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Service Bulletin

Fuels for Cummins Engines

Introduction

This bulletin covers information about fuels for Cummins engines. The purpose of this bulletin is to help the user understand proper fuel selection, and problems associated with fuel.

Diesel Fuel

Diesel fuel performs three major functions in a Cummins diesel engine.

1. It supplies all the energy for the engine.
2. It cools and lubricates the precision parts of the engine's fuel pump and injectors.
3. It enables emissions controlled engines to meet regulated emissions levels.

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 (**www.engine-manufacturers.org/about/guidelines.cfm**). Operators **must** select fuels from these categories to optimize performance and emissions.

Category 1:

Markets with no or minimal requirements for emission controls.

Category 2:

Markets with stringent requirements for emission controls that requires the use of low sulfur fuel, for example, vehicles meeting United States and European on-highway standards. The maximum is 0.05 percent sulfur.

Category 3:

Markets with advanced requirements for emission controls that require ultra low sulfur fuel (less than 50 ppm) for after-treatment devices.
Category 4:
Markets with further advanced requirements for emission control to enable sophisticated NOx and PM after-treatment technologies. This normally requires no detectable sulfur in fuel.

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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

1. Regional, 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.

Diesel Fuel Properties

- Viscosity
  - General Description – Proper viscosity provides adequate pumping and lubricating characteristics to fuel system components.
  - Test Method – ASTM D445, ISO 3104

- Cetane Number
  - General Description – Cetane number is a measure of the starting and warm-up characteristics of a fuel. In cold weather or in service with prolonged low loads, a higher cetane number is desirable.
  - Test Method – ASTM D613, ISO 5165
  - Fuel with a cetane number greater than 55 may cause increased torque peak smoke. Reference ASTM D613, ISO 5165.

- Sulfur Content
  - General Description – Diesel fuels contain varying amounts of various sulfur compounds. Fuel sulfur contributes to acid formation and exhaust particulates. Reduced sulfur is required to meet particulate emissions and to avoid poisoning after-treatment devices. Higher sulfur fuel also needs higher total base number (TBN) lubricants to compensate for acid corrosion.

    NOTE: Catalyst failures caused by the use of fuels with higher than recommended sulfur levels are not warrantable. High sulfur fuel will also shorten the life of certain components in the exhaust system, including the oxidation catalyst.

  - Test Method – ASTM D2622, ISO 4260

- Active Sulfur
  - General Description – Some sulfur compounds in fuel are actively corrosive.
  - Test Method – ASTM D130, ISO 2160

- Water and Sediment
  - General Description – The amount of water and solid debris in the fuel is generally classified as

water and sediment. It is good practice to filter fuel while it is being put into the fuel tank. More water vapor condenses in partially filled tanks due to tank breathing caused by temperature changes. Filter elements, fuel screens in the fuel pump, and fuel inlet connections on injectors **must** be cleaned or replaced whenever they become dirty. These screens and filters, in performing their intended function, become clogged when using a poor or dirty fuel and will need to be changed more often.
    - Test Method – ASTM DI796

- Carbon Residue
    - General Description – The tendency of a diesel fuel to form carbon deposits in an engine can be estimated by determining the Ramsbottom or Conradson carbon residue of the fuel after 90 percent of the fuel has been evaporated.
    - Test Method – ASTM D524, ASTM D189, ISO 10370

- Density
    - General Description – Density is an indication of the energy content of the fuel. Higher density indicates more thermal energy and better fuel economy.
    - Test Method – ASTM D287, D4052, ISO 3675

- Cloud Point
    - General Description – The cloud point of the fuel is the temperature at which crystals of paraffin wax first appear. Crystals can be detected by the cloudiness of the fuel.
    - Test Method – ASTM D97, ISO 3015

- Cold Filter Plugging Point
    - General Description – The cold filter plugging point of the fuel is the lowest temperature at which fuel can still flow through a 45 micron wire mesh. This test method can be directly related to a fuel's tendency to plug fuel filters at reduced temperatures due to the formation of paraffin wax crystals.
    - Test Method – ASTM D6371

- Ash
    - General Description – The small amount of noncombustible metallic material found in almost all petroleum products commonly is called ash.
    - Test Method – ASTM D482, ISO 6245

- Distillation
    - General Description – At least 90 percent of the fuel **must** evaporate at less than 360°C [680°F]. All of the fuel **must** evaporate at less than 385°C [725°F].
    - Test Method – ASTM D86, ISO 3405

- Lubricity (ball on cylinder evaluator) BOCLE
    - General Description – Lubricity is the ability of a liquid to provide hydrodynamic and boundary lubrication to prevent wear between moving parts. Fuel with lower sulfur and viscosity tends to have lower lubricity. It can be measured by either one of two procedures.
    - Test Method:
      ASTM D6078, Scuffing Load Ball On Cylinder Evaluator (SLBOCLE), or
      ASTM D6079, ISO 12156, High Frequency Reciprocating Rig (HFRR)

Contingency Diesel Fuel Specifications

This section presents the specifications for fuels which are **only** to be used when fuel meeting the required specifications are **not** available. In the case that fuels meeting the Required Specifications in Table 1 are **not** available, Cummins has prepared contingency specifications to aid the user in choosing the most acceptable contingency fuel.

CAUTION

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.

Guidelines for The Use of Contingency Fuels

1. A calibration change of the fuel pump or injectors is **not** recommended when changing to a contingency fuel that meets all the specifications shown in Contingency Diesel Fuel Specifications, although changing to a contingency fuel can cause a slight power loss and can result in higher than normal wear of certain components. See the sections in this bulletin on Power Loss and Component Wear and Durability for additional information.
2. Although it is **not** anticipated that smoke levels will increase when fuels meeting the contingency fuel specifications are used for short periods of time, the user **must** make sure that the use of such fuels does **not** result in a smoke level which exceeds legal limits applied to the owner or operator. Continued use of fuels meeting the contingency fuel specifications can result in increased smoke levels.
3. Some jet fuel lubricities can be too low to provide the necessary lubrication for the fuel system components. If (based on the fuel supplier's specifications) a fuel does **not** have the minimum lubricity listed for contingency fuels in Contingency Diesel Fuel Specifications, a fuel additive **must** be added to the fuel to increase the lubricity and specially enhanced fuel system components **must** be used. Refer to the section in this bulletin on fuel additives. Consult Cummins for available hardware options.

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.

Additional maintenance can be required when using contingency fuels. Those using contingency fuels **must** consult with their fuel supplier to determine any problems which can result from using fuels meeting Contingency Diesel Fuel Specifications. If there is still a question, data on the fuel's physical properties **must** be submitted to Cummins Service Engineering Department for review before use in Cummins engines.

Table 2: Contingency Diesel Fuel Specifications [1]	
Viscosity	1.3 to 13.1 centistokes
Cetane Number	35 minimum above 0°C [32°F]; 40 minimum below 0°C [32°F]
Sulfur Content	Less than 2.0 mass-percent. Catalyst equipped engines may **not** be able to use high sulfur fuel even for a short period of time without permanent damage to the catalyst.
Active Sulfur	Copper Strip Corrosion **not** to exceed Number 2
Water and Sediment	**Not** to exceed 0.5 volume-percent
Carbon Residue	**Not** to exceed 5.0 mass-percent on 10 volume-percent residuum

Density	0.750 to 0.965 g/cc at 15°C
Cloud Point	Lowest temperature at which fuel can be maintained without forming paraffin wax crystals.
Pour Point	Lowest temperature at which fuel can still flow.
Ash	**Not** to exceed 0.05 mass-percent
Distillation	90 volume-percent at 395°C [743°F]
Lubricity (ball on cylinder evaluator) SLBOCLE	Minimum of 2300 grams SLBOCLE, maximum of 0.6 mm Wear Scar Diameter WSD at 60°C [140°F] HFRR
Vanadium	5 ppm, maximum
Aluminum	1 ppm, maximum
Silicon	1 ppm, maximum
Sodium	10 ppm, maximum

1. Reference test methods in Diesel Fuel Properties

Effects of Contingency Diesel Fuels on Engine Operation

- Viscosity
  - Low viscosity causes rapid wear of fuel pump and injectors. High viscosity causes hard starting, white smoke when cold, injector cup cracking, and injector train failures. Governor wear on rotary fuel pumps can cause loss of regulation.

