

2003 HEAVY DUTY DIESEL MANUFACTURER FUEL RECOMMENDATIONS

CATERPILLAR

***Caterpillar Machine Fluids
Recommendations SEBU6250-12 (July
2002)***

**Fuel Specifications
Diesel 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 are distillate fuels. Distillate fuels provide maximum engine service life and performance. These fuels are commonly called diesel fuel, furnace oil, gas oil, or kerosene. Blends of distillate fuels can be used.

Diesel fuels that meet the specifications in Table 9 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 9 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.

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 and in Caterpillar machine engines. This diesel fuel will be used when low emissions are required. This fuel will be used when the fuel supplier can 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 10. However, the fuel that is selected must meet the requirements that are specified in Table 9. These fuels are intended to be used in operating temperatures that are down to 34 °C (65 °F).

These fuels are lighter than the No. 2 grades of fuel. The cetane number of the fuels in Table 10 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 9.

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Table 9
Caterpillar Specifications for Distillate Diesel Fuel

Specifications	ASTM Test	ISO Test	Requirements
Aromatics	"D1319"	"ISO 3837"	35% maximum
Ash	"D482"	"ISO 6245"	0.02% maximum (weight)
Carbon Residue on 10% Bottoms	"D524"	"ISO 4262"	0.35% maximum (weight)
Cetane Number	"D613"	"ISO 5165"	40 minimum (DI engines) 35 minimum (PC engines)
Cloud Point	"D97"	"ISO 3016"	The cloud point must not exceed the lowest expected ambient temperature.
Copper Strip Corrosion	"D130"	"ISO 2160"	No. 3 maximum
Distillation	"D86"	"ISO 3405"	10% at 282 °C (540 °F) maximum
			90% at 360 °C (680 °F) maximum
Flash Point	"D93"	"ISO 2719"	legal limit
API Gravity	"D287"	N/A No equivalent test	30 minimum
			45 maximum
Pour Point	"D97"	"ISO 3016"	6 °C (10 °F) minimum below ambient temperature
Sulfur ⁽¹⁾	"D3605" or "D1552"	"ISO 8691"	3% maximum
Kinematic Viscosity ⁽²⁾	"D445"	"ISO 3104"	1.4 cSt minimum and 20.0 cSt maximum at 40 °C (104 °F)
Water and Sediment	"D1796"	"ISO 3734"	0.1% maximum
Water	"D1744"	N/A	0.1% maximum
Sediment	"D473"	"ISO 3735"	0.05% maximum (weight)
Gums and Resins ⁽³⁾	"D381"	"ISO 6246"	10 mg per 100 mL maximum
Lubricity ⁽⁴⁾	"D6078"	N/A	3100 g minimum
	"D6079"	"ISO 12156"	0.45 mm (0.018 inch) maximum at 60 °C (140 °F)
			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.

⁽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 D6078 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.

Table 10
Distillate Fuels ⁽¹⁾

Specification	Grade
"MIL-DTL-5624T"	JP-5
"ASTM D1655"	Jet-A-1
"MIL-DTL-83133E"	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.

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Biodiesel

Biodiesel is a fuel that can be made from a variety of sources, primarily from soybean oil or rapeseed oil. Without esterification, these oils gel in the crankcase and fuel tank and may not be compatible with many of the elastomers used in today's engines. In their original form, these oils are not suitable for use as a fuel in compression engines. To use these oils as fuel, they must be esterified. Alternate base stocks for biofuel may include animal tallow, waste cooking oils, or a variety of other feedstocks.

Caterpillar certifies its engines using the prescribed EPA and European Certification Fuels. Caterpillar does not certify engines on any other fuel. It is the user's responsibility to use the correct fuel as recommended by the manufacturer and allowed by EPA or other local regulatory agencies. It is the responsibility of the user to obtain the proper local, regional, and/or national exemptions required for the use of biodiesel in any emissions regulated Caterpillar engine.

Warranty and the Use of Biodiesel Fuel in Caterpillar Engines

Caterpillar neither approves nor prohibits the use of biodiesel fuels. Caterpillar is not in a position to evaluate the many variations of biodiesel fuels, and the long-term effects on performance, durability or emissions compliance of Caterpillar products. The use of biodiesel fuels does not affect Caterpillar's materials and workmanship warranty. **Failures resulting from the use of any fuel are not Caterpillar factory defects and therefore the cost of repair would NOT be covered by Caterpillar's warranty.**

Recommendation for the Use of Biodiesel Fuel in Caterpillar Engines

For Caterpillar 3046, 3064, 3066, 3114, 3116, 3126, 3176, 3196, 3208, 3306, C10, C12, 3406, C15, C16, 3456, 3408, 3412, 3500 series, 3600 series, CM20, CM25 and CM32 engines: Biodiesel meeting the requirements listed in Caterpillar's biodiesel specification or, meeting either ASTM D6751 or DIN 51606, are acceptable. They may also be blended in any

percentage with an acceptable diesel fuel, provided the biodiesel constituent meets the requirements outlined in Table 11 prior to blending.

For Caterpillar 3003 through 3034, 3054 and 3056 engines: Biodiesel meeting the requirements listed in Caterpillar's biodiesel specification or, meeting either ASTM D6751 or DIN 51606, may be blended with an acceptable diesel fuel at a maximum of 5% biodiesel fuel blended with 95% diesel fuel. The biodiesel fuel must meet the requirements listed in Table 11 prior to blending. Use of more than a 5% biodiesel fuel can cause premature failures whose repair would not be covered under Caterpillar warranty.

When burning biodiesel, or any blend of biodiesel, it is the responsibility of the user to obtain the proper local, regional, and/or national exemptions required for the use of biodiesel in any emissions regulated Caterpillar engine. When using a fuel that meets Caterpillar's Biodiesel specification, ASTM D6751, or DIN 51606 specifications, and when adhering to the following recommendations, the use of biodiesel should pose no problems.

Recommendations

- The oil change interval can be affected by the use of biodiesel fuel. Use Scheduled Oil Sampling (S-O-S) to monitor the engine oil condition and to determine the optimum oil change interval.
- Biodiesel provides approximately 5-7% less energy per gallon of fuel when compared to distillate fuels. To avoid engine problems when the engine is converted back to 100% distillate diesel fuel, do not change the engine rating to compensate for the power loss.
- Elastomer compatibility with biodiesel is still being monitored. The condition of seals and hoses should be monitored regularly.
- Biodiesel has poor oxidation stability, which can result in long term storage problems. The poor oxidation stability qualities may accelerate fuel oxidation in the fuel system. This is especially true in engines with electronic fuel systems because they operate at higher temperatures. Consult the fuel supplier for oxidation stability additives.

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- Biodiesel fuel is an excellent medium for microbial growth. Microbes cause fuel system corrosion and premature filter plugging. The effectiveness of conventional anti-microbial additives, when used in biodiesel is not known. Consult your fuel and additive supplier for assistance.
- Care must be taken to remove water from fuel tanks. Water accelerates microbial growth. Water is naturally more prevalent in biodiesel fuels than in distillate fuels.

