CUMMINS FUEL THOUGHTS --- November 2007

NOTE: sections on Natural Gas, re-circulating fuel warmers and most cautions and warnings have been removed--Refer to Cummins QSOL for complete text

Service Bulletin Number Date
3379001-13 31-OCT-2007
Design Application Market Application – All Applications

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.

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

CAUTION
Engines equipped with exhaust aftertreatment must operate on ultra-low sulfur diesel (ULSD), with a maximum sulfur content of 15 ppm in the US and Canada, and 10 ppm in Europe. Failure to do so will result in damage to the aftertreatment system.

Required Diesel Fuel Specifications

This section presents the Cummins Inc. required fuel specifications.

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 will 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 4.1 centistokes 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 5000 ppm. Other regional regulations may apply.

In the US and Canada, 2007 and later on-highway engines require the use of ULSD (15 ppm maximum). 1

Active Sulfur Copper Strip Corrosion not to exceed Number 3 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 [59°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 2
Distillation The distillation curve must be smooth and continuous
Lubricity HFRR 0.52 mm maximum: Wear Scar Diameter (WSD) at 60°C [140°F] HFRR

Regional, national, or international regulations can require a lower sulfur content than 5000 ppm. Consult all applicable regulations before selecting a fuel for a given engine application. Fuel with sulfur higher than 5000 ppm is not allowed without Cummins Inc. prior approval. 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 meet proper flash point requirements to satisfy local safety regulations.
For vehicles equipped with exhaust aftertreatment, there shall be no detectable ash in the fuel.
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 can 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 aftertreatment devices. Higher sulfur fuel also needs higher total base number (TBN) lubricants to compensate for acid corrosion.
Test Method - ASTM D2622, ISO 4260
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
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 commonly found in almost all petroleum products 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)

Ultra-Low Sulfur Diesel

Ultra-low sulfur diesel (ULSD) fuel is defined as diesel fuel not exceeding 0.0015 mass percent (15 ppm) sulfur content. The following Cummins® engines are required to operate on ULSD.

2007 and later on-highway engines in the United States and Canada equipped with exhaust aftertreatment devices.

Engines operating where regional, national, or international regulations require the use of ULSD in diesel engines.

The use of ULSD is essential for lowering exhaust emissions, protecting the environment, and for proper functionality of modern exhaust aftertreatment devices. The low sulfur content does slightly change some of the fuel properties. However, transitioning from low sulfur diesel (LSD), which can contain up to 500 ppm sulfur, to ULSD can go smoothly if, a few precautions are taken, such as:

Properly label all fuel tanks and delivery pumps.
Be sure the fuel lubricity meets the Cummins® Required Diesel Fuel Specifications outlined in Table 1 of this bulletin.
ULSD has lower lubricity than LSD, so lubricity additives need to be added by the fuel supplier to prevent fuel system damage. More information on fuel additives can be found in the "Additives" section of this service bulletin.
Be sure that fuel tanks are completely empty before transitioning from LSD to ULSD, and consider tank cleaning.
It takes only a small amount of LSD blended with ULSD to bring the fuel sulfur content above 15 ppm.
Consider using a stability additive for fuel in bulk storage.
ULSD is more prone to oxidation than LSD. Consult your fuel supplier to determine if an additive is needed to maintain fuel quality in storage tanks.
Closely monitor fuel system for leaks, especially when first transitioning to ULSD, and correct them immediately.
ULSD reacts differently than LSD with certain seal and gasket compounds commonly found in fuel systems, which means that leaks are more likely to occur, especially in older engines which were designed to run on LSD.

Contingency Diesel Fuel Specifications

This section presents the specifications for fuels which are only to be used when fuel meeting the required specifications is not available. In the case that fuels meeting the Required Specifications in Table 1 are not available, Cummins Inc. 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

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 the 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.
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.
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. Go to the section in this bulletin on fuel additives. Consult Cummins Inc. 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 the 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 at 40°C [104°F]
Cetane Number 35 minimum above 0°C [32°F]; 40 minimum below 0°C [32°F]
Sulfur Content Less than 2.0 mass-percent (20,000 ppm). Catalyst equipped engines will 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 rating after 3 hours at 50°C [122°F]
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 6°C [10°F] below lowest ambient temperature at which the fuel is expected to operate
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

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 5000 ppm requires the use of higher total base number (TBN) lubricants (TBN greater than 10) and shorter oil drain intervals.