- Cetane Number
  - A cetane number below 42 can cause poor starting, excessive white smoke, and poor idling. A cetane number above 55 can increase smoke at peak torque conditions.

- Sulfur Content
  - High sulfur content increases wear in injectors, piston rings, and bearings. Use of fuels with sulfur content above 0.5 mass-percent requires the use of higher total base number (TBN) lubricants (TBN greater than 10) and shorter oil drain intervals.

    NOTE: Catalyst failures caused by the use of fuels with higher than recommended sulfur levels are not warrantable. High sulfur fuel will also shorten the life of certain components in the exhaust system, including the oxidation catalyst.

- Active Sulfur
  - Excessive active sulfur increases the corrosive attack on the fuel pump, injectors, and other fuel system components.

- Water and Sediment
  - Contaminated fuels reduce filter life, fuel system life, and cause on-road failures.

- Carbon Residue
  - High carbon residue causes increased combustion chamber carbon deposits, more exhaust smoke, and higher soot contamination of the lubricating oil.

- Density
  - Lighter fuels contain less thermal energy per gallon and result in somewhat lower fuel economy. A fuel with a density of 0.876 g/cc contains about 3.5 percent more energy per gallon than a fuel with a density of 0.815 g/cc.

- Cloud Point
  - Operating below the cloud point temperature can cause the fuel filter to clog with wax crystals, restrict fuel flow, and cause loss of power. It is suggested that if fuels with cloud points above the expected ambient temperatures are purchased, the consumer **must** consult the fuel supplier and Cummins Inc. concerning fuel handling techniques. For more information, refer to Common Issues With Winter Fuel.

- Pour Point
  - Operating near or below the pour point will cause start-up issues. It is doubtful that most fuel pumps could operate at the pour point. In fact, it is recommended that systems be operated at 10 to 15 degrees F above the pour point of a fuel.

- Cold Filter Plugging Point
  - Operating below the cold filter plugging point temperature will cause the fuel filter to clog with wax crystals, restrict fuel flow, and cause loss of power. If is suggested that if fuels with cold filter plugging points above the expected ambient temperatures are purchased, the consumer **must** consult the fuel supplier and Cummins Inc. concerning fuel handling techniques. For more information, refer to Common Issues with Winter Fuel.

- Ash
  - High ash content causes deposits of noncombustible metallic material in the combustion chamber and on the exhaust valves.

- Distillation, Maximum
  - Fuels with high distillation temperature can leave gummy deposits in the fuel system and result in poor fuel combustion.

- Lubricity
  - Fuels with low lubricity can cause increased wear or seizure of fuel system components.

- Vanadium
  - Fuels with high vanadium content can cause valve burning.

- Aluminum
  - Fuels with high levels of aluminum can cause premature ring and liner wear which can lead to excessive oil consumption.

- Silicon
  - Fuels with high levels of silicon can cause premature ring and liner wear which can lead to excessive oil consumption.

- Sodium
  - Fuels with high levels of sodium can cause premature ring and liner wear which can lead to excessive oil consumption. Sodium can combine with vanadium, if present, and catalyze, causing valve burning.

- Zinc
  - Fuels with high levels of zinc can cause injector spray hole carboning. Do not use galvanized pipe or fittings in the fuel system plumbing. Diesel fuel will leach zinc galvanized material.

Power Loss

This section gives guidelines on power loss to be expected when using recommended or contingency fuels, or fuels that are above normal temperature.

NOTE: The values given concerning power loss due to the use of contingency fuels are intended only to help estimate power loss. Power loss can vary greatly, depending on operating conditions, engine type, fuel system type, fuel composition, and other factors. These guidelines can not be used to precisely calculate engine power loss.

The use of contingency fuels can cause a decrease in the power output of the engine due to differences in fuel density and viscosity. In addition, changes in fuel temperature also affect engine power output because temperature affects both viscosity and density.

Density

All engines will have a predictable variation in power output depending on the density of the fuel used. Engines using fuels with a high density will produce more power than those using fuels with a lower density because the thermal energy content of the fuel is higher. Since fuel is marketed by volume, lower density fuel carrying less thermal energy results in a proportional decrease in fuel economy or power output.

Viscosity

In general, lower viscosity results in lower power due to increased internal leakage in the fuel system. Also, lower viscosity fuels generally have lower thermal energy content. The effect viscosity has on power depends on the type of fuel system used.

Temperature

Temperature causes changes in engine power because it affects both viscosity and density. An increase in fuel temperature will cause a decrease in viscosity, which will reduce power due to internal leakage in the fuel system as described above. The maximum recommended fuel pump inlet temperature for Cummins engines is 70°C [158°F].

An increase in fuel temperature will also cause a decrease in fuel density (increase in API gravity), which will reduce power due to lower energy content of the fuel. On Cummins engines using the PT®, Quantum, or HPI fuel systems, the power loss due to increasing temperature is less than that on engines using the in–line, distributor, or CELECT™ systems (less than 1 percent per 5°C [10°F]), due to the inherent viscosity compensating characteristics of these systems.

Component Wear and Durability

This section shows the effects of contingency fuels on wear and durability of fuel systems components.

The use of contingency fuels can affect the wear and durability of both fuel pump and injector components within the fuel system. Many of these fuels are low in viscosity and lubricity as measured in the Ball On Cylinder Lubricity Evaluator (BOCLE) tests. Fuels with lubricity values below 2300 grams are considered to have poor lubricity and can cause failure of fuel system components. Other factors that affect wear and durability are sulfur, water, and sediment content. High sulfur content increases wear of the fuel system components. Abnormal quantities of water and sediment in the fuel will also cause excessive wear, as well as other engine problems.

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 used 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 and Lubricating Oil for On-Highway Applications

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.

CAUTION

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.

CAUTION

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.

Used engine lubricating oil can be blended with fuel using the Cummins Lube Oil Blender, Part Number 3376317 (110 volt, 60 Hz) or Part Number 3376362 (220 volt, 50 Hz). This process can be used to supplement fuel supply as well as provide a means of disposing of used lubricating oil.

To blend used engine oil with fuel, follow the instructions provided with the Cummins Lube Oil Blender.

Two rulings by the United States Environmental Protection Agency (EPA) affect the practice of blending lubricating oil with diesel fuel in the United States. First, on September 10, 1992, the Office of Solid Waste of the United States Environmental Protection Agency determined that used lubricating oil was **not** classified as hazardous waste. In addition, the blending of used lubricating oil with diesel fuel for burning in diesel powered vehicles was determined to be an acceptable method for disposing of used lubricating oil (57 Federal Register, R 41583, September 10, 1992). Second, beginning October 1, 1993, diesel fuel used in motor vehicles, as defined by the EPA, in on-highway applications **must** contain less than 0.055 percent sulfur by weight (Mandated in Section 211 of the 1990 Clean Air Amendments; 57 Federal Register, P. 19535, May 7,1992). Fuel blended with lubricating oil **must** also meet this specification.

Cummins allows the blending of lubricating oil with fuel used in their engines, except those equipped with an oxidation catalyst, often referred to as a catalytic converter (such as 1994 M11's and 1994 C8.3's used in urban transit buses, and 1994 B5.9's and C8.3's used in automotive applications). Cummins permits a maximum of 5 percent used lubricating oil to be blended with fuel. This helps to reduce operating costs and aids in the disposal of used engine oil. The blending of new lubricating oil to raise viscosity is also permissible. This helps to increase the viscosity of lighter fuels to acceptable levels. Cummins' recommendations for the blending of lubricating oil with fuel used in its engines have **not** changed; however, if blended fuel used in motor vehicles, as defined by the EPA, in on-highway applications exceeds the maximum sulfur content, United States federal law has been violated and penalties can be assessed. To be sure that blended fuel complies with the law, the following procedure **must** be followed. Both the diesel fuel and lubricating oil **must** have their sulfur content measured by a qualified laboratory using the testing

method specified in ASTM D2622 (American Society of Testing and Materials Standard, or ISO 4260). Once the correct blend factor has been determined, multiply this by the volume of fuel to be blended. The result is the amount of this oil that can be blended with this fuel and remain within legal limits. Similar restrictions and processes **must** be followed worldwide where regional or national regulations can impose such sulfur limits.

