples

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

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

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

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

- Use an in-line sampling valve on the pressurized oil manifold (oil rail)
- Use a sampling gun (vacuum pump) that is inserted into the oil pan.

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

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

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

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

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

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

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

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

Oil Sampling Interval

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

Recommended interval for engine oil samples is given in table 32 . A 250 hour sampling interval can provide a timely indication of oil contamination and oil degradation.

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

Table 32

Oil Sampling Interval for Engine crankcase	
Recommended Interval (1)(2)	Oil Type
Every 250 Service Hours	Perkins DEO / API CI-4 / ACEA E7 Perkins DEO-ULS / API CK-4 / ACEA E11

(1) Severe applications may require a more frequent oil sampling, for example 125 service hours interval.
(2) Under certain conditions, the Perkins distributor or the Operation and Maintenance Manual may allow a longer interval between oil samplings.

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

For other acceptable oil types and specifications, refer to the “Lubricant Viscosities for Ambient Temperatures” Table in this Perkins Diesel Engines Fluids Recommendations.

Consult your Perkins distributor for complete information and assistance to establish an oil sampling program for your engine.

More Frequent Sampling Improves Life-Cycle Management

Traditionally, the suggested oil sampling intervals for diesel engines have been at 250 hours. However in severe applications, more frequent oil sampling is recommended. Severe service for engines occurs at high loads, in high temperatures, and in dusty conditions. If any of these conditions or other severe service indicators exist, sample the engine oil at 125-hour intervals. These additional samples will increase the chance of detecting a potential failure.

Determining Optimum Oil Change Intervals

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

This Perkins Diesel Engines Fluids Recommendations does not address recommended oil drain intervals. Refer to your engine Operation and Maintenance Manual, and consult your Perkins distributor for additional guidance, including but not limited to guidance on establishing optimized and/or acceptable oil drain intervals.

Note: The use of oil sampling analysis helps environmental sustainability as the best way to optimize oil life. A fluid sampling program will help engines reach expected life. Consult your Perkins distributor regarding the testing required to establish a safe, optimized oil drain interval.

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

- Use recommended oils, as described in this document or the OMM
- Use of recommended fuels, as described in this document or the OMM
- Using recommended filters
- Using industry standard good maintenance practices
- Following maintenance intervals as detailed in engine Operation and Maintenance Manual

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

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

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

To help protect your engine, and help optimize oil drain intervals for engine applications and duty cycles, use oil sampling analysis as follows:

- Recommended as a standard practice
- Recommended to determine oil drain intervals when using fuel with sulfur levels between 0.05% (500 ppm) and 0.1% (1000 ppm)
- Required to determine oil drain intervals when using fuel with sulfur levels that are above 0.1% (1000 ppm)

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

Lubricants for Extended Oil Drains

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

Fuel Sulfur Impact on Engine Oil

The use of oil analysis is recommended for determining oil life.

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

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

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

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

These recommendations apply for Perkins DEO-ULS and DEO.

Note: Engine operating conditions play a key role in determining the effect that fuel sulfur will have on engine deposits and on engine wear. Refer to the Diesel Fuel Chapter in this Perkins Diesel Engines Fluids Recommendations and consult your Perkins distributor for guidance when fuel sulfur levels are above 0.2% (2000 ppm) Base the oil change interval on the oil analysis. Ensure that the oil analysis includes the condition of the oil and a wear metal analysis.

Consult a trained analyst when making oil drain decisions based on oil sample results.

NOTICE

Depending on application severity and localized environmental conditions, and also depending on maintenance practices, operating Direct Injection (DI) diesel engines and operating PC (Precombustion Chamber) diesel engines on fuel with sulfur levels over 0.1 percent (1000 ppm) may require significantly shortened oil change intervals in order to help maintain adequate wear protection. Refer to Perkins Diesel Engines Fluids Recommendations, “Diesel Fuel Characteristics” section for more information.

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

For fuel and coolant analysis and use of analysis, refer to the “Diesel Fuel” and “Coolants” chapters in this Perkins Diesel Engines Fluids Recommendations.

Note: Engine operating conditions play a key role in determining the effect that fuel sulfur will have on engine deposits and on engine wear. Consult your Perkins distributor for guidance when fuel sulfur levels are above 0.2% (2000 ppm).