CAUTION

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, go 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 can operate at the pour point. In fact, it is recommended that systems be operated at 5.5°C to 8°C [10°F to 15°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, go 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.

Marine Distillate Oils

Cummins Inc. requires that diesel fuel meeting the specifications in Table 1 of this service bulletin be used in Cummins® Marine engines. However, the possibility exists that fuel of this quality may not be readily available in certain marine markets. The International Standards Organization (ISO) has defined specifications for fuels called Marine Distillate Oils (MDO's), including distillate fuels in category ISO-F. This category consists of four distinct fuels; DMX, DMA, DMB, and DMC. The characteristics of these fuels are presented in Table 3.

Cummins Inc. **does not recommend the use of fuels meeting the specifications in Table 3**, because some characteristics of these fuels do not meet the required diesel fuel specifications in Table 1. However, DMX, DMA, and DMB do meet the contingency fuels specifications listed in Table 2 and can be used as such. Additionally in some areas (such as the European Union Territory) the sulfur content has been limited to 0.2 mass percent (2000 ppm) or less for all category ISO-F fuels. Therefore, some low sulfur DMX and DMA fuels may meet the required diesel fuel specifications and would be acceptable for use in Cummins® Marine engines. Low sulfur marine fuel is not available in all markets. It is the user's responsibility to select the correct fuel.

Warranty and the use of Marine Distillate Oils in Cummins® Engines

Cummins Inc. engine warranty covers failures that are a result of defects in material or factory workmanship. Engine damage, service issues, and/or performance issues determined by Cummins Inc. to be caused by the use of MDO fuel are not considered to be defects in material or workmanship, and are not covered under Cummins Inc. engine warranty.

Table 3: Marine Fuel Characteristics

Characteristics Limit Category ISO-F Test Method Reference
DMX DMA DMB DMC
Appearance Visual - - - - - -
Density at 15°C, kg/m 3 Maximum (1) 890 900 920 ISO 3675 or ISO 12185
Viscosity at 40°C, centistokes Minimum 1.40 1.50 - - - - - - ISO 3104
Maximum 5.50 6.00 11.0 14.0 ISO 3104
Flash Point, °C Minimum 43 60 60 60 ISO 2719
Pour Point (upper), °C (2)
Winter quality Maximum - - - -6 0 0 ISO 3016
Summer quality Maximum - - - 0 6 6 ISO 3016
Cloud Point, °C Maximum -16 (4) - - - - - - - - - ISO 3015
Sulfur, mass % (3) Maximum 1.0 1.5 2.0 2.0 ISO 8754

Cetane Number Minimum 45 40 35 - - - ISO 5165
Carbon Residue (micro method), mass %
10% (volume) distillation, bottoms Maximum 0.30 0.30 - - - - - - ISO 10370
Carbon Residue (micro method), mass % Maximum - - - - - - 0.30 2.50 ISO 10370
Ash, mass % Maximum 0.01 0.01 0.01 0.05 ISO 6245
Sediment, mass % Maximum - - - - - - 0.07 - - - ISO 3735
Total Existent Sediment, mass % Maximum - - - - - - - - - 0.10 ISO 10307-1
Water, volume % Maximum - - - - - - 0.3 0.3 ISO 14597
Vanadium, mg/kg Maximum - - - - - - - - - 100 ISO 14597
Aluminum plus silicon, mg/kg Maximum - - - - - - - - - 25 ISO 10478
In some geographical areas, there may be a maximum density limit.

Purchasers recommended to make sure that this pour point is suitable for the equipment on board, especially if the vessel operates in both the northern and southern hemispheres.