As an example, consider 50,000 gallons of fuel with a sulfur content of 0.04 percent by weight and lubricating oil with a sulfur content of 0.5 percent by weight. Of this oil, 450 gallons can be blended with 50,000 gallons of this fuel and remain within legal limits for sulfur content in the United States. Margins **must** be allowed for measurement errors.

Blending Fuel with Fuel

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

In cold-weather operation, the most common method of preventing fuel waxing problems is to dilute heavier, higher wax content fuels such as U.S. Number 2-D diesel fuel with lighter, lower wax content fuels such as Number 1-D diesel or jet fuel. This reduces the concentration of wax, and thereby reduces both the cloud point and pour point. Blended fuels of this nature are more expensive to use both because they cost more and because they have a lower thermal energy content. A typical blended fuel contains 30 to 60 volume-percent light distillate fuel, usually yielding a 3 to 7°C [5 to 12°F] drop in cloud point, and a 5 to 11°C [9 to 20°F] drop in pour point. Lower wax content fuels **must** be added BEFORE wax forms to be effective.

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 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 cetane improver additive can be used with low cetane fuels.
2. A pour point depressant or flow improver additive can help with high pour point fuels.
3. A wax crystal modifier can help with fuels with high cold filter plugging points (CFPP).
4. An anti-icer can help prevent ice formation in wet fuel during cold weather.
5. An anti-oxidant or storage stability additive can help with fuel system deposits and poor storage stability.
6. A lubricity enhancer can be used to increase the lubricity of fuels so that they meet the requirements given in Table 1.
7. A biocide or fungicide can help when fuels are prone to contamination with bacteria or fungus. Although other additives may provide some performance benefits, Fleet-tech™ Microbicide (quart - CC2661 and gallon - CC2662) is the **only** product recommended by Cummins to treat fuels with biological contamination problems.
8. Fleetguard's Fleet-tech™ Turbo Diesel All Season Fuel Additive (pint - CC2588) can be used with low cetane fuels to boost cetane values. Although other additives are available that may boost the cetane number, Fleetguard's Fleet-tech™ All Season Fuel Additive is the **only** diesel fuel additive recommended by Cummins for cetane number improvement.
9. Fleetguard's Fleet-tech™ Asphaltene Conditioner (quart - CC2597 and 2.5 gallon CC2596) or Fleetguard's Fleet-tech™ Turbo Diesel All Season Fuel Additive (pint -CC2588) can be used to clean carbon deposits from injectors and improve lubricity in fuels that fall below the recommended lubricity specification in Table 1. Although other additives may provide some performance benefits, Fleet-tech™ Asphaltene Conditioner, and Turbo Diesel All Season Fuel Additive are the **only** diesel fuel additives recommended by Cummins for use with fuels that do **not** meet the lubricity specification in Table 1.
10. Fleetguard's Fleet-tech™ Winter Conditioner (pint - CC2591, quart - CC2592, 2.5 gallon - CC2595, 5 gallons - CC2593, 55 gallons - CC2594, and bulk - CC2590) and Turbo Diesel All Season Fuel Additive (pint - CC2588) can be used to improve the pour point and cold filter plugging point of diesel fuels in addition to preventing ice formation in wet fuels during cold storage. Although other additives are available that may provide some winter performance benefits, Fleet-tech™ Winter Conditioner and Turbo Diesel All Season Fuel Additive are the **only** diesel fuel additives recommended by Cummins for winter performance improvements.

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).

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 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.

Water-Emulsions

Water, up to 20 percent, is blended into fuel with the use of some fuel additives such as detergents. The milk-like water emulsified diesel fuel is often referenced as an emission reducing fuel. The reduction of emissions normally range from 8 to 30 percent depending on engine type, operating conditions, and engine calibrations. Cummins engines are **not** tuned specifically to this kind of fuel, therefore can **not** warrant the reduction of emissions.

Since water is **not** combustible, the emulsified fuel usually results in fuel economy reduction of 15 percent or more. Other potential problems include water separation and water related problems like corrosion, change of ignition timing, and fuel system wear.

Cummins Inc. disapproves of the use of water emulsified fuels. 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.

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.

Fuel Filters

This section explains the types of fuel filters and their uses.

Fuel filters are standard equipment on all Cummins engines. They are designed to remove water and harmful particles from the fuel before they damage the fuel pump and other engine components.

Effective September 1, 1991, Cummins Inc. requires a fuel-water separator or fuel filter and water separator combination be installed in the fuel supply system. This requirement applies to all 1991 and later automotive certified engines and all future automotive engines. In addition to this requirement, Cummins Inc. recommends that a fuel-water separator or fuel filter and water separator combination be installed in the fuel supply system on all Cummins engines regardless of application.

NOTE: It is strongly recommended that the "N" and "L" series engines, built with CELECT™ and STC prior to September 1, 1991, be up-fitted with a fuel-water separator.

Water can be introduced to a diesel engine's fuel system in two ways. Water can be present in the fuel and enter the engine's supply tank at fill-up or water that is normally in the air above the fuel can condense on the walls of the fuel tank.

Water in diesel fuel is normally present as both free and emulsified water. Free water settles to the fuel tank bottom where it can be drained. Emulsified water stays in suspension where it can enter the fuel lines, fuel pump, and injectors. Once this suspended water is in the fuel system, it can cause corrosion and failure of key fuel system components.

Throw Away Canister

The standard fuel filter is the spin-on element. These filters contain a porous, pleated, chemically treated paper element that will pass fuel freely but trap impurities and sediment.

When the element is serviced, it is simply detached from the fuel filter head assembly, discarded, and replaced with a new element. The element **must** be tightened to the manufacturer's specifications.

NOTE: Do not pour fuel from an old fuel filter into a new filter in an effort to prime the fuel system. Use only clean fuel to prime the fuel system. It is not necessary to add fuel to a new fuel filter if the engine is equipped with an electric fuel transfer pump. Fuel systems on these engines can be

primed by turning the vehicle keyswitch on and off several times to activate the fuel transfer pump.

CAUTION

Overtightening will distort the filter cartridge or crack the filter head. Do not use a filter element that has been dented or damaged prior to, or during, installation.

Replaceable Element Type

Another type of fuel filter used on Cummins engines has a replaceable pleated paper element.

Pre-Filters

Midrange B and C series engines require the use of a fuel pre-filter (150 micron maximum).

Fuel-Water Separators

Free and emulsified water can be removed from the fuel. Integral fuel filter and water separators are available that remove both free and emulsified water with varying degrees of efficiency. The standard fuel filter (FF105, FF202, FF213, FF5052) does remove some free and emulsified water, but with low efficiency. Due to the above facts and the requirement that a fuel-water separator or fuel filter and water separator be installed in the fuel supply system, Cummins has increased the requirements for free water and emulsified water removal. For engines with CELECT™ fuel systems, the fuel-water separator or fuel filter and water separator combination **must** remove a minimum of 95 percent of free water (per SAE J1839) and 95 percent of emulsified water (per SAE J1488). Fuel-water separator filters produced by Fleetguard® and most other major filter manufacturers meet or exceed these requirements.

Cummins engines with CELECT™ fuel systems are factory fit with Fleetguard® fuel-water separators that utilize StrataPore™ filter media. These StrataPore™ filters provide high efficiency removal of harmful particles and both free and emulsified water.

The fuel-water separator requires daily draining. See Owner's Manual or Operation and Maintenance Manual for other regular service intervals of fuel filters.

NOTE: The drained fluids (mixture of water and fuel) must be properly disposed of according to regulations.

Table 1 lists the Cummins and Fleetguard® fuel filters that are available from Cummins Distributors and Dealers. Change or clean the fuel pre-filter, if so equipped.

Fuel Filter Maintenance

Fuel filters **must** be changed periodically to prevent restriction of fuel flow from the fuel tank to the fuel pump. Change fuel filters as recommended by the appropriate Cummins Engine Operation and Maintenance Manual.

Check the fuel restriction when operating under severe conditions in order to determine if additional fuel filter changes are needed. These measurements **must** be taken at full load and peak power on engines with PT® and in-line fuel pumps or high idle with no load on Celect™ model engines. After checking the restriction a few times, a maintenance schedule for fuel filter changes can be established for each type of operation.