Additives Section

Fuel Additives

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Fuel Additive General Information

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

In special circumstances, Perkins recognizes the need for fuel additives. Use fuel additives 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. Perkins discourages the use of metallic fuel additives in most applications. Metallic fuel additives should only be used in applications, where the use of metallic fuel additives is specifically recommended by Perkins.

Note: Diesel fuel additives or 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.

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Diesel Fuel Conditioner

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Perkins Diesel Fuel System Cleaner

Note: Perkins Diesel Fuel System Cleaner, part number T400012, is the only fuel system cleaner available to the end user that is tested and approved by Perkins for use in Perkins diesel engines.

Perkins 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. Perkins 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. Perkins 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 Perkins Diesel Fuel System Cleaner is proven to inhibit the growth of new deposits.

Perkins Diesel Fuel System Cleaner can be added directly to diesel fuel, biodiesel, or biodiesel blends. Perkins 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.

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

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

For engines experiencing problems such as power loss, increased fuel consumption, or black smoke due to the presence of fuel-related deposits in fuel injectors, a high-strength cleaning cycle is recommended. Add one 946 mL (32 oz) bottle of Perkins Diesel Fuel System Cleaner per 250 L (66 US gal) of fuel, which corresponds to a treat rate of 0.4 percent by volume. Prior to refueling, pour Perkins 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, Perkins Diesel Fuel System Cleaner, add the cleaner to the fuel as previously described, but at a 0.2 percent treat rate. In this case, one 0.946 L (57.728 cubic inch) bottle will treat 500 L (132 US gal) of fuel. Perkins 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 Perkins Diesel Fuel System Cleaner does not lessen the responsibility of the engine owner and/or responsibility of the fuel supplier to follow all industry standard maintenance practices for fuel storage and for fuel handling. Refer to General Fuel Information section in this Perkins Diesel Engines Fluids Recommendations for additional information. Also, use of Perkins Diesel Fuel System Cleaner does not reduce the responsibility of the owner of the engine to use appropriate diesel fuel. Refer to Fuel Recommendations section in this Perkins Diesel Engines Fluids Recommendations for guidance.

Perkins strongly recommends that Perkins Diesel Fuel System Cleaneris used with biodiesel and biodiesel blends. Perkins Diesel Fuel System Cleaner is suitable for use with biodiesel/biodiesel blends that meet Perkins biodiesel recommendations and requirements. Not all fuel cleaners are suitable for use with biodiesel/biodiesel blends. Read and follow all applicable label usage instructions. Also, refer to this Perkins Diesel Engines Fluids Recommendations, Distillate Diesel Fuel section and also refer to the Biodiesel section, which includes Perkins biodiesel recommendations and requirements.

When used as directed, Perkins 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, Perkins 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 Perkins 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: Perkins Diesel Fuel System Cleaner contains less than 15 ppm of sulfur and is acceptable for use with ULSD fuel.

Oil Additives

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Oil Additive General Information

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

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

To achieve the best performance from Perkins engines, conform to the following guidelines:

- Select the correct Perkins oil or select commercial oil that has passed the Field Performance Evaluation. Refer to the “Commercial Engine Oil Recommendations” section in the Engine Oil section of this Perkins Diesel Engines Fluids Recommendations.
- Refer to the appropriate “Lubricant Viscosities for Ambient Temperatures for Perkins Diesel Engines” table in this Perkins Diesel Engines Fluids Recommendations to find the correct oil viscosity grade for the engine
- At the specified interval, service the engine. Use appropriate new oil and install an appropriate new oil filter.
- Perform maintenance at the intervals that are specified in the engine Operation and Maintenance Manual, “Maintenance Interval Schedule”.

Maintenance Section

Contamination Control Guidance

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Contamination Control General Information

Defining Contamination

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

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

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

Some contaminants are generated within the fluid system due to the normal operation of the system. Contaminants may be drawn into the system from the outside environment or contaminated fill fluids or improper maintenance and repair practices.

Particle contaminants are visible to the naked eye if the particles are approximately 40 µm (microns) and larger while smaller particles are not visible. Particle contaminants can cause damage even if the particles are not visible to the naked eye. The critical particle size for wear particles in a modern diesel engine fuel system is 4 µm.