1.0 mass percent = 10,000 ppm.

This fuel is suitable for use without heating at ambient temperatures down to -15°C.

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.

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 the 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 shutdown. 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 Inc. 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.

Fuel Blending

This section presents the effects of blending fuels with used and new lube oil, other fuels, and with gasoline, gasohol, or alcohol. Biodiesel fuel blends are discussed in a separate section of this service bulletin.

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
Never 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. Additional oil blending restrictions are outlined in this section.

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 the 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.

CAUTION
Blending fuel with lubricating oil is not allowed for Cummins® Midrange and Heavy Duty engines equipped with exhaust aftertreatment. Oil blending on these engines will result in engine damage and possibly cause higher emission levels.

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 Inc. provides the following guidelines for blending lubricating oil with fuel:

Engines required to use ultra-low sulfur diesel fuel (15 ppm sulfur maximum) **are not allowed** to blend used lubricating oil with diesel.
Midrange and Heavy Duty engines (displacements up to 18L) **are not allowed** to blend used lubricating oil with diesel fuel if the engine is equipped with an exhaust aftertreatment device, such as an oxidation catalyst, diesel particulate filter, or SCR system.
High Horsepower engines (displacements of 18L or larger) equipped with high pressure common rail fuel systems **are allowed** to blend used lubricating oil with diesel fuel up to a maximum volume-concentration of 0.5 percent using the Centinel™ system, regardless of the presence of an exhaust aftertreatment system.
All other Cummins® engines which do not fall in to the above categories **are allowed** to blend used lubricating oil with diesel fuel up to a maximum volume-concentration of 5 percent.

The blending of new lubricating oil to raise viscosity is also permissible, and is subject to the same restrictions previously mentioned. This helps to increase the viscosity of lighter fuels to acceptable levels. However, if the blended fuel used in motor vehicles for on-highway applications (as defined by the EPA) 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 Inc. recommends the use of a premium diesel fuel during winter (ambient conditions at -7°C [20°F] or below) operating conditions. Blended fuel must meet the requirements of Table 1. See the Additives section in this service bulletin.

In cold-weather operation, the most common method of preventing fuel waxing problems is to dilute heavier, higher wax content fuels such as diesel number 2 (D2) fuel with lighter, lower wax content fuels such as diesel number 1 (D1) 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 [5.4 to 12.6°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
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 Inc. 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 material or workmanship as supplied by Cummins Inc. and can not be compensated under the Cummins® warranty.

Additives

This section gives information on the use of fuel additives in Cummins® engines, including 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 material or workmanship as supplied by Cummins Inc. and can not be compensated under the Cummins® warranty.