Table 3: Fuel Filter Part	

Numbers				
Fleetguard® Model Number	Cummins Part Number	Length mm [in]	Outside Diameter mm [in]	Used On
FF-104	3315846*	107 [4.2]	94 [3.7]	L10, NT, Small Vee, Medium Vee, K19 fuel filter
FF-105	3315844*	137 [5.4]	94 [3.7]	L10, NT, Small Vee, Medium Vee, K19 fuel filter
FF-105–D (with drain)	3315847*	152 [6.0]	94 [3.7]	L10, NT, Small Vee, Medium Vee, K19 fuel filter
FF-202	3313306*	286 [11.3]	118 [4.7]	V28, K38, K50 fuel filter
FF-213	3300901*	174 [6.9]	94 [3.7]	NT fuel filter
FF-5052	3931063*	116 [4.6]	77 [3.0]	Midrange fuel filter
FS-1280	3930942	162 [6.4]	94 [3.7]	Midrange fuel-water separator
FS-1212	3315843	174 [6.9]	94 [3.7]	L10, NT, and K19 and QSK19 fuel-water separator
FS-1216	3313304	308 [12.1]	118 [4.7]	V28 and KV fuel-water separator
FS-1251	3286503	141 [5.6]	77 [3.0]	Midrange fuel-water separator
FS-1232	3834656	115 [4.5]	77 [3.0]	Fuel-water separator for B-Series in pre-1994 Dodge Ram (distributor fuel pumps **only**)
FS-1232V	3912104	170 [6.7]	77 [3.0]	Fuel water separator for B-Series in pre-1994 Dodge Ram (distributor fuel pumps **only**)
FS-1253	3923108	118 [4.6]	94 [3.7]	Fuel-water separator for B-Series in 1994 through 1996 Dodge Ram
FS-1253V	3865402	173 [6.8]	94 [3.7]	Fuel-water separator for B-Series in 1994 through 1996 Dodge Ram
FS-1000	3329289**	249 [9.8]	94 [3.7]	Fuel–water separator for M11, N14, ISM/QSM, and K19/QSK
FS-1001	3413084**	203 [8.0]	94 [3.7]	Short version of FS-1000
FS-1003	3406889**	250 [9.8]	94 [3.7]	ISM/QSM fuel-water separator
FS-1006	3089916**	310 [12.2]	120 [4.7]	QSK45/60/78 fuel-water separator
FS-1007	4010650**	298 [11.7]	119 [4.7]	ISX/QSX fuel-water separator
FS-1022	3800394**	238 [9.4]	94 [3.7]	ISC/QSC fuel-water separator
FS-1040	4010651**	298 [11.7]	119 [4.7]	ISX/QSX fuel-water separator

FS-19519	3942533**	148 [5.8]	94 [3.7]	ISB/QSB fuel-water separator
FS-19519V	3894519**	148 [5.8]	94 [3.7]	ISB/QSB fuel-water separator
FS-19528	3931476	110 [4.4]	105 [4.1]	Fuel-water separator for B-Series in 1997 through 1999 Dodge Ram
FS-19579	3945213**	103 [4.1]	87 [3.4]	Fuel-water separator for 1996 through current midrange (2000 and 2001 Dodge Ram)
* These filters are recommended **only** when using a standalone water separator. ** These filter utilize StrataPore™ filter media.				

Fuel restriction can be checked as follows. Refer to the appropriate troubleshooting and repair manual for more detailed instructions.

1. On the PT® fuel system, measure the restriction at the suction side (inlet) of the fuel gear pump. Change the filter element if the restriction is above 203 mm Hg [8 in Hg].
2. On in-line or distributor fuel systems, measure the restriction at the inlet of the fuel lift pump. Also measure the pressure drop across the fuel filter and the pressure at the inlet to the fuel injection pump. Change the filter element if the pressure drop across the filter is more than 34 kPa [5 psi].
3. On the CELECT™ system, measure the restriction at the suction side (inlet) of the fuel gear pump. Change the filter element if the restriction is above 254 mm Hg [10 in Hg].
4. On the HPI-TP system (ISX/QSX/Signature) there are different test locations and limits depending on the engine option. See the engine Troubleshooting and Repair Manual for specific instructions.
5. On the CAPS system, measure the restriction at the inlet of the fuel gear pump. Change filter if restriction is above 254 mm Hg [10 in Hg].
6. On the Quantum system, there are different test locations and limits depending on the engine option. See the engine troubleshooting and repair manual for specific instructions.

NOTE: If the restriction exceeds these limits, the fuel flow to the pump will be reduced and engine power will decrease.

Hot Restarts

This section shows how contingency fuels affect the ability of the engine to restart while still hot.

On Cummins engines which use a distributor type fuel system, the use of contingency fuels can cause difficulty restarting the engine while it is still hot. In addition, if excessive wear exists in the fuel pump, the same difficulty can occur even when using fuels within the range listed in Required Diesel Fuel Specifications. The problem is caused by excessive leakage of fuel around the internal components of the fuel pump. Fuel leakage becomes excessive due to the high temperatures and low viscosity of the fuel. Excessive wear of the fuel pump components will make the problem worse. The leakage can become so great that the pump will **not** produce the fuel rate necessary to restart the engine. If this problem is encountered, it can be corrected by using fuel which meets the specifications in the Required Diesel Fuel Specifications section of this bulletin. If this does **not** correct the problem, repair or replacement of worn fuel pump components is necessary.

Alternate or contingency fuels can cause difficulty restarting a hot engine. The hot restart complaint can be caused by fuel burning prematurely during the first compression stroke. Lighter alternate or contingency fuels can enter the cylinder through an open injector caused by the thermal expansion that occurs during the

heat soak after engine shut down. The burning fuels increase the starting cylinder pressure and increase the amount of torque needed to start the engine. Lighter alternate or contingency fuels with lower flash points increase the probability of fuel entering and burning in the cylinder. This issue can, on occasion, occur when using fuels that meet the required properties listed in Table 1. Various Hot Restart kits (sometimes referred to as a Hot Start Knock kit) have been released by Cummins to address this issue.

If this complaint is encountered, it can be corrected by using fuels which meet the requirements in the Required Diesel Fuel Specifications section of this bulletin. If this does **not** correct the hot restart complaint or if the recommended fuel can **not** be used, refer to the Service Information Bulletin Number, 90SIB6-1.

Common Issues With Winter Fuel

This section presents the various winter fuel issues and methods of dealing with them.

Two winter fuel handling issues, wax and ice, have annoyed diesel operators for years. There is no solution to either of these problems that is ideal for all situations, but the better one understands the problem, the less difficult the process of finding a solution becomes. Determining whether a low power complaint is due to fuel filter plugging complaint is fairly simple: replace the fuel filter with a new filter. If this allows the vehicle to operate normally even for a short period of time, then obviously something in the fuel is plugging the filter and causing the complaint. A simple way of determining whether the filter plugging is caused by wax or ice is to bring the plugged filter into a warm shop, drain out the liquid fuel, place the filter upside down on a piece of paper or in a shallow pan, and allow the filter to warm to room temperature. If there is ice in the filter, it will melt and run out of the filter and the water on the paper or in the pan will be obvious. Most petroleum wax, on the other hand, will **not** melt at room temperature. To speed the analysis process, the filter can be cut open and spread out. Once the cause of the low power complaint is determined, then a logical solution can be chosen.

Fuel Wax

All middle (or intermediate) distillate fuels, such as jet fuels, heating fuels, and diesel fuels, contain paraffin wax. Paraffin wax is a solid, crystalline mixture of straight-chain or normal hydrocarbons melting in the approximate range of 40 to 60°C [104 to 140°F]. This paraffin wax occurs naturally in the crude oil from which fuel oils are distilled. The wax content of a distillate fuel varies greatly, depending on the crude oil from which the fuel is produced and in the processing of the fuel. Generally, higher boiling distillate fuels, such as U.S. Number 2-D diesel fuel, have a higher concentration of paraffin wax than lower boiling distillate fuels, such as jet fuel.