**Table 11
Caterpillar Biodiesel**

Property	Test Method		Units	Limits
	United States	International		
			Fuel Specific Properties	
Density @ 15°C	"ASTM D1298"	"DIN/ISO 3675"	g/cm ³	0.86-0.90
Viscosity @ 40°C	"ASTM D445"	"DIN/ISO 3104"	mm ² /s	4.0-6.0
Flash Point	"ASTM D93"	"DIN/ISO 22719"	°C	100 minimum
Cold Filter Plugging - Summer - Winter	"ASTM D4539"	"DIN EN 116"	°C	0 6 below ambient
Pour Point - Summer - Winter	"ASTM D97"	"ISO 3016"	°C	-9 maximum -20 maximum
Sulfur Content	"ASTM D2622"	"ISO 8754"	% weight	0.005 maximum
Distillation - 10% Evaporation - 90% Evaporation	"ASTM D1160"	"ISO 340"	°C	To Be Determined 345
Carbon Residue, Conradson (CCR)	"ASTM D189"	"DIN/ISO 10370"	% weight	0.5 maximum
Cetane Number	"ASTM D613"	"ISO 5165"	45 minimum	
Ash Content	"ASTM D482"	"DIN 51575" "ISO 6245"	mg/kg	0.02 maximum
Water Content	"ASTM D1796"	"DIN 51777-1" "ISO 3733"	g/m ³	500 maximum
Particulate Matter	"DIN 51419"	"DIN 51419"		15
Copper Corrosion	"ASTM D130"	"DIN/ISO 2160"		No. 1
Oxidation Stability	"ASTM D2274"	"IP 306 mod."	mg/100mL	15 maximum
Esterification		% volume	98.0 minimum	
Acid Value	"ASTM D664"	"DIN 51558"	mg NaOH/g	0.5 maximum
Methanol Content	GC Method	"DIN 51608"	% weight	0.2 maximum
Monoglycerides	GC Method	"DIN 51609"	% weight	0.8 maximum
Diglycerides	GC Method	"DIN 51609"	% weight	0.2 maximum
Triglycerides	GC Method	"DIN 51609"	% weight	0.2 maximum
Free Glycerine	GC Method	"DIN 51609"	% weight	0.02 maximum
Total Glycerine	GC Method	"DIN 51609"	% weight	1.2 maximum
Iodine Number	"DIN 53241 or IP 84/81"	"DIN 53241 or IP 84/81"	cg I ₂ /g	110 maximum
Phosphorus Content	"DGF C-VI4"	"DIN 51440-1"	mg/kg	0.2

Note: Fuels meeting "ASTM D6751" or "DIN51606" may be used.

CUMMINS

Fuels for Cummins Engines Service Bulletin

Premium Diesel Fuel

Cummins diesel engines will run on a great variety of fuels, but some fuels will give better

performance, higher efficiency, improved reliability, or lower maintenance costs than others. Fuel must be selected based on overall operating costs, not just on the purchase price. Cummins recommends the use of premium fuels meeting the requirements of Category 1 through 4 as outlined in the Worldwide Fuel Charter.

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Required Diesel Fuel Specifications

This section presents the fuel specifications required by Cummins.

Fuels meeting national and international specifications can be used if they observe the specifications listed in Table 1: Required

Diesel Fuel Specifications. Cummins engines will operate satisfactorily on fuels meeting all the properties listed in Table 1; however, fuels meeting **only** the required specifications may **not** give the same level of performance, efficiency, reliability or maintenance costs as premium fuels.

Table 1
Required Diesel Fuel Specifications

Viscosity	1.3 to 5.8 centistokes (1.3 to 5.8 mm per second) at 40°C [104°F]
Cetane Number	42 minimum above 0°C [32°F]; 45 minimum below 0°C [32°F]
Sulfur Content	Not to exceed 0.5 mass-percent ¹
Active Sulfur	Copper Strip Corrosion not to exceed Number 2 rating after 3 hours at 50°C [122°F]
Water Sediment	Not to exceed 0.05 volume-percent
Carbon Residue	Not to exceed 0.35 mass-percent on 10 volume-percent residuum
Density	0.816 to 0.876 grams per cubic centimeter (g/cc) at 15°C [60°F]
Cloud Point	6°C [10°F] below lowest ambient temperature at which the fuel is expected to operate
Ash	Not to exceed 0.02 mass-percent (0.05 mass-percent with lubricating oil blending)
Distillation	The distillation curve must be smooth and continuous
Lubricity SLBOCLE, or HFRR	3100 grams or greater SLBOCLE, or 0.45 mm maximum: Wear Scar Diameter (WSD) at 60°C [140°F] HFRR

¹Regional, national, or international regulations can require a lower sulfur content than 0.5 percent. Consult all applicable regulations before selecting a fuel for a given engine application. Fuel with sulfur higher than 0.5 percent is **not** allowed without prior approval by Cummins. Fuel system corrosion, heightened emissions, and reduced oil drain intervals are just some of the possible adverse effects of fuels with very high sulfur. Fuel **must** observe proper flash point requirements to satisfy local safety regulations.

Fuel Blending

This section presents the effects of blending fuels with used and new lube oil, other fuels, and with gasoline, gasohol, or alcohol. There are two different types of fuel blending processes referred to in this section. The first is the blending of engine lubricating oil to reduce fuel costs and to aid in disposing of used engine oil. This section also discusses the blending of fuel and engine oil in on-highway applications. The second is the blending of heavier fuels with lighter fuels to lower the wax content, cloud point, and pour point, and thus improve cold weather operation. In addition, the effects and hazards of mixing alcohol with diesel fuel are discussed.

Blending Fuel with Gasoline, Gasohol, and Alcohol

WARNING

Under no circumstances must gasoline or alcohol be used to dilute diesel fuel. This practice creates an extreme fire hazard and under certain circumstances an explosive hazard. Gasoline dilution is not an effective way to lower cloud point (20 volume-percent gasoline only lowers cloud point 4°C [7°F] and it lowers the fuel viscosity, cetane number, and flash-point). Alcohol dilution will increase the cloud point.

Additives

This section gives information on the use of fuel additives in Cummins engines including the use of bio-diesel and water emulsifiers.

Cummins Inc. neither approves nor disapproves of the use of any fuel additive, fuel extender, fuel system modification, or the use

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of any device not manufactured or sold by Cummins Inc. or its subsidiaries. Engine damage, service issues, or performance problems that occur due to the use of these products are not considered a defect in workmanship or material as supplied by Cummins Inc. and can not be compensated under the Cummins warranty.

Fuel Additives

Cummins engines are designed, developed, rated, and built to operate on commercially available diesel fuel as listed in Required Diesel Fuel Specifications; therefore, it is not our policy to recommend fuel additives.