Fuel Additives

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

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

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

A cetane improver additive can be used with low cetane fuels.
A pour point depressant or flow improver additive can help with high pour point fuels.
A wax crystal modifier can help with fuels with high cold filter plugging points (CFPP).
An anti-icer can help prevent ice formation in wet fuel during cold weather.
An anti-oxidant or storage stability additive can help with fuel system deposits and poor storage stability.
A lubricity enhancer can be used to increase the lubricity of fuels so that they meet the requirements given in Table 1.
A biocide or fungicide can help when fuels are prone to contamination with bacteria or fungus. Although other additives can provide some performance benefits, Cummins Filtration™ Microbicide (quart - CC2661 and gallon - CC2663) are the only products approved by Cummins Inc. to treat fuels with biological contamination problems.
Cummins® Filtration 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 will boost the cetane number, Cummins® Filtration All Season Fuel Additive is the only diesel fuel additive approved by Cummins Inc. for cetane number improvement.
Cummins Filtration™ Asphaltene Conditioner Base (pint - CC2598, quart - CC2597, 5 gallons - CC2549, and 55 gallons - CC2550) and Asphaltene Conditioner Concentrate (2.5 gallons - CC2596, Bulk - CC2559) or Cummins Filtration™ Turbocharger 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 can provide some performance benefits, Cummins Filtration™ Asphaltene Conditioner, and Turbo Diesel All Season Fuel Additive are the only diesel fuel additives approved by Cummins Inc. for use with fuels that do not meet the lubricity specification in Table 1.
Cummins Filtration™n Winter Conditioner Base (pint - CC2591, quart - CC2592, 5 gallons - CC2593, 55 gallons - CC2594, and Bulk - CC2590), Winter Conditioner Concentrate (5 gallons - CC2552, 55 gallons - CC2553, and Bulk - CC2554), and Turbocharger 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 can provide some winter performance benefits, Cummins Filtration™ Winter Conditioner and Turbo Diesel All Season Fuel Additive are the only diesel fuel additives approved by Cummins Inc. for winter performance improvements.
Cummins Filtration™ Platinum Plus DFX Fuel Borne Catalyst can be used to enhance fuel economy and improve the performance of Diesel Oxidation Catalyst and Catalyzed Wire Mesh Filters. Additionally, Platinum Plus DFX lowers the temperature at which soot captured in emission control systems will oxidize. Platinum Plus DFX is available in various package sizes (gallons - CC2767, 5 gallons - CC2766, and 55 gallons - CC2771). Cummins Filtration™ Platinum Plus DFX-DPF Fuel Borne Catalyst (gallons - CC2773, and 5 gallons - CC2772) can be used with passive regenerated, high efficiency wall flow Diesel Particulate Filter systems. It is specially formulated to enhance fuel economy, reduce Diesel Particulate Filter regeneration temperatures, and further reduce particulate matter. Although other additives are available that can provide some performance benefits, Cummins Filtration™ Platinum Plus DFX and Platinum Plus DFX-DPF Fuel Borne Catalyst are the only diesel fuel additives approved by Cummins Inc. for use in reducing regeneration temperatures and/or reducing particulate matter.

Cummins Filtration™ offers lubricity enhancing fuel filters that can improve the lubricity of fuels that fall below the recommended lubricity specification given in Table 1. The following filters

are required by Cummins Inc. when the corresponding engine is operated using low lubricity fuels such as Jet A or JP8.
Filter Fuel System Compatibility Engine Compatibility
FS20000 Rotary Fuel Systems B Series - Tier II Industrial
FS20022 Common Rail B Series - Tier III Industrial and Marine
FS20023 Common Rail C and L Series - Tier III Industrial

If deposits are found in critical components of the fuel system, and an engine meets three or more of the following conditions, a fuel detergent additive is required to improve the dispersancy of the fuel.
The engine is used in a hybrid power train.
The average vehicle speed is 11 km/hr [7 mi/hr] or less.
The engine exhaust is equipped with a diesel particulate filter.
The fuel used is 50 percent, or more, diesel number 1 (D1).
Premium diesel fuels can possibly contain several additives that can accomplish the same as buying additives and adding them to lower quality diesel fuel.

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

CAUTION
Over use of fuel additives can cause adverse effects such as fuel filter plugging and reduced aftertreatment life.

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 approved. Consult your fuel supplier for guidance on additive use.

Water-Emulsions

Fuel Characteristics - Water-emulsified diesel fuel is an alternative fuel that is made by blending water and other additives (e.g. detergents) into diesel fuel.

Emissions - Water-emulsified diesel fuels have been verified by EPA and some state agencies as an emissions reduction technology.

Cummins Inc. does not certify engines with water-emulsified fuels. Cummins Inc. does not warranty any emissions improvements with the use of water-emulsified fuels.

Performance Issues - Water emulsified fuels have lower energy content than Number 2 diesel fuel. Customers must expect at least a 15 percent power reduction and a 15 percent fuel consumption increase when water-emulsified fuels are used. Because of the lower energy

content in water-emulsified diesel fuels, engines running on water-emulsified diesel fuels can require idle governor adjustments to prevent engine stalling.

Durability Issues - Many fuel system components in Cummins® engines are made of materials that are susceptible to corrosion from water in fuel. Prolonged exposure to water in fuel can result in fuel system component failures from corrosion.