Because of the strong relationship between temperature and solubility of wax, wax separation is a problem in handling and using diesel fuel during cold weather. As fuel cools, a temperature is reached at which the soluble paraffin wax in the fuel begins to come out of solution (Cloud Point); any further cooling will cause wax to separate out of solution. The temperature at which a certain fuel will become saturated with wax and causes filter plugging problems is termed the Cold Filter Plugging Point (ASTM D 6371). The temperature at which fuel will no longer flow is the Pour Point (ASTM D-97). At the pour point, most of the fuel is still liquid oil although it is very thick or viscous and trapped in a honeycomb-lick network of wax crystals.

Since diesel powered equipment is frequently used at temperatures low enough to cause wax to separate, a number of techniques have been devised to prevent the wax from causing problems by plugging fuel screens, lines, filter, and so on, and preventing fuel flow to the engine. Vehicles designed to operate at very low temperatures have provisions for heated fuel tanks, insulated fuel lines, heated fuel filters and other mechanisms to warm the fuel so that the wax does **not** separate. These more elaborate systems are usually **not** practical in more temperate climates where they are needed **only** a few days a year.

Fuel Filters

Fuel filters have already been discussed in detail in the Fuel Filters section of this bulletin. The **only**

additional consideration in terms of common issues with winter fuels is that using a large filter or multiple filters in parallel will allow more fuel wax to be filtered before a power loss occurs. Also, relocating the fuel lines and filter out of the wind-stream and wheel splash and into the engine compartment near the engine block will help keep them warm.

Engine Idling

CAUTION

Do not idle the engine for excessively long periods of time. Long periods of idling (more than 10 minutes) can damage an engine because combustion chamber temperatures drop so low the fuel may not burn completely. This will cause carbon to form in the injector spray holes and on the piston rings and can result in stuck valves.

Additives

There are a number of fuel additives available which reduce the pour point and cold filter plugging point (CFPP) of diesel fuel. These are commonly referred to as pour point depressant additives, cold flow improver additives, wax crystal modifiers, or fluidity improver additives (and can be collectively termed “Winter Additives”). Certain additives can reduce the Pour Point by as much as 70°F and the CFPP by as much as 30°F. A survey of winter blend fuels by the Bureau of Mines (now a part of the Energy Research and Development Administration) revealed that a large percentage of the commercially marketed diesel fuels had been treated with a winter additive. Before purchasing such an additive to treat fuel, ask the fuel supplier whether the fuel already contains a winter additive. Depending on the amount and type of additive already in the fuel, additional additization may or may **not** be necessary.

These additives alter the size and shape of wax crystals allowing pumping of fuel at lower temperatures. Although certain additives can be very effective, they are **not** a cure all. Their performance varies depending on the paraffin type and content of the fuel treated. Severe weather applications may require fuel warmers in addition to additives. Although other additives are available that may provide some benefits, Fleetguard's Fleet-tech™ Winter Conditioner and Turbo Diesel All Season Fuel Additive are the **only** fuel additives recommended by Cummins to help prevent filter gelling in cold weather applications.

Fuel Warmers

Warming diesel fuel just prior to filtration is an excellent method of preventing fuel filter plugging. If cold fuel is warmed sufficiently, the wax crystals will dissolve in the fuel. The dissolving requires warming to a temperature of approximately 11 to 22°C [20 to 40°F] above the fuel's cold filter plugging point.

In order for a fuel warmer to reliably prevent fuel filter plugging due to wax, it **must** be capable of supplying enough heat to the fuel at the maximum fuel flow (**not** just fuel consumption) rate to raise the fuel temperature from the lowest expected fuel temperature (probably the lowest expected ambient temperature) to 11 to 22°C [20 to 40°F] above the fuel's cold filter plugging point. There are four different fuel warmers presently offered by Fleetguard® to raise the temperature of the inlet fuel.

1. Fuel Filter Heater - The Fleetguard® Positive Temperature Coefficient (PTC) fuel filter heats the fuel before the fuel flows into the fuel filter. The heater is installed on the fuel filter head. Most complaints of fuel waxing occur in the fuel filter. The heater uses ceramic discs that sense the fuel temperature and heats the fuel to a temperature just above the cloud point.

The PTC heater is self-regulating. Depending on battery voltage, the heaters use from 6 to 25 amps at maximum output. When no heat is required, the heater uses less than 0.5 amp. The heater can be left on during engine operation or it can be turned off with the cab switch. The heater reaches full heating capacity

in about two minutes. The PTC heater kit is available (see Table 4).

Table 4: Fuel Filter Heaters	
Watts	Fleetguard® Part Number
300	3836029–S

A Fleetguard® kit, Part Number 3837317-S, adapts the heater to most fuel filter heads with 1 in-14 threads. Refer to the following fuel filter list. The heater adds about one inch in height to the fuel filter head assembly.

Fuel Filter List with 1 in –14 Threads	
FF–104	FF-213
FF–105	FF-105C
FS-1242(B)	FS-1001
FS-1000	FS-1212
FF-105D	FS-1003

The Fleetguard® kit, Part Number 3832054-S, adapts to FS–1251 filter.

2. Recirculating Fuel Warmer - Part Number 3305782, can be used to warm inlet fuel for flow up to 9.5 l/pm [2.5 gpm]. The unit circulates engine coolant around the inlet fuel to warm the fuel. The unit is most effective when immersion or tank heaters are used to warm the coolant. An optional thermostat, Part Number 3305783, can be used to bypass fuel when 27°C [80°F] is reached. Use Table 5 to determine the performance capability of this fuel warmer for different operating conditions.

Table 5: Recirculating Fuel Warmer, Part Number 3305782 - Performance Data

Temperature Rise Chart			
Inlet Fuel Temperature (°F)	**Outlet Fuel Temperature (°F) Fuel Flow Rate**		
	2–1/2 GPM	**1–1/2 GPM**	**1/2 GPM**
-30	32	38	52
-10	39	45	55
10	47	53	59
30	60	62	67
50	71	74	77
70	85	87	88

3. Thermo Blend - The Fleetguard® Thermo Blend fuel warmer recirculates warm deaerated drain fuel from the engine to the filter and injection system, rather than allowing it to return to the tank. A 10 to 15 minute engine-running warm up period is usually necessary to provide successful operation. A built-in thermostat automatically bypasses fuel at 43°C [110°F]. Part Number 3310200 **must** be used for all Midrange and Heavy Duty diesel engines. Part Number 3308750 **must** be used for all heavy duty off-highway equipment (such as 12 and 16 cylinder engines).
4. Thermo Blend FM, Part Number 3310630 - The Fleetguard® Thermo Blend FM fuel warmer combines the return fuel heating principle with a special filter head. When used with Cummins Part Number 3315843 (Fleetguard® Part Number FS-1212) fuel-water separator, it provides fuel dewaxing, water

removal, and filtration. A built-in thermostat automatically bypasses fuel at 21°C [70°F]. When using fuel warmers, do **not** overheat the fuel. The maximum fuel temperature at the inlet to the fuel pump is 70°C [158°F]. Alterations of heating devices **must** be reversible, or have some means to turn them off during warm weather operation. The fuel tank is heated by the injector return (drain) fuel from the engine. On typical installations, the cooling effect of the tank maintains fuel temperatures at an acceptable level.

On some installations, such as acoustically enclosed units, little cooling of the tank occurs because of the design. On these installations, a fuel oil cooler can be used to limit the temperature of the fuel at the fuel pump inlet to 70°C [158°F] or less.

Depending on the particular engine model involved, the engine horsepower will begin to decrease slightly above fuel inlet temperatures of 46°C [115°F]. The percent of power loss is **not** as great on engines with the Cummins PT® and HPI fuel system (less than 1 percent per 5°C [9°F]), due to the inherent viscosity compensating characteristics (see Power Loss section in this bulletin). Operation above 70°C [158°F] is **not** recommended due to the loss of the lubricating quality of the fuel with resultant wear to the fuel system components which depend on fuel for lubrication. A fuel warmer will **not** help if the fuel is below the pour point and can **not** be pumped to the warmer; therefore, in extremely cold conditions, fuel can be treated with light distillate fuel or treated with a pour point depressant to reduce the pour point, or it can be necessary to heat the fuel to allow it to flow.