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

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

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Contamination Control Measurement

Measuring Cleanliness

Fluid cleanliness can be measured by taking fluid samples from various machine compartments. Your Perkins distributor can analyze the samples. Particle contaminants are typically measured by particle counters. Chemical contaminants can be measured by specific analysis techniques such as oxidation, water, or soot tests. Some chemical contaminants, such as water in fuel, can interfere with the particle counters and can be counted as particles. Refer to your Perkins distributor for more information.

The number of particles in fluids is expressed in “ISO (International Organization for Standardization)” ratings. “ISO 4406” Standard, classifies fluid cleanliness by the number and size of particles in 1 mL of fluid. “ISO 4406” Standard measures particle size in µm (microns) and reports the resulting count in three code ranges X, Y & Z. The three code range defines the size and distribution of particles in 1 mL of fluid:

- The first code range, X represents the number of particles equal to or larger than 4 µm per milliliter of fluid.
- The second code range, Y represents the number of particles equal to or larger than 6 µm per milliliter of fluid.
- The third code range, Z represents the number of particles equal to or larger than 14 µm per milliliter of fluid.

An example of an “ISO 4406” particle count is 18/16/13. Perkins “ISO” cleanliness recommendations are expressed as two or three codes, depending on the engine type. The three code range follows “ISO 4406” definitions and is used for liquid fuels such as diesel and gasoline. The two code system, example “ISO -/16/13”, is used for certain lubricant systems. In the two code system, the first number is the number of particles equal to or larger than 4 µm per milliliter of fluid. This number is not required and may be represented by a dash (-). The second number (Y) and the third number (Z) follow “ISO 4406” definitions. Perkins reports the Y and Z codes for lubricating oils to keep consistency with older data and reports.

An example of the particle size and distribution of the “ISO 4406” codes are given in Table33 .

Table 33

ISO 4406 Code	Number of particles in 1 mL of fluid		
	4µm and up	6µm and up	14µm and up
“ISO 18/16/13”	1300 - 2500	320 - 640	40 - 80
“ISO 21/19/17”	10000 - 20000	2500 - 5000	80 - 160

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

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

Note: American Society for Testing and Measurement has developed “ASTM D7619” “Standard Test Method for Sizing and Counting Particles in Light and Middle Distillate Fuels, by Automatic Particle Counter”. This test procedure was developed in 2010 to count and measure the size of dispersed dirt particles, water droplets, and other particles in 1-D and 2-D diesel fuels when the specified particle counter is used. “ASTM D7619” is also applicable to biodiesel fuels.

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Contamination Control Recommendations

Cleanliness Standards for Machine Systems

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

Perkins has established minimum fluid cleanliness targets for fuels and fill oils and for machine roll-off. Fluids filled into the machine or engine fill tanks are recommended to be at the target levels provided in Table 34 or cleaner. Cleanliness targets for applicable machine component systems are referred to as “Roll-off”. Roll-off is defined as the cleanliness specification of the fluid that is to be obtained before the machine returns to work after maintenance and or system invasion repair. When the system fill fluids and Roll-off are maintained at or cleaner than the “ISO” cleanliness targets, contamination-related effects will be reduced.

Table 34

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

(1) The fluids should meet or exceed the cleanliness requirements of the listed ISO levels.
(2) For engine oils optical particle counters may not be effective. Instead filter the oil prior to dispensing into the engine tank, use engine oil filters of 12 micron absolute efficiency and ensure that the oil temperature is 20° C (68° F) or higher. Refer to the details given in this article.
(3) For transmission, gear, differential and axle oils, additives and the viscosity of the oil may interfere with particle counting. An alternative is to use adequate filtration to ensure clean oils prior to filling in the machine compartment.
(4) This cleanliness standard applies only to the Series 700 family of rigid frame trucks, 777 size and larger.

The “fill” fluids cleanliness target is not a fluid “delivery” target. The level of cleanliness for delivered fluids is not specified by Perkins. Customers can work with the distributors or carriers to determine the cleanliness level of delivered fluids. However, a more effective and economic means to achieve the fill cleanliness targets is to filter the fluids prior to filling into machine tanks as compared with specifying delivery fluid cleanliness level. Follow the guidelines provided in this Contamination Control section.

Although older technology machines may not be able to maintain the recommended cleanliness targets of advanced models, the same contamination control intervention measures such as filtration and subsequent service procedures should be used on all Perkins products.

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

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

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

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

Consult your Perkins distributor for information and solutions to your oil and fuel analysis needs.

General Contamination Control Recommendations or Practices

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

The following are general guidelines for controlling contaminants.