Vehicle System Issues - Some water-emulsified diesel fuel suppliers recommend the removal of the fuel water separator from the vehicle's fuel system. Removal of the fuel-water separator violates Cummins Inc. engine installation requirements.

Since water is a significant component of water-emulsified diesel fuels, conductivity sensors that detect water in fuel will not function properly with water-emulsified diesel fuels.

Some water-emulsified diesel fuels use a surfactant in the emulsifier. Surfactants can strip the fuel tank and fuel lines of deposits, resulting in fuel filter plugging. Fuel filters must be monitored closely during the initial use of water-emulsified diesel fuels.

Water-emulsified diesel fuels can not remain static for more than a month in storage or in vehicle fuel tanks. Most water-emulsified diesel fuel storage facilities are required to have circulation pumps for daily or weekly agitation. Engines operating on water-emulsified diesel fuel must be operating for at least 15 minutes every 30 days to avoid fuel-water separation in the vehicle fuel tank and in the engine fuel system.

Cummins Inc. Engine Warranty - Cummins Inc. engine warranty covers failures that are a result of defects in material or factory workmanship. Engine damage, service issues, and/or performance issues determined by Cummins Inc. to be caused by the use of water-emulsified diesel fuel are not considered to be defects in material or workmanship and are not covered under Cummins Inc. engine warranty.

Some water-emulsified fuel suppliers provide a comprehensive warranty for fuel system failures caused by the use of water-emulsified diesel fuel. Customers are encouraged to contact the water-emulsified diesel fuel supplier to determine the warranty provisions.

Biodiesel Fuel

Cummins Inc. certifies its engines using the prescribed EPA and European Certification Fuels. Cummins Inc. 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, EPA allows only registered fuels and fuel additives to be entered into commerce. EPA has additional alternative fuel information at:

http://www.epa.gov/otaq/consumer/fuels/altfuels/altfuels.htm

Biodiesel Terminology

Biofuels - Fuels produced from renewable resources.
Biodiesel - A fuel comprised of methyl or ethyl ester-based oxygenates of long chain fatty acids derived from the transesterification of vegetable oils, animal fats, and cooking oils. These fuels are commonly known as Fatty Acid Methyl Esters (FAME) or Fatty Acid Ethyl

Esters (FAEE). Biodiesel properties are similar to those of diesel fuel, as opposed to gasoline or gaseous fuels, and thus are capable of being used in compression ignition engines.
B100 - A fuel containing 100 percent biodiesel.
Petrodiesel - Diesel fuel produced purely from petroleum. Petrodiesel can also be referred to as distillate diesel.
Biodiesel Blend - A fuel comprised of a mixture of petrodiesel and B100 biodiesel. A biodiesel blend is typically designated by the percentage of biodiesel in the blend. For example: B5 is a fuel containing 95 percent petrodiesel and 5 percent B100.
Rapeseed Methyl Ester (RME) diesel - Biodiesel derived from rapeseed oil. RME diesel is the most common biodiesel used in Europe.
Soy Methyl Ester (SME or SOME) diesel - Biodiesel derived from soybean oil. SME diesel is the most common biodiesel used in the United States.
BQ-9000 - The National Biodiesel Accreditation Program, which is called BQ-9000, is a cooperative and voluntary program for the accreditation of producers and marketers of biodiesel fuel. The program is a unique combination of the ASTM standard for biodiesel, ASTM D6751, and a quality systems program that includes storage, sampling, testing, blending, shipping, distribution, and fuel management practices.
With increased interest in emissions and reducing the use of petroleum distillate based fuels, many governments and regulating bodies encourage the use of biofuels, such as biodiesel.

Cummins Inc. test data on the operating effects of biodiesel fuels indicates that typically smoke, power, and fuel economy are all reduced. There are specifications for biodiesel issued in Europe under EN14214 and in North America under ASTM D6751. These specifications define only the biodiesel (B100) used as the blend component with diesel fuel. They are not applicable to fuel blends purchased by the end user. Despite the existence of these standards, the general quality of available biodiesel remains inconsistent.