In extreme situations, when available fuels are of poor quality or problems exist which are peculiar to certain operations, additives can be used. However, Cummins recommends consultation with the fuel supplier or Cummins Service Engineering Department prior to use of fuel additives.

Among the situations where additives can prove useful are the following:

1. A pour point depressant or flow improver additive can help with high pour point fuels. These depressants do not affect the cloud point (waxing)
2. An anti-oxidant or storage stability additive can help with fuel system deposits and poor storage stability
3. A biocide or fungicide can help when fuels are prone to contamination with bacteria or fungus
4. An anti-icer can help prevent ice formation in wet fuel during cold weather
5. A cetane improver additive can be used with low cetane fuels
6. Cummins Premium Plus - Diesel Fuel Additive can be used to clean carbon deposits from injectors and improve lubricity in fuels that fall below the recommended lubricity specification in Required Diesel Fuel Specifications. Refer to Cummins Service Information Bulletin 89SIB6-2 for more information on cleaning fuel injectors with Premium Plus. Premium Plus is the only diesel fuel additive recommended by Cummins for use with fuels that do not meet the lubricity specification in Required Diesel Fuel Specifications.

Premium diesel fuels can possibly contain several additives that can accomplish the same as buying additives and adding them to lower quality diesel fuel. A premium diesel fuel is defined by the Worldwide Fuel Charter as described on page 1.

Cummins recommends the use of a premium diesel fuel during winter (ambient conditions at -7°C [20°F] or below) operating conditions.

Great care must be exercised in the choice and use of additives. Some fuel additives can be harmful to the engine. Fuel additives containing ash forming materials will cause combustion chamber deposits. Most legitimate fuel additives perform only one function. Multifunctional fuel additives are mixtures of several additives. All fuel additives perform differently in different fuels; therefore, the additive used must be one to which the fuel will respond. There are no known additives that increase the power or improve the efficiency of a properly maintained engine.

NOTE: Cummins Inc. accepts no liability for engine damage resulting from the use of fuel additives which are not specifically recommended by Cummins.

Bio-Diesel Fuel

With increased interest in emissions and reducing the use of petroleum distillate based fuels, many governments and regulating bodies encourage the use of bio-fuels. Bio-diesel fuels must be considered experimental at this time.

Bio-diesel fuels are methyl/ethyl ester-based oxygenates derived from a broad variety of renewable sources such as vegetable oils, animal fats, and cooking oils. Their properties are similar to diesel fuel, as opposed to gasoline or gaseous fuels, and thus are capable of being used in compression ignition engines. Soy Methyl Ester (SME) or some SME Diesel is the most common bio-diesel in the United States and is derived from soybean oil. Soy Diesel is a bio-diesel or petro-diesel blend based on SME. Rape Methyl Ester (RME) Diesel is the most common bio-diesel in Europe and is derived from rapeseed oil. These fuels are collectively known as Fatty Acid Methyl Esters (FAME).

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Cummins test data on the operating effects of bio-diesel fuels indicates that typically smoke, power, and fuel economy are all reduced. However, as there are no firm industry standards on the content and properties for bio-fuels, consistency and predictability of bio-diesel operation is not well documented. There are provisional specifications for FAME issued in Germany under DIN V 51 606 and also recently through ASTM as PS121; however, these standards are under development and are subject to change.

Cummins certifies its engines using the prescribed EPA and European Certification Fuels. Cummins does not certify engines on any other fuel. It is the user's responsibility to use the correct fuel as recommended by the manufacturer and allowed by EPA or other local regulatory agencies. In the United States, the EPA allows use of only registered fuels for on-highway applications. The EPA has additional alternative fuel information at: <http://www.epa.gov/otaq/consumer/fuels/altfuels/altfuels.htm>.

It is the responsibility of the user to obtain the proper local, regional, or national exemptions required for the use of bio-diesel in any emissions regulated Cummins engine.

Warranty and the Use of Bio-Diesel Fuel in Cummins Engines

Cummins neither approves nor disapproves of the use of bio-diesel fuel blends. There is a major difference between operating on pure (100 percent concentration) bio-diesel fuels and bio-diesel or petro-diesel fuel blends. Cummins is not in a position to evaluate the many variations of bio-diesel fuels, and the long-term effects on performance, durability or emissions compliance of Cummins products. The use of bio-diesel fuel does not affect Cummins materials and workmanship warranty. Failures caused by the use of bio-diesel fuels or other fuel additives are not defects of Cummins parts or workmanship and therefore would not be covered by Cummins warranty.

Given the current industry understanding of bio-fuels and blending with quality diesel fuel, it would be expected that blending up to a 5 percent volume-concentration should or most

probably will not cause serious problems. This is consistent with the position taken by worldwide fuel system manufacturers.

For customers intent on blending bio-fuels above a 5 percent volume-concentration, the following concerns represent what is currently known in the industry. Concentrations beyond 5 percent by volume can have an adverse affect on the engine's performance and the fuel system integrity or durability. The affects are more serious with increasing concentration levels. Areas of concern when operating with bio-diesel fuels include low temperature operability (fuel gelation, filter plugging), heat content (poor fuel economy), and storage and thermal stability (filter plugging, injector deposits). In addition, from our fuel systems suppliers, the following issues are also noted:

- Swelling and hardening or cracking of some elastomer seals within the fuel system or engine
- Corrosion of fuel system and engine hardware, especially aluminum and zinc
- Solid particle blockage of fuel nozzles and passages
- Filter plugging
- Injector coking
- Higher injection pressures due to physical flow properties, reduced fuel system life
- Added stress and heat to injection components, especially rotary fuel pumps
- Increased pump seizures and early life failures
- Poor fuel spray atomization, reduced fuel economy
- Poor lubricity, reduced service life of fuel pump and fuel system.

Pure bio-diesel fuel is not stable and its acid content increases over time which can damage powdered metal components.

Operational Factors to Consider

- The oil change interval can be affected by the use of bio-diesel fuel. End users are advised to use oil sampling to monitor the engine oil condition and to determine the optimum oil change interval. Pure bio-diesel fuel can cause a chemical reaction with lube oil resulting in oil sludging.
- Bio-diesel provides approximately 5-7 percent less energy per gallon of fuel when compared to distillate fuels. To avoid engine problems when the engine is

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converted back to 100 percent distillate diesel fuel, do not change the engine rating to compensate for the power loss when operated with bio-diesel fuels.