- Refer to the Recommendations for Fuel Systems in this manual for recommended fuel cleanliness levels and guidelines.
- Refer to the machine Operation and Maintenance Manual for the required maintenance for all machine compartments.
- When you add oil to a machine, use adequate filtration to clean the oil to meet the targets provided in Table 34 .

- Perform scheduled fluid sampling - oil analysis for contamination to maintain the recommended ISO cleanliness level of fill and machine fluids. Refer to fluid sampling - Oil Analysis section in this manual. The particle count analysis can be performed by your Perkins distributor. Particle count can be conducted during the scheduled fluid sampling - Oil Analysis for the compartment. Extra oil samples are not required for the particle count sampling.
- Use only coolants that are recommended by Perkins for your machine. Follow the recommended maintenance procedure for the cooling system in the Operation and Maintenance Manual for your machine.
- Maintain the engine air filters and air intake system to avoid unwanted contaminant ingression.
- Follow contamination control practices for the shop area, component/machine disassembly areas, parts, shop tools, test setups, test areas, storage areas, and waste collection areas, Keep components clean during inspection, assembly, testing, and filling machines with clean fluids. Good practices will enhance component life and reduce downtime associated with contaminants. Your Perkins distributor can provide details on suitable contamination processes and practices.
- Follow contamination control practices for the workplace and for the worksite. Maintaining clean oil fill fluids saves time and effort and ensures that fill fluids are at the correct cleanliness levels.
- Use properly designed and maintained bulk storage fluids tanks.
- Protect the fluids storage tanks from dirt and water entry by using 4 µm or less absolute efficiency breathers with the ability to remove water.
- Keep the areas around the tanks filler necks clean of debris and water.
- Drain the storage tanks from water and sediments frequently. The draining schedule depends on use of proper inlet and outlet filters, the use of 4 µm breathers with the ability to remove water, and following recommended contamination control practices. Based on the contamination control program followed, and/or on the fuel supplier recommendations, the storage tank draining schedule may be as frequent as daily until no water is present, and then can be extended to longer periods.
- Install and maintain a properly designed and grounded filtration system. Filtration should include at the entry and at the dispensing point. Continuous bulk filtration may be required to ensure that dispensed oils meet the cleanliness target.
- Cover, protect, and ensure cleanliness of all connection hoses, fittings, and dispensing nozzles.

Note: Bulk fuel filtration units are available through your Perkins distributor. Proper maintenance practices of the bulk filtration systems are available through your Perkins distributor.

General Recommendations and Contamination Control Guidelines for Fuels

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

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

Note: Where recommendations for draining water and/or sediment and/or debris are stated, dispose of this waste according to all applicable regulations and mandates.

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

Fuels of “ISO 18/16/13” cleanliness level or cleaner as dispensed into the engine or machine fuel tank should be used. Reduce power loss, failures, and related down time of engines will result. This cleanliness level is important for new fuel system designs such as Common Rail injection systems and unit injection systems. Injection system designs utilize higher fuel pressures and tight clearances between moving parts to meet required stringent emissions regulations. Peak injection pressures in current fuel injection systems may exceed 200 MPa (29000 psi). Clearances in these systems are less than 5 µm. As a result, particle contaminants as small as 4 µm can cause scoring and scratching of internal pump and injector surfaces and of injector nozzles.

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

To reduce downtime due to contamination, follow these fuel maintenance guidelines. Also, follow the General Contamination Control Recommendations or Practices given above in this section:

- Use high-quality fuels per recommended and required specifications (refer to the “Fuel” chapter in this Special Publication).
- Do not add new engine oil, waste engine oil, or any oil product to the fuel unless the engine is designed and certified to burn diesel engine oil (for example Perkins ORS designed for large engines). Engine oils may raise the sulfur level of the fuel and may cause fouling of the fuel system and loss of performance. Engine oils in fuels can also reduce the maintenance intervals of aftertreatment devices in Tier 4 machines.
- Use recommended Perkins filtration products, including Perkins Advanced Efficiency Fuel Filters. Change your fuel filters per recommended service requirements or as needed. Never fill the new secondary and tertiary fuel filter with fuel before installation. Use the fuel priming pump to remove air from the system.
- Follow proper practices of fuel transport and filtration from storage tank to the machine to allow the delivery of clean fuel to machine tank. Keep the fuel storage tank clean of water, debris, and sediment.
- Filter the fuel coming into the bulk storage fuel tank and at every subsequent transfer into and out of any container and prior to adding to the engine fuel tank preferably through filters with a rating of 20 microns (c) absolute or less. The use of wire mesh media (strainer-type filters) is NOT recommended except when filters with standard media (cellulose or synthetic) are downstream of the wire mesh media filters. Wire mesh filters typically have poor filtration efficiency and can corrode with time, allowing the passing of large particles.
- Perkins recommends the use of properly designed and grounded bulk fuel filter / coalescer units which remove both particulate contamination and water in a single pass. These units can clean fuel to “ISO 16/13/11” or cleaner and can remove free water to 200 ppm (mg/kg) or less.
- Fill machine fuel tanks with fuels of “ISO 18/16/13” cleanliness level or cleaner, in particular for engines with common rail and unit injection systems. When you refuel the machine, filter the fuel through a 4 µm absolute filter (Beta = 75 up to 200 at 4 microns) to reach the recommended cleanliness level. This filtration should be located at the device that dispenses the fuel to the engine or machine fuel tank. In addition, filtration at the dispensing point should have the ability to remove water to ensure that fuel is dispensed at 200 ppm water or less.
- Keep the area around the fuel tank filler neck clean of debris to prevent dirt entry and contamination of the fuel tank.
- Drain your water separators daily per the Operation and Maintenance Manual of your machine.
- Install desiccant type breathers of 4 µm or less absolute efficiency with the ability to remove water on bulk storage tanks.
- Drain your fuel tanks of sediment every 500 hours or 3 months per the Operation and Maintenance Manual of your machine.
- Centrifugal filters may need to be used as a prefilter with fuel that is severely contaminated with gross amounts of water or large particulate contaminants. Centrifugal filters can effectively remove large contaminants but may not be able to remove the very small abrasive particles required to achieve the recommended “ISO” cleanliness level. Bulk filter / coalescers are necessary as a final filter to achieve the recommended cleanliness level.
- Cover, protect, and ensure cleanliness of all connection hoses, fittings, and dispensing nozzles.
- Test for microbial contamination regularly and take proper corrective action if contamination is present. Properly dispose of cleanup waste according to all applicable local regulations and mandates.

- Every 3 months, or sooner if problems are suspected, analyze the fuel for acid number, density, particle content, water, and microbial growth (tank bottom fuel sample). Refer to Fuel Analysis Section. Take corrective action if necessary. Corrective actions may include, but are not limited to, treating the fuel, cleaning of the fuel storage tank/system, and replacing the problematic fuel with fresh fuel.
- When fuels are stored for extended periods, follow all the fuel supplier and tank maintenance procedures. Circulate the fuel regularly through a filter to remove sediments. Test the fuel regularly for acid number, density, particle content, water, and microbial growth. Observe trends of these properties to ensure no detrimental changes. The fuel is not recommended for use when its properties change negatively. For fuels containing biodiesel, the storage duration may be significantly reduced. Observe all the guidelines given in this section.

NOTICE
To meet expected fuel system component life, 4 micron(c) absolute or less secondary fuel filtration is required for all Perkins diesel engines that are equipped with common-rail fuel systems. Also, 4 micron(c) absolute or less secondary fuel filtration is required for all Perkins diesel engines that are equipped with unit injected fuel systems. For all other Perkins 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: Thorough cleaning of fuel storage tanks is strongly recommended before converting to Ultra Low Sulfur Diesel (ULSD) (15 ppm or less sulfur) and/or biodiesel/biodiesel blends. Conversion to ULSD and/or biodiesel/biodiesel blends can loosen fuel system and fuel storage tank deposits. Bulk tank filtration unit and dispensing point filters, and onboard engine filters change intervals may need to be shortened for an extended period of time to allow for this cleaning effect.

Note: All current Perkins diesel engines are factory equipped with Perkins Advanced Efficiency 4 micron (c) absolute fuel filters.

Consult your local Perkins distributor for additional information on Perkins designed and produced filtration products.

Reference Information Section

Reference Materials

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Reference Material

Note: The information that is contained in the listed publications is subject to change without notice. Consult your local Perkins distributor for the most current recommendations.

Note: Refer to this Perkins Diesel Engines Fluids Recommendations, the respective product data sheet, and to the appropriate Operation and Maintenance Manual for product application recommendations.