CAUTION
To successfully use biodiesel, it is imperative that the fuel be of high quality and meet or exceed the specifications outlined in this bulletin or engine damage will occur.

It is the responsibility of the user to verify/obtain the proper local, regional, or national exemptions required for the use of biodiesel in any emissions regulated Cummins® engine.

Warranty and the Use of Biodiesel Fuel in Cummins® Engines

Cummins Inc. engine warranty covers failures that are a result of defects in material or factory workmanship. Engine damage, service issues, and/or performance issues determined by Cummins Inc. to be caused by the use of biodiesel fuel not meeting the specifications outlined in this Service Bulletin are not considered to be defects in material or workmanship and are not covered under Cummins Inc. engine warranty.

Requirements for Using Biodiesel Fuel in Cummins® Engines

Cummins Inc. provides the specifications found in Table 1 for diesel fuel and biodiesel blends up to B5. For biodiesel blends above B5 and up to B20, Cummins Inc. provides the specifications found in Table 4. The specifications in Table 4 have been developed by the Engine Manufacturers Association (EMA), and are not an approved national or commercial fuel standard. All biodiesel fuel blends are to be comprised of petrodiesel meeting ASTM D975, and B100 meeting either ASTM D6751 or EN14214.

Biodiesel fuel can be blended with an acceptable diesel fuel up to 5 percent volume-concentration (B5) for all Cummins® engines.

Biodiesel fuel can be blended with an acceptable diesel fuel up to a 20 percent volume concentration (B20) for the following Cummins® engines:

ISB CM850, ISB CM2150*, ISBe Euro 3, QSB4.5 Tier 3, and QSB6.7 Tier 3.

ISC/ISL CM850, ISC/ISL CM2150*, ISCe/ISLe Euro 3, and QSC/QSL Tier 3.

ISM CM870 and CM570, ISM CM875, ISM CM876, QSM11 Tier 3, QSM11 Marine, and QSM11 G-Drive.

ISX CM870, ISX CM871, QSX15 Tier 3, and QSX15 G-Drive.

*For ISB CM2150 and ISC/ISL CM2150 products, Cummins Inc. requires fuel dilution monitoring. See below for details.

For Cummins® engines in Chrysler Dodge Ram™ trucks, biodiesel fuel can be blended with an acceptable diesel fuel up to a 20 percent volume concentration (B20) for municipal, government, and commercial fleets only. This applies to selected model year vehicles. Please consult Chrysler for specific requirements and approved vehicle models.

Customers choosing to run biodiesel blends above B5 and up to B20 must adhere to the following requirements from Cummins Inc.

NOTE: For North American markets, Cummins Inc. requires that the biodiesel fuel blend be purchased from a BQ-9000 Certified Marketer. The B100 biodiesel fuel used in the blend must be sourced from a BQ-9000 Accredited Producer. Certified Marketers and Producers can be found at the following website: http://www.bq-9000.org. For areas outside of North America, consult your local Cummins Inc. representative for applicable fuel quality standards.

Oil Sampling

Fuel dilution of lubricating oil has been observed with the operation of biodiesel under certain operating conditions. Fuel dilution monitoring can be accomplished by performing oil sampling. Fuel levels in lubricating oil must not exceed 5 percent. Additional information on oil contamination and oil sampling can be found in Cummins® Engine Oil Recommendations, Bulletin 3810340.

For ISB CM2150 and ISC/ISL CM2150 products, end users are required to use oil sampling during the first 6 months of operation with biodiesel to monitor engine oil condition and fuel dilution of lubricating oil in order to determine if the oil change interval needs to be modified. Consult a Cummins® Authorized Repair Location for guidance in oil sampling.

Fuel Water Separation

Biodiesel has a natural affinity to water, and water accelerates microbial growth. Storage tanks must be equipped with a fuel water separator to make sure that water is stripped out before entering the vehicle tank. Make sure that the vehicle and storage tanks are kept full to reduce the potential for condensation accumulating in the fuel tank.

