

Operation and Maintenance Manual

Caterpillar Commercial Diesel Engine Fluids Recommendations

For All Commercial Diesel Engines Except 3600 Series Engines

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PATRIOT

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FUEL

Fuel Specifications

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General Fuel Information

SMCS Code: 1250; 1280

- Purchase fuel from a reputable supplier.
- Use fuel that meets the minimum Caterpillar specifications for diesel fuel. The specifications are included in the table Caterpillar Specifications for Distillate Fuel. This table is included in the recommendations for diesel fuel. These fuels have a minimum lubricity level of 3100 g. This result is obtained by conducting the Scuffing Load Wear Test (SBOCLE). If a High Frequency Reciprocating Rig (HFRR) is used for testing, the maximum allowable wear scar is .45 mm (0.018 inch) at 60 °C (140 °F). The maximum allowable wear scar is .38 mm (0.0150 inch) at 25 °C (77 °F).
- Keep the fuel storage tank clean of water, debris and sediment.
- Drain water and sediment from the fuel storage tank weekly. Drain water and sediment before the tank is refilled.
- Keep the area around the fuel tank filler neck clean of debris in order to prevent contamination of the fuel tank.
- As required, clean the inside of the engine's fuel tank.
- Drain water and sediment from the engine's fuel tank daily. Drain the tank at the start of a shift. After the fuel tank has been filled, allow the fuel to settle for ten minutes. This will allow the water and sediment to separate from the fuel. Then, drain the water and sediment from the tank.
- Install water separators.
- Drain the water from the water separator daily.
- For some applications, Caterpillar high efficiency fuel filters are required in order to provide maximum life to the fuel system.
- Change fuel filters at the scheduled interval. Never fill the new fuel filter with fuel before installation. Use the fuel priming pump to remove air from the system.
- Install breather filters on the fuel tanks.

Fuel Information for Diesel Engines

SMCS Code: 1250; 1280

The two basic types of diesel fuel are No. 2 diesel fuel and No. 1 diesel fuel. No. 2 diesel fuel is a heavier diesel fuel than No. 1 diesel fuel. Heavier fuels can cause problems with fuel filters, fuel lines, fuel tanks, and fuel storage in cold weather. Heavier diesel fuels such as No. 2 diesel fuel can be used in diesel engines that operate in cold temperatures with a minimum amount of pour point depressant additive. For more information on fuels which include blends of No. 1 and No. 2 diesel fuel, consult your fuel supplier.

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

Starting Aids

The use of a starting aid is a conventional method of assistance for cold starts in low temperature conditions. A variety of starting aids are available for Caterpillar engines. Follow the recommendations that are provided by the manufacturer of the starting aid.

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 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 use either engine coolant or exhaust gas as a heat source. These systems may prevent filter waxing problems without the use of de-icers. 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: Only use fuel heaters that are controlled by thermostats or use fuel heaters that are self-regulated. Do not use fuel heaters in warm temperatures.

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, see your Caterpillar dealer.

De-icers

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

Fuel Recommendations

SMCS Code: 1250; 1280

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

The preferred fuels provide maximum engine service life and performance. The preferred fuels are distillate fuels. These fuels are commonly called diesel fuel, furnace fuel, gas oil, or kerosene.

The permissible fuels are crude oils or blended fuels. Use of these fuels can result in higher maintenance costs and in reduced engine service life.

Diesel fuels that meet the specifications in Table 7 will help to provide maximum engine service life and performance. In North America, diesel fuel that is identified as No. 1-D or No. 2-D in "ASTM D975" generally meet the specifications. Table 7 is for diesel fuels that are distilled from crude oil. Diesel fuels from other sources could exhibit detrimental properties that are not defined or controlled by this specification.