When using fuel warmers that use engine coolant as a source of heat, some form of coolant heating during shutoff will allow the heater to become effective much more quickly after start-up. These fuel warmers **must** also be checked for leaks. Since the fuel warmer is on the suction side of the fuel pump and the cooling system is pressurized, any small leak will allow coolant to enter the fuel system.

Other Considerations

Wax in the fuel will deposit in any restriction or sharp bend in the fuel plumbing system. If fuel starvation occurs during cold-weather operation and plugged fuel filters are **not** found, look for plugging of tank pick-up screens, sharp bends in the fuel lines, fittings, and so forth.

Water Contamination

Free water (non-dissolved) in the fuel can freeze at low temperatures and the resulting ice crystals can plug fuel filters causing fuel starvation. Care **must** be taken to keep fuel storage tanks dry. Tanks can be “stuck” often with water detecting paste (usually obtainable from fuel suppliers) to be sure they are dry. If water is detected, it **must** be pumped out.

Keeping bulk fuel storage tanks dry has already been mentioned; however, if this is a persistent issue, a dryer (fuel-water separator) can be installed on the bulk fuel dispensing system.

Condensation in the vehicle fuel tank(s) occurs when the air in the fuel tank(s) cools down during a shutdown period. This moisture can be reduced by filling the vehicle fuel tank before engine shutdown to reduce the air space above the fuel.

Dissolved water comes out of solution as fuel cools. As fuel cools from 4 to -29°C, [40 to -20°F] the solubility of water in the fuel reduces 70 percent. Therefore, fuel pumped from a relatively warm underground tank into a vehicle which sits overnight in sub-zero temperatures can cause some free water to separate. However, this source of free water is almost negligible, because even at high temperatures fuel will dissolve very little water (0.1 mass-percent at 71°C) [160°F]).

Additives can be used to prevent fuel line freeze up. These additives work by lowering the freeze point of water so that it will not freeze and cause lines and filters to plug. Although other additives may provide some benefits, Fleetguard's Fleet-tech™ Winter Conditioner and Turbo Diesel All Season Fuel Additive are the

only additives recommended by Cummins for this application.

NOTE: More cold weather engine operation recommendations are in Service Bulletin Number 3379009 and in the engine operation and maintenance manual.

Microbial Contamination of Fuel

WARNING

Although most of the microbes that will live in fuel tanks are common organisms to which humans are constantly exposed, contact with microbes or fungi from a fuel tank must be avoided. When a fuel system is contaminated and cleaning is necessary, workers must be protected. Remember that the fungi produce reproductive spores and when dry these can easily become airborne, so breathing protection must be provided or the microorganisms must be kept wet. Dispose of the water and sludge removed from fuel tanks properly. Never place these materials in sanitary sewer system since they can kill bacteria used in sewage treatment. Never place them in storm sewers or surface water streams since they can kill fish and other aquatic animals.

WARNING

The most common problem associated with exposure to these microbes is dermatitis which in some people can be quite serious. Any exposed skin must be thoroughly washed with warm, soapy water.

WARNING

Avoid eating, drinking and smoking while working with these microbes. Any ingestion of the microbes or exposure to broken skin must be considered serious. It is recommended that if this happens the worker be taken to a doctor, along with a sample of the microbes.

WARNING

Biocides are generally only mildly toxic to humans and animals but must still be handled carefully. In cases of ingestion or contact with the eye, follow manufacturer's recommendations. Seek medical attention.

This section covers the recognition of and solutions to microbial contamination of diesel fuel.

To protect against fuel shortages, many users have been storing fuel and, as a result, the frequency of microbial contamination has increased. Microbial contamination of fuel, though **not** a new concern, is more common in metalworking industries which use water- soluble oils as cutting fluids or in long-term storage of hydrocarbon fuels than it is in diesel fleet operations. All hydrocarbon fuels are essentially sterilized by the high temperatures encountered in the refining process; however, they can become contaminated soon after leaving the refinery by microorganisms. These microorganisms, primarily bacteria and fungi, exist rather harmlessly in moisture-free fuel, passing through fuel systems without having any negative effects.

However, in the presence of water, these microorganisms begin to grow and reproduce. The rate of growth depends on how well the environment suits the particular microorganism's needs.

The growth of a large colony of microorganisms in a fuel system can cause several issues. The first and usually most obvious is fuel filter plugging with a greenish-black or brown slime, frequently accompanied by a foul odor. This slimy, string-like colony can also plug sharp bends in fuel lines, fuel meters and other restrictions. The second issue these microorganisms can cause is corrosion due to the acid by-products some of them produce. It is also possible, if the microorganisms pass through the fuel filter, that they will form deposits and cause damage in the fuel pump and injectors.

Some indicators of microbial contamination are:

1. Slime deposits on tank walls, piping, or other surfaces which are exposed to fuel. These deposits are usually greenish-black or brown and are slick to the touch.
2. Black or brown "stringy" material suspended in tank water bottoms.
3. Swelling or blistering of any rubber surface (washers, hoses, connectors, and so forth) that comes in contact with fuel.
4. Sludge or slime deposits on filter surfaces.
5. Foul odor resembling that of rotten eggs (hydrogen sulfide).

A more conclusive approach is to routinely check the fuel by means of one of the several available test kits which are listed below. These can detect microorganisms long before there is any visible evidence of contamination.

The following list shows test kits of which we are aware. Listing of a kit can **not** be construed as a recommendation or approval; and, the fact that a kit is **not** listed **only** means we are unaware of it. Cummins has **not** tested any of these kits, but has **only** reviewed the manufacturer's literature. Users **must** evaluate the kits available to them and select one based on their own judgment.

1. Total Count Sampler, Catalog Number MTOO 000 25 for package of 25, from Millipore Corporation, Bedford, MA 01730, 1–800–645-5476. The Total Count Sampler contains a nutrient media specifically designed to encourage bacterial growth; however, many fungi will grow on it. Millipore recommends incubation at 35°C [95°F] for 24 hours; however, they can be incubated at room temperature for 36 to 48 hours. If the results on the Total Count Sampler are low and is still suspected, re-sample using Millipore's Yeast and Mold Sampler (Catalog Number MYOO 000 25 for package of 25). This sampler contains a nutrient media which suppresses the growth of most bacteria, but is rich in nutrients for fungi. For best results, use both samplers each time water bottoms are tested. These Millipore samplers are probably the most sensitive of those listed, and in fact, can lead one to overtreat a fuel system. Millipore samplers are also available from Millipore in Australia, Belgium, Brazil, Canada, Denmark, England, Finland, France, Italy, Japan, Mexico, Norway, Spain, Sweden, Switzerland, and West Germany. Inquiries from other countries can be directed to Millipore Intertech, Inc., P.O. Box 255, Bedford, MA 01730 U.S.A.
2. Microbe Monitor Test Kit (From Air BP) British Petroleum Cleveland-Hopkins International Airport Cleveland, OH 44135 1–800–533-2340. One sample per kit. Incubates at room temperature.

When it has been established that microbial contamination is present and action **must** be taken, there are several approaches. The most obvious solution is prevention. Most of the bacteria and fungi involved are soil organisms which can become airborne or waterborne. Prevention of the entrance of microorganisms is **not** possible because these organisms can enter the fuel through many different routes.

Growth of these microorganisms can be prevented. Since all metabolic processes of an organism are conducted in water, denying the microorganism access to water will prevent growth, thus preventing the development of large, troublesome colonies. Therefore, the first and most important step in prevention is to keep fuel systems dry. Keeping a fuel system entirely dry is impossible. In cases where microbial contamination is a recurring issue, a microbicide can be used to chemically treat the fuel or the water.

There are three general classes of biocides: water-soluble, fuel-soluble, and universally soluble. Fuel-soluble biocides are best suited for treating fuels which are to pass through several storage steps in the distribution process. A fuel-soluble biocide injected into the fuel early in the distribution system is carried with the fuel through the entire downstream system, effectively sterilizing the fuel until usage. Fuel-soluble biocides are easier to add to the fuel system since the exact amount needed to treat a volume of fuel is easily determined and they have a low toxicity to human and other life forms. The obvious disadvantage to fuel-soluble biocides is cost; each batch of new fuel added to the system **must** be treated since the biocide is consumed as the fuel is consumed.