Due to the solvent nature of biodiesel, and the potential for “cleaning” of the vehicle fuel tank and lines, new fuel filters must be installed when switching to biodiesel on used engines. Fuel filters will need to be replaced at half the standard interval for the next two fuel filter changes.

Cummins Inc. requires the use of a StrataPore™ fuel filter media, and strongly recommends using Cummins Filtration™ filters equipped with StrataPore™ media. This filter media removes water more efficiently than standard cellulosic filter media, which will not provide adequate fuel water separation capabilities. However, even StrataPore™ fuel filter media is not as effective in removing water from biodiesel as it is in removing water from petrodiesel. Therefore, preventing water from entering the fuel supply (vehicle or storage) remains very important.
If Stratapore™ filter media is not available, a substitute synthetic filter media may be used, but it must provide 95 percent emulsified fuel water separation efficiency per SAE J1488. This test method must be run using B20 biodiesel, having an interfacial surface tension of 22 dyne/cm + or - 2 dyne/cm. The filter must meet this specification when run at the rated flow of the engine platform's fuel system. Fuel filter gaskets must also be compatible with B20 biodiesel blends, with performance equal to or greater than what is outlined in the Cummins Filtration™ Engineering Standard FES1544 - Seals, Static, Rubber (Supplier Requirements, Fuel Applications).
Cummins Filtration's™ Fuel Pro®, Diesel Pro®, Industrial Pro®, and Sea Pro® products can be used to provide remote mounted additional fuel filtration efficiency, with integrated fuel pre-heaters. Consult a local Cummins® Authorized Repair Location for guidance in fuel filter selection and installation.

Biodiesel Fuel Storage
Use biodiesel fuel within six months of its manufacture. Biodiesel has poor oxidation stability, which can result in long term storage problems. For this reason, Cummins Inc. does not recommend using biodiesel for low use applications, such as standby power or seasonal applications. Consult your fuel supplier for oxidation stability additives.
The poor oxidation stability qualities of biodiesel can accelerate fuel oxidation in the fuel system, especially at increased ambient temperatures.
CAUTION

Avoid storing equipment with biodiesel blends in the fuel system for more than three months or fuel system damage can occur.

If biodiesel is used for seasonal applications, the engine system must be purged before storage by running the engine on pure diesel fuel for a minimum of 30 minutes.
Care must also be taken when storing biodiesel in bulk storage tanks. All storage and handling systems must be properly cleaned and maintained. Steps must be taken to minimize moisture and microbial growth in storage tanks. Consult your fuel supplier for assistance in storing and handling biodiesel.
Energy Content

B100 biodiesel provides approximately 7% to 10% less energy per gallon of fuel when compared to conventional diesel fuels. Operation with B20 biodiesel blends can potentially result in a slight decrease in fuel economy and/or power, depending on the application. To avoid engine problems when the engine is converted back to 100 percent petrodiesel, do not change the engine rating to compensate for the potential power loss when operated with biodiesel fuels.

Materials Compatibility
The engines listed in this bulletin are compatible with biodiesel blends up to B20. However, the following must be taken into account:

Natural rubber, butyl rubber, and some types of nitrile rubber (depending on chemical composition, construction, and application) may be particularly susceptible to degradation. Also, copper, bronze, brass, tin, lead, and zinc can cause deposit formations. The use of these materials and coatings should be avoided for vehicle fuel tanks and fuel lines.

CAUTION
Contact your vehicle manufacturer to determine if any of the OEM supplied components are at risk with biodiesel in order to prevent engine damage.

Low Temperature Performance

Biodiesel fuel properties change at low ambient temperatures, which can pose problems for both storage and operation. Precautions can be necessary at low ambient temperatures, such as storing the fuel in a heated building or a heated storage tank, or using cold temperature additives.
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. A fuel heater is recommended for ambient temperatures below -5°C [23°F]. Consult your fuel and additive supplier for assistance in attaining proper cloud point fuel.
Microbial Growth

Biodiesel fuel is an excellent medium for microbial growth. Microbes cause fuel system corrosion and premature filter plugging. The effectiveness of all commercially available conventional anti-microbial additives, when used in biodiesel, is not known. Consult your fuel and additive supplier for assistance.
It is strongly recommended that customers running biodiesel blends of B5 or below follow the above precautions as well.