Table 7

Caterpillar Specifications for Distillate Diesel Fuel		
Specifications	Requirements	ASTM Test
Aromatics	35% maximum	"D1319"
Ash	0.02% maximum (weight)	"D482"
Carbon Residue on 10% Bottoms	0.35% maximum (weight)	"D524"
Cetane Number	40 minimum (DI engines)	"D613"
	35 minimum (PC engines)	
Cloud Point	The cloud point must not exceed the lowest expected ambient temperature.	-
Copper Strip Corrosion	No. 3 maximum	"D130"
Distillation	10% at 282 °C (540 °F) maximum	"D86"
	90% at 360 °C (680 °F) maximum	
Flash Point	legal limit	"D93"

(continued)

(Table 7, contd)

Caterpillar Specifications for Distillate Diesel Fuel		
Specifications	Requirements	ASTM Test
API Gravity	30 minimum	"D287"
	45 maximum	
Pour Point	6 °C (10 °F) minimum below ambient temperature	"D97"
Sulfur ⁽¹⁾	3% maximum	"D3605" or "D1552"
Kinematic Viscosity ⁽²⁾	1.4 cSt minimum and 20.0 cSt maximum at 40 °C (104 °F)	"D445"
Water and Sediment	0.1% maximum	"D1796"
Water	0.1% maximum	"D1744"
Sediment	0.05% maximum (weight)	"D473"
Gums and Resins ⁽³⁾	10 mg per 100 mL maximum	"D381"
Lubricity ⁽⁴⁾	3100 g minimum	"D6708"
	0.45 mm (0.018 inch) maximum at 60 °C (140 °F)	"D6079"
	0.38 mm (0.015 inch) maximum at 25 °C (77 °F)	

- (1) Caterpillar fuel systems and engine components can operate on high sulfur fuels. Fuel sulfur levels affect exhaust emissions. High sulfur fuels also increase the potential for corrosion of internal components. Fuel sulfur levels above 1.0 percent may significantly shorten the oil change interval. For additional information, see this publication, "Engine Oil" topic (Maintenance Section).
- (2) The values of the fuel viscosity are the values as the fuel is delivered to the fuel injection pumps. If a fuel with a low viscosity is used, cooling of the fuel may be required to maintain a 1.4 cSt viscosity at the fuel injection pump. Fuels with a high viscosity might require fuel heaters in order to bring down the viscosity to a 20 cSt viscosity. For additional information, see Special Publication, SEBD0717, "Diesel Fuel and Your Engine".
- (3) Follow the test conditions and procedures for gasoline (motor).
- (4) The lubricity of a fuel is a concern with low sulfur fuel. To determine the lubricity of the fuel, use either the "ASTM D6708 Scuffing Load Wear Test (SBOCLE)" or the "ASTM D6079 High Frequency Reciprocating Rig (HFRR)" test. 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.

NOTICE

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

In the USA, 0.05 percent diesel fuels have been used in all on-highway truck engines since 1 January 1994. This low sulfur diesel fuel was mandated as a means of directly reducing particulate emissions from diesel truck engines. This low sulfur fuel will also be used in Caterpillar commercial diesel engines when low emissions are required or when the fuel supply sources provide this type of fuel. Caterpillar has not seen any detrimental effects with 0.05 percent sulfur fuel in Caterpillar diesel engines.

NOTICE

Heavy Fuel Oil (HFO), Residual fuel, or Blended fuel must NOT be used in Caterpillar diesel engines (except in 3600 Series HFO engines). Severe component wear and component failures will result if HFO type fuels are used in engines that are configured to use distillate fuel.

In extreme cold ambient conditions, you may use the distillate fuels that are specified in Table 8. However, the fuel that is selected must meet the requirements that are specified in Table 7. These fuels are intended to be used in operating temperatures that are down to -54 °C (-65 °F).

Table 8

Distillate Fuels ⁽¹⁾	
Specification	Grade
"MIL-T-5624R"	JP-5
"ASTM D1655"	Jet-A-1
"MIL-T-83133D"	JP-8

- (1) The fuels that are listed in this Table may not meet the requirements that are specified in the "Caterpillar Specifications for Distillate Diesel Fuel" Table. Consult the supplier for the recommended additives in order to maintain the proper fuel lubricity.

These fuels are lighter than the No. 2 grades of fuel. The cetane number of the fuels in Table 8 must be at least 40. If the viscosity is below 1.4 cSt at 38 °C (100 °F), use the fuel only in temperatures below 0 °C (32 °F). Do not use any fuels with a viscosity of less than 1.2 cSt at 38 °C (100 °F). Fuel cooling may be required in order to maintain the minimum viscosity of 1.4 cSt at the fuel injection pump.

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 this specification. To ensure optimum engine performance, a complete fuel analysis should be obtained before engine operation. The fuel analysis should include all of the properties that are listed in Table 7.