Lubricant

- “ASTM D2896 Standard Test Method for Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration”
- “ASTM D4485 Standard Specification for Performance of Active API Service Category Engine Oils”
- “ASTM D4739 Standard Test Method for Base Number Determination by Potentiometric Hydrochloric Acid Titration”
- “ASTM D6681 Standard Test Method for Evaluation of Engine Oils in a High Speed, Single-Cylinder Diesel Engine—Caterpillar 1P Test Procedure”
- “ASTM D8047 Standard Test Method for Evaluation of Engine Oil Aeration Resistance in a Caterpillar C13 Direct-Injected Turbocharged Automotive Diesel Engine”
- “ASTM D8048 Standard Test Method for Evaluation of Diesel Engine Oils in T-13 Diesel Engine”

Fuel

ASTMs

- “ASTM D86 Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure”
- “ASTM D93 Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester”
- “ASTM D97 Standard Test Method for Pour Point of Petroleum Products”
- “ASTM D129 Standard Test Method for Sulfur in Petroleum Products (General High-Pressure Decomposition Device Method)”
- “ASTM D130 Standard Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test”
- “ASTM D287 Standard Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)”
- “ASTM D445 Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)”
- “ASTM D473 Standard Test Method for Sediment in Crude Oils and Fuel Oils by the Extraction Method”
- “ASTM D482 Standard Test Method for Ash from Petroleum Products”
- “ASTM D524 Standard Test Method for Ramsbottom Carbon Residue of Petroleum Products”
- “ASTM D613 Standard Test Method for Cetane Number of Diesel Fuel Oil”
- “ASTM D664 Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration”
- “ASTM D874 Standard Test Method for Sulfated Ash from Lubricating Oils and Additives”
- “ASTM D975 Standard Specification for Diesel Fuel Oils” (includes requirements for B5 and lower biodiesel blends)
- “ASTM D976 Standard Test Method for Calculated Cetane Index of Distillate Fuels”
- “ASTM D1298 Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method”
- “ASTM D1319 Standard Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption”
- “ASTM D1655 Standard Specification for Aviation Turbine Fuels”
- “ASTM D1744 Standard Test Method for Determination of Water in Liquid Petroleum Products”

- “ASTM D1796 Standard Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)”
- “ASTM D2274 Standard Test Method for Oxidation Stability of Distillate Fuel Oil (Accelerated Method)”
- “ASTM D2500 Test Method for Cloud Point of Petroleum Products”
- “ASTM D2622 Standard Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry”
- “ASTM D2624 Test Methods for Electrical Conductivity of Aviation and Distillate Fuels”
- “ASTM D2709 Standard Test Method for Water and Sediment in Middle Distillate Fuels by Centrifuge”
- “ASTM D3241 Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels”
- “ASTM D4052 Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter”
- “ASTM D4176 Standard Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)”
- “ASTM D4308 Test Method for Electrical Conductivity of Liquid Hydrocarbons by Precision Meter”
- “ASTM D4530 Standard Test Method for Determination of Carbon Residue (Micro Method)”
- “ASTM D4539 Test Method for Filterability of Diesel Fuels by Low-Temperature Flow Test (LTFT)”
- “ASTM D4951 Standard Test Method for Determination of Additive Elements in Lubricating Oils by Inductively Coupled Plasma Atomic Emission Spectrometry”
- “ASTM D5453 Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence”
- “ASTM D5761 Standard Practice for Emulsification/Suspension of Multiphase Fluid Waste Materials”
- “ASTM D5771 Test Method for Cloud Point of Petroleum Products (Optical Detection Stepped Cooling Method)”
- “ASTM D5772 Test Method for Cloud Point of Petroleum Products (Linear Cooling Rate Method)”
- “ASTM D5773 Test Method for Cloud Point of Petroleum Products (Constant Cooling Rate Method)”
- “ASTM D6079 High Frequency Reciprocating Rig (HFRR)”
- “ASTM D6217 Standard Test Method for Particulate Contamination in Middle Distillate Fuels by Laboratory Filtration”
- “ASTM D6371 Test Method for Cold Filter Plugging Point of Diesel and Heating Fuels”
- “ASTM D6468 Standard Test Method for High Temperature Stability of Middle Distillate Fuels”
- “ASTM D6584 Standard Test Method for Determination of Total Monoglycerides, Total Diglycerides, Total Triglycerides, and Free and Total Glycerin in B-100 Biodiesel Methyl Esters by Gas Chromatography”
- “ASTM D6751 Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels”
- “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)””
- “ASTM D7467 Standard Specification for Diesel Fuel Oil, Biodiesel Blend (B6 to B20)”
- “ASTM D7501 Standard Test Method for Determination of Fuel Filter Blocking Potential of Biodiesel (B100) Blend Stock by Cold Soak Filtration Test (CSFT)”
- “ASTM D7619 Standard Test Method for Sizing and Counting Particles in Light and Middle Distillate Fuels, by Automatic Particle Counter[1, 2]”
- “ASTM D7688 Standard Test Method for Evaluating Lubricity of Diesel Fuels by the High-Frequency Reciprocating Rig (HFRR) by Visual Observation”
- “ASTM D7806 Standard Test Method for Determination of the Fatty Acid Methyl Ester (FAME) Content of a Blend of Biodiesel and Petroleum-Based Diesel Fuel Oil Using Mid-Infrared Spectroscopy”