- Elastomer compatibility with bio-diesel is still being monitored. The condition of seals, hoses, gaskets, and wire coatings must be monitored regularly.
- Bio-diesel fuels can pose low ambient temperature problems for both storage and operation. At low ambient temperatures, fuel can possibly need to be stored in a heated building or a heated storage tank. The fuel system can require heated fuel lines, filters, and tanks. Filters can plug and fuel in the tank can solidify at low ambient temperatures if precautions are not taken. Consult your bio-diesel supplier for assistance in the blending and attainment of the proper cloud point fuel.
- Bio-diesel has poor oxidation stability which can result in long term storage problems. The poor oxidation stability qualities can accelerate fuel oxidation in the fuel system. This is especially true in engines with electronic fuel systems because they operate at higher temperatures. Consult the fuel supplier for oxidation stability additives.
- Bio-diesel fuel is an excellent medium for microbial growth. Microbes cause fuel system corrosion and premature filter plugging. The effectiveness of conventional anti-microbial additives, when used in bio-diesel, is not known. Consult your fuel and additive supplier for assistance.
- Care must be taken to remove water from fuel tanks. Water accelerates microbial growth. Water is naturally more prevalent in bio-diesel fuels than in distillate fuels.

Oxy-Diesel or E-Diesel

WARNING

Do not mix gasoline, alcohol, or gasohol with diesel fuel. This mixture can cause an explosion.

WARNING

Under no circumstances must gasoline or alcohol be used to dilute diesel fuel. This practice creates an extreme fire hazard and under certain circumstances an explosive hazard. Gasoline dilution is not an effective way to lower cloud point (20 volume-percent gasoline only lowers cloud point 4°C [7°F] and it lowers the fuel viscosity, cetane number, and flash-point). Alcohol dilution will increase the cloud point.

Alcohol is considered a renewable energy source. Some suppliers integrate up to 15 percent alcohol in diesel fuel to form oxy-diesel or e-diesel. While the use of special additives addresses some of the problems with alcohol blending in diesel fuel, Cummins recommends against the use of such blends due to safety reasons. This kind of fuel is considered experimental and is not covered by warranty. Engine damage, service issues or performance problems that occur due to the use of these products are not considered a defect in workmanship or material as supplied by Cummins Inc. and can not be compensated under the Cummins warranty.

WARNING

Under no circumstances must gasoline or alcohol be used to dilute diesel fuel. This practice creates an extreme fire hazard and under certain circumstances an explosive hazard. Gasoline dilution is not an effective way to lower cloud point (20 volume-percent gasoline only lowers cloud point 4°C [7°F] and it lowers the fuel viscosity, cetane number, and flash-point). Alcohol dilution will increase the cloud point.

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WARNING

Fuels outside the recommended fuel specifications, but within the contingency specifications, are only meant to be used for short periods of time when no other fuels are available. Use of contingency fuels can have an adverse effect on engine performance and durability. Cummins assumes no warranty responsibility for repairs or increased costs of operation resulting from the use of fuels that do not conform to the specifications listed in Table 1.

WARNING

Some contingency fuels, such as jet fuels and kerosene, are much more flammable than normal diesel fuel. Use extreme care to keep cigarettes, flames, pilot lights, sparks, arcing equipment and switches, and other sources of ignition away and out of areas sharing ventilation.

WARNING

Some state and federal agencies have determined that used engine oil can be carcinogenic and can cause reproductive toxicity. Avoid inhalation of vapors, ingestion, and prolonged contact with used engine oil. If not reused, dispose of in accordance with local environmental regulations.

WARNING

Engines equipped with an oxidation catalyst must not use fuel blended with lubricating oil. The lubricating oil causes deposits in the catalyst which will plug the catalyst and possibly cause higher emission levels and reduced engine performance.

WARNING

Do not blend more than 5 percent used lubricating oil with the fuel. Do not blend other used oils with fuel, such as transmission fluid, gear case oil, and so forth.

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DETROIT DIESEL

Lubricating Oil, Fuel, and Filters Engine Requirements (2001)

Diesel Fuel Quality and Selection

The quality of fuel used is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. Detroit Diesel engines are designed to operate on most diesel fuels marketed today. In general, fuels meeting the properties listed in Table 9 are recommended for satisfactory performance. Many fuels marketed today are claimed to meet ASTM Designation D 975. This specification is inadequate in defining the fuel quality necessary for modern low emission diesel engines. For optimum engine operation and maximum service life, diesel fuels meeting the property requirements listed in Table 9, or the properties of EMA FQP-1a or b are recommended for use.

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**Table 9
Diesel Fuel Specification Table**

Property	Test Method ASTM	ISO	On-road No. 1	On-road No. 2	Off-road
API Gravity, @ 60°F	D 287				
Minimum			40	34	33
Maximum			44	38	43
Specific Gravity, g/ml @ 60°F	D 1298	3675			
Minimum			0.806	0.835	0.810
Maximum			0.825	0.855	0.860
Flash Point, °C, Minimum	D 93	2719	38	52	Note 1
Viscosity, Kinematic cSt @ 40°C	D 445	3104	1.3	1.9	1.3
Minimum			2.4	4.1	4.5
Maximum					
Sulfur, wt% Maximum	D 2622	EN 24260	0.05	0.05	0.4
Cloud Point	D 2500			Note 2	
Filter Plugging Point	D4359	309		Note 3	
Cetane No., Minimum	D 613	5165	45	45	45
Cetane Index, Minimum	D 4737	4264	40	40	40
Distillation % Vol. Recovery, °F (°C)	D 86	3405			
IBP, Typical			350 (177)	375 (191)	320 (160) - 392 (200)
10%, Typical			385 (196)	430 (221)	
50%, Typical			425 (218)	510 (256)	437 (225) - 527 (275)
90%, Maximum			500 (260)	625 (329)	626 (330)
95% Maximum			550 (288)	671 (355)	680 (360)
Recovered Volume, % Minimum			98	98	98
Water, % Maximum (Note 4)	D 2709		0.02	0.02	0.02
Sediment > 1 µm, mg/L Maximum	D2276 or D5452		10	10	10
Total Contamination, mg/kg Maximum		DIN 51419	24	24	24
Ash, % mass Maximum	D 482	6245	0.01	0.01	0.01
Carbon Residue, on 10%, % mass	D 524	10370	0.15	0.35	0.3
Copper Corrosion, Maximum	D 130	2160	No. 3a	No. 3a	No. 3a
Accelerated Storage Stability mg/L, Maximum	D 2274		15	15	15
Dupont Pad Test, Reflectance, at 150°C, Minimum	D6468		70	70	70
Heat Content, Net, BTU/gal	D4868		125,000 - 127,300	128,500 - 130,900	126,600 - 131,500
Lubricity					
Load, gms, Minimum	D6078		3100	3100	3100
Wear Scar, µm, Maximum	D6069		460	460	460

Note 1: The flash point temperature is a safety related property which must be established according to applicable local requirements.

Note 2: The cloud point should be 10°F (6°C) below the lowest expected fuel temperature to prevent clogging of fuel filters by wax crystals.

Note 3: The Filter Plugging Point temperature should equal to or below the lowest expected fuel temperature.

Note 4: No free water visible

Note 5: Transit Coach engines are emission certified on either No. 1 or No. 2 fuel. To maintain emission compliance, only the correct certified fuel should be used.

Note 6: When prolonged idling periods or cold weather conditions below 32°F (0°C) are encountered, the use of 1-D fuel is recommended.