Water-soluble biocides are more economical for use in treating one step in a fuel distribution system, such as the end-user's storage tank. The water-soluble biocides, since they are insoluble in fuel, stay where they are placed until the water bottoms are pumped from the tank; therefore, the total amount of biocide purchased is less. There are a number of disadvantages to water soluble biocides. Since no biocide is carried downstream by the fuel, each successive tank in the system **must** be individually treated. There is some difficulty in determining how much biocide to place in a tank since that depends on how much water is in the tank. The biocide can **not** be thoroughly mixed with the water in the bottom of a tank. Water-soluble biocides are much more easily taken in by humans and other life forms: and therefore, **must** be disposed of properly when water bottoms are pumped from a tank. Water bottoms containing a water-soluble biocide **must not** be placed in a sanitary sewer system because the biocide can destroy the bacteria used by sewage treatment plants. These water bottoms **must** be treated as an acidic, industrial oily waste.

Universally soluble biocides are soluble in both water and diesel fuel. They allow you to treat the entire downstream system. However, each subsequent load of fuel does **not** need to be treated. The biocide will remain in any water that has collected at the bottom of the storage tank and continue to inhibit microbial growth. With certain types of biocides, the interval between treatments can be as long as six months. Like water-soluble biocides, universally soluble biocides are more easily taken up by humans and other forms of life. They also tend to be more expensive than the other types of biocides.

Treating a fuel tank that is infested with a large population of microorganisms will kill the microorganisms, but it will **not** eliminate the filter plugging they can be causing. The water and sludge containing the microorganisms **must** be removed from the fuel systems. First, clean the fuel system thoroughly. Next, a fuel-soluble or universally-soluble biocide **must** be added to the next few batches of fuel to kill any remaining microorganisms. Finally, the addition of a water-soluble or universally-soluble biocide can be continued for at least several months to be sure the microorganisms are all dead. If microbial contamination is a recurring issue, it is recommended that use of the water-soluble or universally-soluble biocide be continued permanently since this would be the most cost effective solution to the problem. This can be done by determining the amount of water that accumulates in tank bottoms between pump outs and adding about double or triple the amount of water-soluble biocide recommended to treat that volume of water. For example: you normally pump out approximately 379 liters [100 gallons] of water bottoms. In this case, after pumping the bottoms, immediately add to the fuel tank two or three times the amount of biocide normally used to treat 379 liters [100 gallons] of water. Since the biocide is more dense than fuel, it will settle to the bottom of the tank and will dissolve in the water as it accumulates. After refilling a fuel tank, the biocide **must** be allowed to settle before drawing fuel from it to keep from pumping the biocide out with the fuel.

Although other products may provide some benefits, the **only** biocide recommended by Cummins is Fleetguard's Fleet-tech™ Microbiocide. It is a universally soluble biocide. For specific treatment recommendations, contact Fleetguard's Service Engineering department at 1–800–22FILTER.

Natural Gas (NG)

WARNING

Compressed natural gas is normally treated with an odor producing chemical so that

users will be able to smell gas leaks. Always be alert for the smell of gas. If you enter a room or approach a vehicle and a smell of gas is present, immediately shut off all engines and ignition sources. Avoid sparks, arcing switches and equipment, cigarettes, pilot lights, flames, and other sources of ignition in the area and in areas with common ventilation. Provide extra ventilation to the area and do not start the equipment or nearby equipment until the leak is corrected and the area is ventilated. Avoid leaving natural gas fueled equipment in unventilated rooms overnight or for extended periods. Store and service natural gas fueled equipment in large well-ventilated areas or outside.

WARNING

If natural gas leaks are present, do not store the vehicle inside or in any area that is covered. Severe personal injury can result from asphyxiation or explosion.

WARNING

Natural gas is highly flammable. Keep all cigarettes, sparks, arcing switches and equipment, pilot lights, flames and other sources of ignition out of the work area and areas sharing ventilation.

WARNING

Do not troubleshoot or repair gas leaks while the engine is running.

CAUTION

Natural gas is lighter than air and can accumulate under the hood and awnings.

CAUTION

Always torque fasteners and fuel connections to the required specifications. Overtightening or under tightening can allow leakage. These connections are critical to the fuel and air systems.

CAUTION

Always test for fuel leaks as instructed, as odorant can fade.

CAUTION

Close the manual fuel valves prior to performing maintenance and repairs, and when

storing the vehicle inside.

Specifications

This section presents the specifications for natural gas engines.

Cummins spark-ignited engines that use natural gas as a fuel source provide a low emission alternative for various applications. In order for the engines to continually provide extremely low emission levels and provide the best durability and reliability, Cummins has developed several fuel standards. Cummins Engineering Standard (CES) 20067, Natural Gas Fuel; CES 14604, Natural Gas Fuel; and CES 14608 Wide Range Natural Gas Fuel define some of the natural gas specifications. Depending on the type of engine and application (automotive, industrial, or generator), refer to the appropriate engine's operation and maintenance manual for the correct fuel specification. Operators of Cummins natural gas engines should refer the standard or specification to the potential fuel suppliers and request confirmation as to local availability.

These specifications apply to fuel as it is delivered to the engine, regardless of whether its origin was liquid or gaseous. These specifications are **not** intended to cover certification requirements. Landfill gas and gas with chlorine additives are **not** permitted. The fuel **must not** contain water, dust, sand, dirt, oils, or any other substance or component in an amount that is detrimental to the operation of the engine. More specifications and test methods are detailed in these standards.

For CES 20067, the basic chemical composition is detailed in Table 6: CES 20067 Chemical Composition. The Wobbe index **must** be between 1300 and 1377 as measured by ASTM D 3588. The Wobbe index is a calculated value. Refer to CES 20067 for more information.

Table 6: CES 20067 Chemical Composition

Constituents	Requirements	Test Method
Methane (CH_4)	90.0 percent volume minimum	ASTM D 1945
Ethane (C_2H_6)	4.0 percent volume maximum	ASTM D 1945
Propane (C_3H_8)	1.7 percent volume maximum	ASTM D 1945
Butane and Heavier ($C_4H_{10}+$)	0.7 percent volume maximum	ASTM D 1945
Carbon Dioxide and Nitrogen ($CO_2 + N_2$)	3.0 percent volume maximum	ASTM D 1945
Hydrogen (H_2)	0.1 percent volume maximum	ASTM D 2650
Carbon Monoxide (CO)	0.1 percent volume maximum	ASTM D 2650
Oxygen (O_2)	0.5 percent volume maximum	ASTM D 1945
Sulfur (S)	0.001 percent weight maximum	Title 17 CCR Section 94112 Method 16

For CES 14604, the methane number based on SAE 922359 **must not** be below 80 and the higher heating

value **must not** be below 975 BTU/Standard Cubic Feet.

“Plus Technology” engines include knock sensing and control and Cummins' CORE hardware based control architecture (currently CM556B ECM). For approved ratings, CES 14608 can be used. The methane number based on SAE 922359 **must not** be below 65 and the lower heating value **must not** be below 18,800 BTU/lbm.

Contact your local Cummins Authorized Repair Location for information regarding calculating methane number, higher heating value, and lower heating values. The following is an example using CES 14604 to determine if the fuel is compliant.

Test Fuel Data Input (See Notes at Right) 6/20/02

Location (Description)		Cert. Fuel	
Methane	CH4	90.20	%
Ethane	C2H6	4.03	%
Propane	C3H8	1.76	%
Butane	C4H10	0.01	%
Pentane	C5H12	0.01	%
Hexane	C6H14	0.00	%
Heptane	C7H16	0.00	%
Octane	C8H18	0.00	%
Carbon Dioxide	CO2	0.00	%
Nitrogen	N2	3.99	%
Oxygen	O2	0.00	%
Sum of Components		100.00	%

NOTES:
1. Fuel requirements for automotive spark-ignited gas engines only.
2. Fuel as delivered to engine regardless if liquid or gaseous.
3. Maximum allowable sulfur content = 0.001% Weight.
4. Landfill gas and gas with chlorine additives are not permitted.
5. Fuel shall not contain water, dust, sand, dirt, oils or any substance that can harm engine operation.