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Characteristics of Diesel Fuel

SMCS Code: 1250; 1280

The primary characteristics that affect engine operation and performance in cold temperatures are the following characteristics: Lubricity, Viscosity, Cetane Number, Cloud Point, Pour Point, and Moisture Content.

Refer to Special Publication, SEBD0717, "Diesel Fuels and Your Engine" for information about the following fuel properties: ignition quality, gravity (density), viscosity, cloud point, pour point, and sulfur content.

Lubricity and Low Sulfur Fuel

Note: The fuel lubricity is important. You should consider the fuel's lubricity whenever you operate the equipment in arctic weather. Also, you should consider the fuel's lubricity whenever you use fuels that are lower in viscosity. There are many aftermarket additives that are available to treat fuel. If the fuel's lubricity is an issue, consult your fuel supplier for proper recommendations regarding fuel additives.

In the USA, a 0.05 percent limit on the amount of fuel sulfur in diesel fuel was mandated in January of 1994 for on-highway trucks. The removal of sulfur from diesel fuel helps to reduce particulate emissions from diesel engines. While limits for fuel sulfur have not generally been mandated for off-highway use, some local governments have regulations that include off-highway use. There is frequently no difference in the fuel that is sold for different applications. The same fuel is often used for both on-highway applications and off-highway applications. Other areas of the world are mandating similar limits. Regulations continue to become more stringent. Lower sulfur limits can be expected in the future.

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

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 with low sulfur require little hydro-treatment to obtain the 0.05 percent limit. Crude oils with high sulfur require a more severe treatment.

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

All low sulfur fuels do not have a low lubricity. The fuel's lubricity may be enhanced with additives. Many fuel suppliers treat the fuel with these additives. Do not use a fuel lubricity additive before you consult the fuel's supplier. Some aftermarket additives may not be compatible with the additives that are already in the fuel. 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 reliable fuel supplier, performing proper maintenance of the fuel system, and installing Caterpillar high efficiency fuel filters in the fuel system.

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

Viscosity

The viscosity of the fuel is significant because the fuel serves as a lubricant for fuel system components. Arctic fuels need to have sufficient viscosity. The fuel must lubricate the fuel system at a temperature of 0°C (32°F) or below freezing. 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.

Cetane Number

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

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

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

Modifying the Cetane Number

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

Additives can also be used to improve the cetane number of a fuel. Additives are evaluated through testing in special engines. However, the fuel characteristics of additives are not identical to a natural product. While both fuels may be rated as having the same cetane number, starting may be different.

Cloud Point

It is important to understand that the cloud point of a fuel is different from the pour point. There is no relationship between cloud point and the pour point. The cloud point is the temperature that allows some of the heavier components in the wax to solidify in the fuel. This wax is not a contaminant in the fuel. The wax is an important element of No. 2 diesel fuel. The wax has a high fuel energy content and the wax has a 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 stop the flow of fuel. Fuel filters are necessary in order to remove dirt from the fuel. The filters block foreign material, and the filters protect the parts for the fuel injection system. Since fuel must flow through the filters, installing a fuel heater is the most practical way to prevent the problem. A fuel heater will keep the fuel above the cloud point as the fuel flows through the fuel system. The fuel heater will permit the wax to flow through the filters with the fuel.

Modifying the Cloud Point

You can lower the cloud point of a diesel fuel by mixing the diesel fuel with a different fuel that has a lower cloud point. No. 1 diesel fuel or kerosene may be used to lower the cloud point of a diesel fuel. The efficiency of this method is not good, 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 following illustration contains a table that can be used to find the necessary mixture for two fuels with different cloud points. In order to use the table, you must know the exact fuel cloud point of each fuel. This specification can change from one purchase of fuel to the next purchase of fuel. This specification is normally available from personnel at the source of the fuel supply. When fuels that have a lower cloud point are not available, this method cannot be used.