2003 Heavy Duty Diesel Manufacturer Fuel Recommendations

Fuel Lubricity

Some fuels, such as those containing kerosene and jet fuel, and some low sulfur fuels have characteristics which may cause operational concerns in some fuel injection systems. To assure trouble-free operation it is recommended that all fuels used in DDC engines meet the minimum lubricity requirements listed in Table 9. Fuels not meeting the lubricity requirements may be additized to meet them.

Biodiesel Fuels

Biodiesel fuel is broadly defined in ASTM specification PS 121. However, this specification does not restrict feedstock types, nor does it include all the properties necessary to assure trouble-free operation. Detroit Diesel permits the use of biodiesel derived from virgin soy methyl ester and rapeseed methyl ester when blended up to 20% maximum in diesel fuel. Use of recycled feedstocks is not recommended. The resulting mixture must meet the fuel properties listed in Table 9.

Although such blends purport to reduce exhaust emission particulates, they increase engine exhaust nitrogen oxides content. They also tend to have poorer thermal stability and may deteriorate engine oil TBN more rapidly than wholly petroleum-based diesel fuels. Little long-term use data exists, but concerns from combustion deposits, fuel injection system durability, and accelerated engine oil degradation warrant a cautious approach when considering the use of biodiesel. Use of these fuels may require a reduction in oil drain interval. Failures attributed to the use of biodiesel fuel or blends of biodiesel will not be covered by the Detroit Diesel product warranty.

GENERAL MOTORS

Duramax Diesel Engine (2002)

Diesel Fuel Requirements and Fuel System

Some states and provinces have restrictions on the purchase of diesel fuel for light-duty vehicles and require you to buy permits or pay

special taxes. Some of these restrictions apply only to residents, and others apply to both residents and visitors. These restrictions can change. To learn the current restrictions in any state or province, contact your auto club, the police or other officials.

Diesel Engine Fuel

NOTICE: Diesel fuel or fuel additives not recommended in this manual could damage your fuel system and engine. Your warranty wouldn't cover this damage. And:

- Diesel fuel that has been mixed with engine oil could damage your engine and emission controls. Check with the service station operator to make sure the diesel fuel has not been mixed with engine oil.
- If you ever run out of diesel fuel, it can be difficult to restart your engine. "Running Out of Fuel," later in this section, tells you how to get it started again. To avoid all this, never let your tank get empty.

What Fuel to Use

In the United States, for best results use Number 2-D diesel fuel year-round (above and below freezing conditions) as oil companies blend Number 2-D fuel to address climate differences. Number 1-D diesel fuel may be used in very cold temperatures (when it stays below 0°F or -18°C); however, it will produce a power and fuel economy loss. Avoid the use of Number 1-D diesel fuel in warm or hot climates. It may result in stalling, poor starting when the engine is hot and may damage the fuel injection system.

At a minimum, the diesel fuel you use should meet specifications ASTM D975-98a (Grade Low Sulfur) in the United States. In addition, the Engine Manufacturers Association (EMA) has identified properties of an improved diesel fuel for better engine performance and durability. Diesel fuels corresponding to the EMA Recommended Guideline on Premium Diesel Fuel (FQP-1A) could provide better starting, less noise and better vehicle performance. If there are questions about the fuel you are using, please contact your fuel supplier.

2003 Heavy Duty Diesel Manufacturer Fuel Recommendations

Diesel fuel may foam when you fill your tank. This can cause the automatic pump nozzle to shut off, even though your tank isn't full. If this happens, just wait for the foaming to stop and then continue to fill your tank.

CAUTION: Heat coming from the engine may cause the fuel to expand and force the fuel out of your tank. If something ignites the fuel, a fire could start and people could be burned. To help avoid this, fill your fuel tank only until the automatic nozzle shuts off. Don't try to "top it off."

What Fuel to Use in Canada

Canadian fuels are blended for seasonal changes. Diesel Type "A" fuel is blended for better cold weather starting (below 0°F or -18°C); however, you may notice some power and fuel economy loss. If Type "A" fuel is used in warmer temperatures, stalling and hard starting may occur. Diesel Type "B" fuel is blended for temperatures above 0°F (-18°C). The emission control system requires the use of diesel fuel with low-sulfur (.05% by weight) content. Both low- and higher-sulfur diesel fuels are available in the United States. It is important that diesel-powered trucks are refueled only with low-sulfur fuel. Use of fuels with higher-sulfur content will affect the function of the emission components and may cause reduced performance, excessive smoke and unpleasant odor.

At a minimum, the diesel fuel you use should meet specifications CAN/CGSB-3.517-93 (Low Sulfur Diesel) in Canada. In addition, the Engine Manufacturers Association (EMA) has identified properties of an improved diesel fuel for better engine performance and durability (FQP-1A). Diesel fuels corresponding to the EMA description could provide better starting, less noise and better vehicle performance. If there are questions about the fuel you are using, please contact your fuel supplier.

Very Cold Weather Operation

Follow the instructions listed previously under the heading "What Fuel to Use."

NOTICE: Never use home heating oil or gasoline in your diesel engine. They can cause engine damage.

In cold weather, your fuel filter may become clogged (waxed). To unclog it, move the vehicle to a warm garage area and warm the filter to between 32°F and 50°F (0°C to 10°C). You won't need to replace it. Additional information on the fuel filter follows.

Water in Fuel

CAUTION: Diesel fuel containing water is still flammable. You could be burned. If you ever try to drain water from your fuel, keep sparks, flames and smoking materials away from the mixture.

NOTICE: If there is water in your diesel fuel and the weather is warm or humid, fungus and bacteria can grow in the fuel. They can damage your fuel system. You'll need a diesel fuel biocide to sterilize your fuel system. Your dealer can advise you if you ever need this. If your fuel tank needs to be purged to remove water, see your dealer or a qualified technician. Improper purging can damage your fuel system.

Sometimes, water can be pumped into your fuel tank along with your diesel fuel. This can happen if a service station doesn't regularly inspect and clean its fuel tanks, or if it gets contaminated fuel from its suppliers.

If this happens, a WATER IN FUEL message will come on. If it does, the water must be drained. Your dealer can show you how to do this.

INTERNATIONAL TRUCK AND ENGINE CORPORATION

Fuel Requirements

Recommended Fuel for International Diesels (VT 365)

This fuel information will help the operator obtain maximum performance for the least amount of cost when using an international

2003 Heavy Duty Diesel Manufacturer Fuel Recommendations

diesel engine. The specifications are broad enough to permit the use of low cost fuels yet are restrictive enough to prevent use of low quality fuels which could lead to engine performance concerns.