ENs

- “EN 590 Automotive fuels - Diesel - Requirements and test methods” (includes requirements for B5 and lower biodiesel blends)
- “BS EN ISO 10370 Petroleum products. Determination of carbon residue. Micro method.”
- “BS EN 12662 Liquid petroleum products. Determination of total contamination in middle distillates, diesel fuels, and fatty acid methyl esters.”
- “EN 14078 Liquid petroleum products - Determination of fatty acid methyl esters (FAME) in middle distillates - Infrared spectroscopy method”
- “BS EN 14103 Fat and oil derivatives. Fatty acid methyl esters (FAME). Determination of ester and linolenic acid methyl ester contents.”
- “EN 14104 Fat and oil derivatives - Fatty Acid Methyl Esters (FAME) - Determination of Acid Value”
- “BS EN 14105 Fat and oil derivatives. Fatty acid methyl esters (FAME). Determination of free and total glycerol and mono-, di-, triglyceride contents.”
- “BS EN 14107 Fat and oil derivatives. Fatty acid methyl esters (FAME). Determination of phosphorous content by inductively coupled plasma (ICP) emission spectrometry.”
- “BS EN 14110 Fat and oil derivatives. Fatty Acid Methyl Esters. Determination of methanol content.”
- “BS EN 14112 Fat and oil derivatives. Fatty Acid Methyl Esters (FAME). Determination of oxidation stability (accelerated oxidation test).”
- “BS EN 14214 Automotive fuels - Fatty acid methyl esters (FAME) for diesel engines - Requirements and test methods”
- “BS EN 14538 Fat and oil derivatives. Fatty acid methyl ester (FAME). Determination of Ca, K, Mg, and Na content by optical emission spectral analysis with inductively coupled plasma (ICP OES).”
- “BS EN 15751 Automotive fuels. Fatty acid methyl ester (FAME) fuel and blends with diesel fuel. Determination of oxidation stability by accelerated oxidation method.”
- “BS EN 16709 Automotive fuels. High FAME diesel fuel (B20 and B30). Requirements and test methods.”
- “CEN/TS 15940 Automotive Fuels - Paraffinic Diesel Fuel From Synthesis Or Hydrotreatment - Requirements and Test Methods”

ISOs

- “ISO 2160 Petroleum products — Corrosiveness to copper — Copper strip test”
- “ISO 2719 Determination of flash point — Pensky-Martens closed cup method”
- “ISO 3015 Petroleum and related products from natural or synthetic sources — Determination of cloud point”
- “ISO 3016 Petroleum and Related Products from Natural or Synthetic Sources — Determination of Pour Point”
- “ISO 3104 Petroleum products — Transparent and opaque liquids — Determination of kinematic viscosity and calculation of dynamic viscosity”
- “ISO 3405 Petroleum and related products from natural or synthetic sources — Determination of distillation characteristics at atmospheric pressure”
- “ISO 3675 Crude petroleum and liquid petroleum products — Laboratory determination of density — Hydrometer method”
- “ISO 3679 Determination of flash no-flash and flash point — Rapid equilibrium closed cup method”
- “ISO 3734 Petroleum products — Determination of water and sediment in residual fuel oils — Centrifuge method”
- “ISO 3924 Petroleum products — Determination of boiling range distribution — Gas chromatography method”
- “ISO 3987 Petroleum products — Determination of sulfated ash in lubricating oils and additives”
- “ISO 4264 Petroleum products — Calculation of cetane index of middle-distillate fuels by the four variable equation”
- “ISO 4406 Hydraulic fluid power — Fluids — Method for coding the level of contamination by solid particles”
- “ISO 5165 Petroleum products — Determination of the ignition quality of diesel fuels — Cetane engine method”
- “ISO 5186 Oxygen/fuel gas blowpipes (cutting machine type) with cylindrical barrels — General specifications and test methods”