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

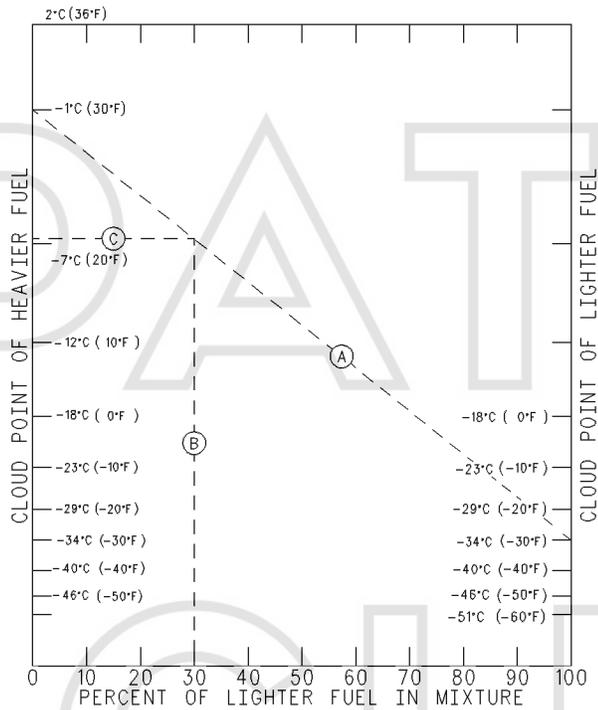


Illustration 5 g00592741

Cloud point of fuel mixtures

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

Pour Point

The fuel's pour point is a temperature below the fuel's cloud point. Fuel stops flowing below the pour point. The pour point is the temperature which limits movement of the fuel with 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 makes the fuel more solid than liquid. The pour point of the fuel can be improved. This does not require the removal of important elements. This process is the same process that is used to improve the cloud point of a fuel.

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

Modifying the Pour Point

You can lower the fuel's pour point by using additives. You can also lower the pour point by mixing the fuel with a fuel that has a lower pour point. See the topic "Cloud Point" for the procedure. This procedure is not the best procedure to use.

The same table that was use for cloud point can be used for an estimate of pour points. This is true only if the fuels do not have additives which change the pour point.

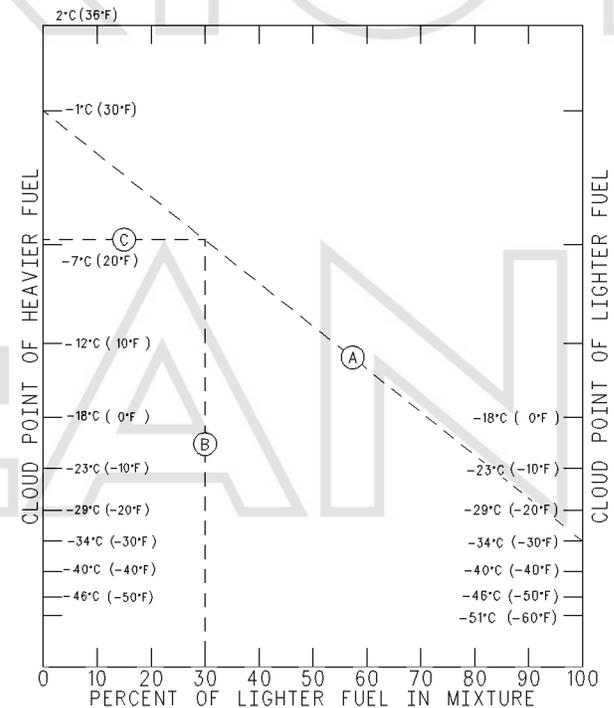


Illustration 6 g00592741

Cloud point of fuel mixtures

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

1. Obtain the specification for fuel cloud point of both fuels from your fuel supplier.
2. Locate the cloud point of the heavier fuel on the left side of the table. Mark the point on the table.
3. Locate the cloud 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".

- Determine the lowest outside temperature for machine operation. Find this point on the left side of the table. Mark this point. Draw a horizontal line from this point. Stop the line at the intersection of line "A". Label this new line "C".
- 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 pour point.

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

Additives are a good method to use in order to lower the pour point of a fuel. These additives are known by the following names: pour depressants, cold flow improvers, and wax modifiers. When the additives are used in a low concentration, the fuel will flow through pumps, lines, and hoses. These additives must be thoroughly mixed into the fuel at temperatures that are above the cloud point. The fuel supplier should be contacted in order to blend the fuel with the additives. The blended fuel can be delivered to your fuel tanks.

Moisture Content

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

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

After the fuel has absorbed the maximum possible 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 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:

- Remove the fuel filters.
- Cut the fuel filters open.
- 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.