Fuel Grade: Use only Grade No. 1-D or Grade No. 2 D diesel fuels. Specifications for these fuels are listed in ASTM D975. If superior quality diesel fuel is desired ask your fuel supplier if they have premium diesel fuel. Do not use fuels sold only as heating or furnace oil. Choose the proper fuel grade as follows:

* With maximum sulfur content of 0.05%	
Expected Temperature	Preferred Fuel Grade
Above +20°F (-7°C)	Grade No. 2-D
Below +20°F (-7°C)	Grade No. 1-D
NOTE: if grade No. 1-D is not available, use a "winterized" or "climatized" Grade No. 2-D fuel, made by blending No. 1-D with No. 2-D fuel to match the temperature conditions in your area. Use diesel fuel with a minimum 45 Cetane number.	

If your engine begins to smoke white, misfire, slumber or hesitate upon acceleration after a fuel fill, you possibly received substandard fuel with a low cetane rating. Whenever feasible, buy diesel fuel from a reputable supplier who sells the recommended minimum 45 Cetane fuel in large quantities.

Sulfur Content: Diesel fuels with a maximum sulfur content of 0.05 percent are required by U.S. EPA Emission Standards for On-Highway applications. Know your fuel sulfur content. (Ask your supplier, or have fuel analyzed.) If fuel contains more than 0.5 percent sulfur, reduce the oil-change interval.

Engine Oil and Filter Change Intervals

Miles	Hours	Gallons / months
10,000	350	1000 gallons or 6 months

International Truck and Engine Corporation DOES NOT recommend or in any way advocate the blending of used engine oil with diesel fuel in any application equipped with an International diesel engine. Blending used engine oil with diesel fuel in on-highway vehicles constitutes the use of fuels NOT recommended for the engine and will significantly increase your vehicle's exhaust emissions. It is also likely using such blends will increase the rate of internal engine wear.

Advisory

Any malfunctions or failure of the vehicle to meet Federal, California or any other State emissions standards due to non-recommended

fuel usage is not covered by the emission control system warranty. Refer to section 3 for warranty statement.

Biodiesel Fuel

International Truck and Engine Corporation allows the use of Biodiesel blend B-5.

Diesel Fuel/Gasoline Alcohol Blends

International Truck and Engine Corporation DOES NOT recommend the blending of gasoline, and/or alcohol with diesel fuel due to the hazards of fire/explosion and the detrimental effects on engine performance.

ISUZU

Diesel Fuel Requirements and Fuel System

Diesel Engine Fuel

NOTICE

Diesel fuel or fuel additives not recommended in this manual could damage your fuel system and engine. Your warranty wouldn't cover this damage. And:

- Diesel fuel that has been mixed with engine oil could damage your engine and emission controls. Check with the service station operator to make sure the diesel fuel has not been mixed with engine oil.

2003 Heavy Duty Diesel Manufacturer Fuel Recommendations

- If you ever run out of diesel fuel, it can be difficult to restart your engine. To avoid all this, never let your tank get empty.

What Fuel to Use

In the United States, for best results use Number 2-D diesel fuel year-round (above and below freezing conditions) as oil companies blend Number 2-D fuel to address climate differences. Number 1-D diesel fuel may be used in very cold temperatures (when it stays below 0 degrees F or -18 degrees C); however, it will produce a power and fuel economy loss. Avoid the use of Number 1-D diesel fuel in warm or hot climates. It may result in stalling, poor starting when the engine is hot and may damage the fuel injection system.

At a minimum, the diesel fuel you use should meet specifications (ASTM D 975-98a (Grade Low Sulfur) in the United States. In addition, the Engine Manufacturers Association (EMA) has identified properties of an improved diesel fuel for better engine performance and durability. Diesel fuels corresponding to the EMA Recommended Guideline on Premium Diesel Fuel could provide better starting, less noise and better vehicle performance. If there are questions about the fuel you are using, please contact your fuel supplier.

Diesel fuel may foam when you fill your tank. This can cause the automatic pump nozzle to shut off, even though your tank isn't full. If this happens, just wait for the foaming to stop and then continue to fill your tank.

CAUTION

Heat coming from the engine may cause the fuel to expand and force the fuel out of your tank. If something ignites the fuel, a fire could start and people could be burned. To help avoid this, fill your tank only until the automatic nozzle shuts off. Don't try to "top it off".

What Fuel to Use in Canada

Canadian fuels are blended for seasonal changes. Diesel Type "A" fuel is blended for better cold weather starting (below 0 degrees F or -18 degrees C); however, you may notice some power and fuel economy loss. If Type

"A" fuel is used in warmer temperatures, stalling and hard starting may occur. Diesel Type "B" fuel is blended for temperatures above 0 degrees F (-18 degrees C). The emission control system requires the use of diesel fuel with low-sulfur (.05% by weight) content. Both low- higher-sulfur fuels will be available in Canada. Only low-sulfur diesel fuels are available in the United States. It is important that diesel-powered trucks are refueled only with low-sulfur fuel. Use of fuels with higher-sulfur content will affect the function of the emission components and may cause reduced performance, excessive smoke and unpleasant odor.

At a minimum, the diesel fuel you use should meet specifications CAN/COSB-3.517-93 (Low Sulfur Diesel) in Canada. In addition, the Engine Manufacturers Association (EMA) has identified properties of an improved diesel fuel for better engine performance and durability (FQ P-1A). Diesel fuels corresponding to the EMA description could provide better starting, less noise and better vehicle performance. If there are questions about the fuel you are using, please contact your fuel supplier.

Very Cold Weather Operation

Follow the instructions listed previously under the heading "What Fuel to Use."

NOTICE

Never use home heating oil or gasoline in your diesel engine. They can cause engine damage

In cold weather, your fuel filter may become clogged (waxed). To unclog it, move the vehicle to a warm garage area and warm the filter to between 32 degrees F and 50 degrees F (0 degrees C to 10 degrees C). You won't need to replace it. Additional information on the fuel filter follows.

JOHN DEERE

Diesel Fuel

Consult your local fuel distributor for properties of the diesel fuel available in your area.

2003 Heavy Duty Diesel Manufacturer Fuel Recommendations

In general, diesel fuels are blended to satisfy the low temperature requirements of the geographical area in which they are marketed. Diesel fuels specified to EN 590 or ASTM D975 are recommended.

In all cases, the fuel shall meet the following properties:

Cetane Number of 45 Minimum. Cetane number greater than 50 is preferred, especially for temperatures below -20°C (-4°F) or elevations above 1500 m (5000 ft).

Cold Filter Plugging Point (CFPP) below the expected low temperature OR **Cloud Point** at least 5°C (9°F) below the expected low temperature.

Fuel Lubricity should pass a minimum load level of 3100 grams as measured by ASTM D6708 or maximum scar diameter of 0.45 mm as measured by ASTM D6079.

Sulfur Content

- Diesel fuel quality and fuel sulfur content must comply with all existing emissions regulations for the area in which the engine operates.
- Sulfur content less than 0.05% (500 ppm) is preferred.
- If diesel fuel with sulfur content greater than 0.05% (500 ppm) is used, crankcase oil service intervals may be affected. (See recommendation for Diesel Engine Oil.)
- DO NOT use diesel fuel with sulfur content greater than 1.0%.