- “ISO 6245 Petroleum products — Determination of ash”
- “ISO 12156 Diesel fuel — Assessment of lubricity using the high-frequency reciprocating rig (HFRR) — Part 1: Test method”
- “ISO 12185 Crude petroleum and petroleum products — Determination of density — Oscillating U-tube method”
- “ISO 12205 Petroleum products — Determination of the oxidation stability of middle-distillate fuels”
- “ISO 12937 Petroleum products — Determination of water — Coulometric Karl Fischer titration method”
- “ISO 20846 Petroleum products — Determination of sulfur content of automotive fuels — Ultraviolet fluorescence method”
- “ISO 20884 Petroleum products — Determination of sulfur content of automotive fuels — Wavelength-dispersive X-ray fluorescence spectrometry”

MIL

- “MIL-DTL-83133 Turbine Fuel, Aviation, Kerosene Type, JP-8 (NATO F-34), NATO F-35, and JP-8 +100 (NATO F-37)”
- “MIL-DTL-5624 Military Specification: Turbine Fuel, Aviation, Grades JP-4, and JP-5”
- “MIL PRF 38219 : C Turbine Fuel, Low Volatility, JP-7”

Miscellaneous

- “Facts You Should Know About Renewable Fuels, EMA (Engine Manufacturer Association)”
- “EMA Technical Position on Use of Biodiesel Position Statement, EMA (Engine Manufacturer Association)”

  http://www.truckandenginemanufacturers.org/articles

Coolant

- “ASTM D1193 Standard Specification for Reagent Water”
- “ASTM D3306 Standard Specification for Glycol Base Engine Coolant for Automobile and Light-Duty Service”
- “ASTM D4985 Standard Specification for Low Silicate Ethylene Glycol Base Engine Coolant for Heavy-Duty Engines Requiring a Pre-Charge of Supplemental Coolant Additive (SCA)”
- “ASTM D5752 Standard Specification for Supplemental Coolant Additives (SCAs) for Use in Precharging Coolants for Heavy-Duty Engines1, 2”
- “ASTM D5828 - 97 Standard Test Method for Compatibility of Supplemental Coolant Additives (SCAs) and Engine Coolant Concentrates”
- “ASTM D6210 Standard Specification for Fully Formulated Glycol Base Engine Coolant for Heavy-Duty Engines1, 2”
- “ASTM D7619 Standard Test Method for Sizing and Counting Particles in Light and Middle Distillate Fuels, by Automatic Particle Counter1, 2”

Diesel Exhaust Fluid (DEF)

- “ISO 22241 Diesel engines — NOx reduction agent AUS 32 — Part 1: Quality requirements”

Additional Reference Material

SAE J183, “Classification” This document can normally be found in the SAE handbook.

SAE J313, “Diesel Fuels” This document can be found in the SAE handbook. Also, this publication can be obtained from your local technological society, from your local library, or from your local college.

SAE J754, “Nomenclature” This document can normally be found in the SAE handbook.

Engine Manufacturers Association, “Engine Fluids Data Book”

Engine Manufacturers Association
Two North LaSalle Street, Suite 2200
Chicago, Illinois USA 60602
http://www.truckandenginemanufacturers.org/articles

For information on the American Petroleum Institute (API) engine oil categories, contact the API at:

1220 L Street, NW
Washington, DC USA 20005-4070
http://www.api.org

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Product and Dealer Information

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

Delivery Date: _____

Product Information

Model: _____

Product Identification Number: _____

Engine Serial Number: _____

Transmission Serial Number: _____

Generator Serial Number: _____

Attachment Serial Numbers: _____

Attachment Information: _____

Customer Equipment Number: _____

Dealer Equipment Number: _____

Dealer Information

Name: _____ Branch: _____

Address: _____

_____

_____

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

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