Methane Number:	89.76	PASS	(Minimum Methane Number: 80)
Higher Heating Value (BTU/Std. Cu. Ft.):	1024.50	PASS	(Min. Higher Heating Value = 975 BTU/Std. Cu. Ft.)

NOTE: Both MN and HHV Criteria Must be Met to Pass a Given Fuel!

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Liquid natural gas (LNG) is an acceptable fuel provided the on-board fuel storage and supply system delivers proper pressure, temperature, and complete vaporization to the engine fuel system inlet.

Cummins natural gas engines are designed and adjusted to meet performance and emissions specifications with fuel meeting these specifications. The engine may operate on a wide range of fuel properties, but performance and emissions will be affected, and in extreme cases, fuel with characteristics out of these specifications can cause engine reliability or durability issues. Cummins assumes no responsibility for the use of fuels that do **not** meet this specification. Engine damage caused by fuel **not** meeting this specification is **not** covered under warranty.

Operators **must** be alert for sudden changes in engine operation, power levels, or pre-ignition. Each of these can be a sign of substandard fuel. If you suspect an issue related to fuel quality, ask your fuel supplier to sample and analyze the fuel in the vehicle, or contact your local Cummins Authorized Repair Location for assistance.

Fuel Filters

CAUTION

Gas is extremely flammable. Contents under pressure. Vent gas from the filter by opening the drain on the filter.

CAUTION

Overtightening will distort the filter cartridge, damage the filter seal, or crack the filter head. Do not use a filter element that has been dented or damaged prior to, or during, installation.

CAUTION

Oil getting inside of the gas mass flow sensor or on the screen pack will cause poor performance.

Fuel filters are required equipment on all Cummins natural gas engines. They are designed to remove oil and harmful particles from the fuel before they damage the fuel system or other engine components. These filters are a coalescent type filter that will capture oil contaminants and moisture typically found in natural gas.

Oil can be introduced into a natural gas engine's fuel system in several ways. The most common is from the fueling station compressor. The oil can also be present in the station tank from the refining process. Oil in the fuel will cause the gas mass flow sensor and the heated oxygen sensor to read incorrectly. Engine performance will be affected.

The fuel filter, Fleetguard® NG 5900, needs to be drained as part of the daily or refueling maintenance check. The interval period for draining the fuel filter is dependent on the fueling station and varies for each location. The drain interval should be adjusted to the time required to accumulate no more than 30 milliliters [1 ounce] of oil in the fuel filter or daily, whichever occurs first.

Refer to the engine operation and maintenance manual for fuel filter replacement intervals.

Liquefied Petroleum Gas (LPG)

WARNING

Liquefied Petroleum Gas (LPG) is normally treated with an odor producing chemical so that users will be able to smell gas leaks. Always be alert for the smell of gas. If you enter a room or approach a vehicle and a smell of gas is present, immediately shut off all engines and ignition sources. Avoid sparks, arcing switches and equipment, cigarettes, pilot lights, flames, and other sources of ignition in the area and in areas with common ventilation. Provide extra ventilation to the area and do not start the equipment or nearby equipment until the leak is corrected and the area is ventilated. Avoid leaving liquefied petroleum gas (LPG) fueled equipment in unventilated rooms overnight or for extended periods. Store and service liquefied petroleum gas (LPG) fueled equipment in large well-ventilated areas or outside.

WARNING

Do not troubleshoot or repair gas leaks while the engine is running.

CAUTION

Liquefied Petroleum Gas (LPG) is heavier than air and can accumulate near the floor, in sumps, and in low-lying areas.

CAUTION

Always torque fasteners and fuel connections to the required specifications. Overtightening or under tightening can allow leakage. These connections are critical to the fuel and air systems.

CAUTION

Always test for fuel leaks as instructed, as odorant can fade.

CAUTION

Close the manual fuel valves prior to performing maintenance and repairs and when storing the vehicle inside.

Specifications

This section presents the specifications for liquefied petroleum gas engines.

Liquefied Petroleum Gas (LPG) has been used as an engine fuel for many years. Modern technology and compliance with various emissions standards now mandate that certified engines be tuned to precise standards and operated on a more restrictive fuel specification for optimum performance and emissions control. Cummins Engineering Standard (CES) 20068 has been developed as a specification for liquefied petroleum gas (LPG) fueled engines. Depending on the type of engine and application (automotive, industrial, or generator), refer to the appropriate engine's operation and maintenance manual for the correct fuel specification. Operators of Cummins liquefied petroleum gas (LPG) engines **must** refer the standard/specification to the potential fuel suppliers and request confirmation as to local availability.

CES 20068 covers liquefied petroleum gas (LPG) fuel for use in automotive spark-ignited liquefied petroleum gas (LPG) engines. The requirements apply to fuel as it is delivered to the engine. This specification is **not** intended to cover certification requirements. The fuel **must not** contain water, dust, sand, dirt, oils, or any other substance or component in an amount that is detrimental to the operation of the engine. More specifications and testing methods are detailed in the standard.

Basic chemical composition is detailed in Table 7: CES 20068 Chemical Composition.

Table 7: CES 20068 Chemical Composition

Constituents	Requirements	Test Method
Propane (C_3H_8)	90.0 percent volume minimum	ASTM D 2163
Propylene (C_3H_6)	5.0 percent volume maximum	ASTM D 2163

Butane and Heavier (C_4H_{10}+)	2.5 percent volume maximum	ASTM D 2163
Hydrogen Sulfide (H_2S)	Pass	ASTM D 2420
Sulfur (S)	123 ppmw	ASTM D 2784
Oxygen (O_2)	0.5 percent weight maximum	ASTM D 1945
Carbon Dioxide and Nitrogen ($CO_2 + N_2$)	3.0 percent volume maximum	ASTM D 1945

Cummins liquefied petroleum gas (LPG) engines are designed and adjusted to meet performance and emissions specifications with fuel meeting these specifications. The engine can possibly operate on a wide range of fuel properties, but performance and emissions will be affected, and in extreme cases, fuel with characteristics out of these specifications can cause engine reliability or durability issues. Cummins assumes no responsibility for the use of fuels that do **not** meet this specification. Engine damage caused by fuel **not** meeting this specification is **not** covered under warranty.

Operators **must** be alert for sudden changes in engine operation, power levels, or pre-ignition. Each of these can be a sign of substandard fuel. If you suspect an issue related to fuel quality, ask your fuel supplier to sample and analyze the fuel in the vehicle, or contact your local Cummins Authorized Repair Location for assistance.

Fuel Filters

CAUTION

Gas is extremely flammable. Contents are under pressure. Vent gas from the filter by opening the drain on the filter.

CAUTION

Overtightening will distort the filter cartridge, damage the filter seal, or crack the filter head. Do not use a filter element that has been dented or damaged prior to, or during, installation.

CAUTION

Oil getting inside of the gas mass flow sensor or on the screen pack will cause poor performance.

Fuel filters are required equipment on all Cummins natural gas engines. They are designed to remove oil and harmful particles from the fuel before they damage the fuel system or other engine components.

Oil can be introduced to a liquefied petroleum gas (LPG) engine's fuel system in several ways. The most common is from the fueling station compressor. Oil in the fuel will cause the gas mass flow sensor and the heated oxygen sensor to read incorrectly. Engine performance will be affected.

The fuel filter, Fleetguard® NG5900, needs to be drained as part of the daily or refueling maintenance checks. The interval period for draining the fuel filter is dependent on the fueling station and varies for each location. The drain interval should be adjusted to the time required to accumulate no more than 30 milliliters

[1 ounce] of oil in the fuel filter or daily, whichever occurs first.

A liquid magnetic in-line filter is required on the liquefied petroleum gas (LPG) fueled engines between the liquefied petroleum gas (LPG) fuel tank(s) and the fuel inlet on the engine. The liquid magnetic in-line filter is **not** Cummins supplied and has a 5–micron requirement.

Refer to the engine operation and maintenance manual for fuel filter replacement intervals.

Fuel Supply Hoses

The vehicle supply hose to the engine **must** be approved for use with liquid phase propane (CGA Type III Approved). Engine damage, service issues, or performance issues that occur due to the use of other products are **not** considered a defect in workmanship or material as supplied by Cummins Inc. and can **not** be compensated under the Cummins warranty.

Last Modified: 23-Apr-2003