IMPORTANT: Do not mix used diesel engine oil or any other type of lubricating oil with diesel fuel.

Bio-Diesel Fuel

Consult your local fuel distributor for properties of the bio-diesel fuel available in your area.

Bio-diesel fuels may be used **ONLY** if the bio-diesel fuel properties meet the latest edition of ASTM PS121, DIN 51606, or equivalent specification.

It has been found that bio-diesel fuels may improve lubricity in concentrations up to a 5% blend in petroleum diesel fuel.

When using a blend of bio-diesel fuel, the engine oil level must be checked daily when the air temperature is -10°C (14°F) or lower. If oil becomes diluted with fuel, shorten oil change intervals accordingly.

IMPORTANT: Raw pressed vegetable oils are NOT acceptable for use as fuel in any concentration in John Deere engines. These oils do not burn completely, and will cause engine failure by leaving deposits on injectors and in the combustion chamber.

A major environmental benefit of bio-diesel fuel is its ability to biodegrade. This makes proper storage and handling of bio-diesel fuel especially important. Areas of concern include:

- Quality of new fuel
- Water content of the fuel
- Problems due to aging of the fuel

Potential problems resulting from deficiencies in the above areas when using bio-diesel fuel in concentrations above 5% may lead to the following symptoms:

- Power loss and deterioration of performance
- Fuel leakage
- Corrosion of fuel injection equipment
- Coked and/or blocked injector nozzles, resulting in engine misfire
- Filter plugging
- Lacquering and/or seizure of internal components
- Sludge and sediments
- Reduced service life of engine components

Consult your fuel supplier for additives to improve storage and performance of bio-diesel fuels

John Deere Press Release (12/03/01)

John Deere has approved the use of soy-based Biodiesel in all of its diesel-powered products. This announcement is just the latest step in John Deere's ongoing 35-year commitment to the development of bio-based alternative fuels that benefit both the environment and the agricultural community.

"We're excited to be able to support the use of Biodiesel in our products," notes Ted Breidenbach, Manager of Worldwide Engine Engineering for John Deere Power Systems.

2003 Heavy Duty Diesel Manufacturer Fuel Recommendations

"Biodiesel is a valuable tool for helping reduce engine emissions. It also stands as one of the linchpins in the movement to develop alternative uses for commodity products that can ultimately deliver more value to our producer customers.

"The quality of Biodiesel as a fuel source has improved tremendously in recent years," Breidenbach adds. "We're confident that when it's used per factory specifications it will generate the performance producers have come to expect from their John Deere equipment."

After thorough testing and analysis John Deere engineers have developed the following guidelines to help ensure optimum use of Biodiesel:

Customers should consult with their local fuel suppliers to be sure the Biodiesel fuel meets the ASTM PS 121-99 or DIN 51606 fuel specifications:

- Biodiesel, by definition is biodegradable, so the higher the concentration of Biodiesel in a fuel blend, the more susceptible the fuel is to degradation and water absorption. While rapeseed methyl ester (RME) concentrations up to 100% have been run successfully, concentrations of up to five

percent Biodiesel have shown improvement in fuel lubricity while minimizing the potential problems associated with fuel degradation.

- Operators should keep storage and vehicle tanks as full as possible to prevent moisture. Storage tanks should be protected from extreme temperatures and extended storage of Biodiesel fuel should be limited. Routine monitoring of the fuel's water content is also recommended.

MACK TRUCKS

TS494 -- Maintenance and Lubrication Manual (1/01)

DIESEL FUEL

DF-A (Diesel Fuel Grades #1D and #2D)

The selection of the proper fuel oil is essential for good economy, performance and engine life. Use diesel fuel oils meeting the specifications as given below. Grade #2D diesel fuel is to be used for most climatic conditions, while grade #1D is intended for use during cold weather operations. Blends of grades 1 and 2 may be used to suit the various climatic conditions which may be encountered.

**Table 1
FUEL GRADES #1D AND #2D REQUIREMENTS**

Property	Requirements		ASTM Method
	#2D	#1D	
Viscosity, cSt @ 104 ° F (40 ° C)	2.2 – 3.0	1.3 – 2.4	D445
API Gravity @ 60 ° F (15 ° C)	32 – 38	38 – 42	D287
Volatility, ° F (° C)			
IBP, Min.	320 (160)	320 (160)	D86
50%	475 to 550 (246 to 288)	430 to 460 (221 to 238)	
90%, Max.	640 (338)	500 to 550 (260 to 288)	
Cetane Number, Min.	40	40	D613
Total Sulfur, % Max.	0.05	0.05	D4294
Pour Point, ° F (° C)	- 10 (- 23) during winter months	- 20 (- 29) Max.	D97
Corrosion — Copper Strip @ 212 ° F (100 ° C)	No. 3B	ASTM 1-Max.	D130
Conradson Carbon on 10% Residium, Max.	.35	.25	D4530
Ash Content, % Max.	.01	.01	D482
Water and Sediment, % Max.	.05	.05	D1796
Flash Point, ° F (° C)	125 (52)	125 (52)	D93
Rust Prevention	Light Rusting Max.	Light Rusting Max.	D665A

2003 Heavy Duty Diesel Manufacturer Fuel Recommendations

The products furnished under this specification may be either cracked residuals, blends or straight-run distillates, provided they come within the scope of the specifications as listed in Table 1— Fuel Grades #1D and #2D Requirements. Straight-run distillates, however, are preferred to recycled or cracked fuels.

For premium diesel fuel, use the Engine Manufacturer's Association recommended specification FQP1B.

Handling and Storing Fuel

Correct handling and storage of diesel fuel during cold and/or inclement winter weather is a key to satisfactory truck performance and reliability.

Observe the following hints and suggestions:

- Storage tanks for diesel fuel should permit periodic removal of sludge and water accumulations. This should be performed on a regular basis at approximately 10-day intervals.
- Fuel should be stored only in clean, non-contaminated tanks situated in a cool, dry location.

CAUTION

Never store diesel fuel in a galvanized container. The fuel will dissolve the zinc in the galvanized coating. This zinc will then remain in solution in the fuel until it is run through the engine where it will be deposited in the pump and/or injectors causing serious damage.

- When parking vehicle overnight or longer, fill its fuel tank(s) to prevent build-up of internal condensation.
- Remove accumulations of snow, ice, oil or other debris from area of filler cap before removing cap from vehicle fuel tank. Also remove snow-ice accumulations at tank vent.

Diesel Fuel and Winter Operation

For winter operation, certain fuel properties become more critical. These properties include:

- Cetane Number — A measure of the ignition value, or the time required to heat, vaporize and ignite the fuel. The higher this rating number, the faster the fuel will burn.

- Pour Point — A temperature-related point at which fuel will no longer flow through system lines and cannot be pumped.
- Cloud Point — A temperature-related point at which fuel may continue to flow through system lines but filter restriction (plugging) can occur due to crystallizing of the heavier parafinic components of the fuel (also referred to as *jelling* or *waxing* in the fuel).
- Impurities — Water and sediment are of particular importance. Water contamination can cause fuel line freeze-up, injection pump and nozzle damage, as well as component corrosion.

When operating in cold weather, fuel waxing can cause many problems similar to engine troubleshooting symptoms. Be sure to check for fuel congealing before proceeding to troubleshooting remedies outlined under Engine Diagnostic Chart. .

Diesel Fuel Additives

Due to potential damage to the fuel system or engine, the use of supplemental diesel fuel additives other than those added by the fuel manufacturer, is not recommended by Mack Trucks, Inc.

Adding isopropyl alcohol to reduce water contamination and freezing is NOT recommended.

CAUTION

Never blend gasoline with diesel fuel. This can cause an explosive mixture resulting in component destruction and engine/fuel system damage.

Cetane Improvers

Mack Trucks, Inc. currently approves the use of cetane improvers and certain pour-point depressants to improve the combustibility and flow characteristics of the fuel *only if these additives are contained in the fuel as delivered* and not added by the consumer.

- Be aware that the minimum Cetane rating is now 40 instead of 45, but higher ratings may still be necessary for operation in high altitudes or extreme cold weather.
- Also note that some experts say Cetane improvers may cause *gum-up* problems.

Cetane improvers have the following benefits:

- Easier cold weather starting

2003 Heavy Duty Diesel Manufacturer Fuel Recommendations

- Smoother engine operation
- Reduced diesel *knock*
- Faster engine warm-up
- Lower emissions
- Reduced misfirings and white smoke cleanup time

[Note: Mack Truck follows Bosch recommendation on allowable use of biodiesel. Bosch allows the use of diesel fuels with up to 5 volume % RME.]

Fuel Injection Equipment Engine Manufacturers

BOSCH

Specification for Fuels for Customer Documents

Basic Specification

1. General Remarks

The fuels allowed for operation in system components must be released by RB. This has to be done for fuels, which are not listed in section 2 by performing endurance tests with systems with corresponding fuels giving positive results. For other fuels RB does exclude any warranty or liability for its systems. In case insufficient fuel (fuel not conforming to this TCD) is used. OEM customer shall indemnify any hold harmless RB from any third party claims.

2. Allowed Fuels

Fuels used for first filling purposes (e.g. in an engine, in a car) require a HFRR value of < 400 µm (according to DIN ISO 12156-1). The following fuels can be used for engine operation:

- Diesel fuels in accordance with DIN EN 590 (2000)
- Diesel fuels with up to 5 Vol. % RME in accordance to DRAFT prEN 14214

For lab tests use test fluids according to ISO 4113 are allowed.

Mixtures of diesel fuels with other fuels and liquids, e.g. gasoline, kerosene, ethanol, methanol, and additives (available in the after-market, e.g. lubricity, flow, cetane-improver) are not allowed.

A water separator, whose correct function is guaranteed over its total lifetime, (> 93%, in accordance with ISO 4020, part 1; in critical regions with raised demands) is necessary if the water content exceeds that given in DIN EN 590. The requirements for the filtration of fuels depending on the content of contamination (e.g. dirt) are specified in the TCD.

For Japan:

- Diesel fuel in accordance with JIS K 2204: 1 and 3, with a lubricity according to EN 590

For USA:

- Diesel fuel in accordance with ASTM D 975: 1 D and 2D, with a lubricity according to EN 590

PERKINS

Acceptability of Fuels for Fuel Injection Equipment used on Perkins Engines Product Bulletin (3/20/00)

This product bulletin has been produced in order to provide you with the latest information regarding the issuing of a Common Statement from Bosch, Stanadyne and Lucas FIE manufacturers. Bio diesel - R.M.E. fuel can be used in Perkins direct injection diesel engines.

However, the following conditions apply:

- The fuel must comply with DIN V 51606 (or other approved national standards as they evolve).
- It can only be used in mixtures of up to 5% RME in mineral oil diesel fuel. No mixture above 5% is acceptable, as this can result in filter blocking.
- Fuel storage must be to recommended standards, to avoid the absorption of water, and degradation. In any event, storage should not exceed 12 months. Fuel

2003 Heavy Duty Diesel Manufacturer Fuel Recommendations

degradation, if allowed to occur, can result in the corrosion of metallic components, and the premature failure of seals.

- RME is a powerful solvent. Damage may occur if it comes into contact with paint work.

DISCLAIMER (Taken from the Common Position Statement)

No legal liability can be accepted for failure attributable to operating products with fuels for which the products were not designed, and no warranties or representations are made as to the possible effects of running these products with such fuels. Non-compliance of the fuel to agreed standards, whether being evident by appearance of the known degradation products of these fuels, or their effects within the fuel injection equipment, will render the FIE manufacturer's guarantee null and void.

DELPHI, STANADYNE, DENSO & BOSCH

Joint FIE Manufacturers Statement (06/02)

Common Position Statement on Fatty Acid Methyl Ester (FAME) Fuels as a Replacement or Extender for Diesel Fuels

The FIE Manufacturers Position

FIE manufacturers encourage the development of renewable compression ignition fuels. Experience to date with Rapeseed Methyl Ester fuels in Europe suggests that with fuels conforming to the existing national FAME standards at the point of sale in mixtures containing up to 5% volume RME, in mineral diesel fuel complying with currently accepted quality Standards, should not give end-users any serious problems.

Certain vehicle models have been adapted by their makers to use blends of 5% and above of good quality RME fuels in mineral diesel fuel. Other vehicles are adapted for using 100% good quality RME. The FIE manufacturers can supply equipment suitable for these applications.

The original quality of the FAME fuel is defined in draft National Standards which cover all relevant impurities and tramp chemicals from the processing. Suppliers of FAME fuels must be able to demonstrate compliance to these draft Standards at the point of delivery to the vehicle or plant.

International Standards are based on experience gained with the National Standards being developed to specify the original quality and long-term stability of FAMES. For the FIE manufacturers as key part of these Standards is resistance to oxidation. Aged or poor quality FAME contains organic acids, free water, peroxides and products of polymerization which attack many components thereby drastically reducing the service life of the FIE.

A fuel list of issues which have been witnessed in service is in the Attachment.

Even if these fuels comply with a suitable Standard as delivered, the enhanced care and attention required to maintain the fuels in vehicle or other tanks may entail a high risk of non-compliance to the Standard during use.

The FIE manufacturers can accept no legal liability for failure attributable to operating their products with fuels for which the products were not designed, and no warranties or representations are made as to the possible effects of running these products with such fuels.

Non-compliance of the fuel to Standards agreed by the FIE manufacturers, whether being evident by appearance of the known degradation products of these fuels, or their known effects within the fuel injection equipment, (see attached list of known issues) will render the FIE Manufacturers' guarantee null and void.