Biodiesel Additives

Cummins Inc. approves the use of Cummins Filtration™ Microbicide for use in biodiesel blends. Product details can be found in the “Additives” section of this Service Bulletin.
Cummins Inc. approves the use of Cummins Filtration™ Asphaltene Conditioner Base for biodiesel blends. Product details can be found in the “Additives” section of this Service Bulletin.
Cummins Filtration™ Biodiesel Winter Conditioner can be used to improve the pour point and cold filter plugging point of biodiesel blend, in addition to preventing ice formation in wet fuels during cold storage. Cummins Filtration™ Biodiesel Winter Conditioner is the only biodiesel fuel additive approved by Cummins Inc. for winter performance improvements. Contact a Cummins® Authorized Repair Location for product details.

Table 4: Final Blend Fuel Requirements (at point of delivery)

Item	Performance Characteristics	Requirements		Test Procedure
		D1 Blends	D2 Blends	
1	Flash Point, °C minimum	38	52	ASTM D93
2	Water and sediment volume %, maximum	0.05	0.05	ASTM D2709 or D1796
3	Physical Distillation, T90 °C, maximum	343	343	ASTM D86
4	Kinematic Viscosity, cSt at 40°C	1.3 - 4.1	1.9 - 4.1	ASTM D445
5	Ash, mass %, maximum	0.01	0.01	ASTM D482
6	Sulfur, st %, maximum	Per regulation	Per regulation	ASTM D482

7 Copper strip corrosion rating, maximum Number 3 Number 3 ASTM D130
8 Cetane Number, minimum 43 43 ASTM D613
9 Cloud Point 1 Per foot note Per foot note ASTM D2500
10 Ramsbottom carbon residue on 10% distillation residue, wt%, maximum 0.15 0.35 ASTM D524
11 Lubricity, HFRR at 60°C, micron, maximum 460 460 ASTM D6079
12 Acid number, mgKOH/g, maximum 0.3 0.3 ASTM D664
13 Phosphorus, wt%, maximum 0.001 0.001 ASTM D4951
14 Total Glycerin - - - - - - N/A
15 Alkali metals (Na+K), ppm, maximum Nd Nd EN14108
16 Alkaline metals (Mg+Ca), ppm maximum Nd Nd EN14108
17 Blend fraction, volume % 2 ±2% ±2% EN14078
18 Thermo - oxidative stability, insolubles, mg/100 mL, maximum 10 10 Modified ASTM D2274 3
19 Oxidation stability, Induction time, hours, minimum 6 6 EN14112 (Rancimat)

The maximum cloud point temperature shall be equal to or lower than the tenth percentile minimum ambient temperature in the geographical area and seasonal time frame as defined by ASTM D975.
Blend fraction refers to the variation in volume percent of B100 in diesel fuel claimed.
Use glass fiber filter.

Fuel Filters

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

Cummins® engines are supplied with the latest in fuel filtration technology from Cummins Filtration™. These systems are designed to remove water and other harmful particles from the fuel before they damage the fuel pump and other engine 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 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. This type of filter is often recommended or required for use as a first stage of filtration to provide additional water separation and/or fine particle removal.

Fuel-Water Separators

Water can enter diesel fuel at various locations along the supply chain, and becomes a serious issue when present as free water. It contributes to corrosion, biological contamination, and fuel system malfunctions. Entry points include:

As free water due to ingress as result of heavy rainfall or cracks in equipment
As dissolved (emulsified) water during fuel refining or delivery (this may become free water further down the supply chain if the fuel is cooled so much that it reaches a saturation point)
As water vapor (moist air) through vents followed by condensation on tank walls, including vehicle tanks.
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.

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 does remove some free and emulsified water, but with low efficiency. Due to the above facts and the importance of removing water from fuel for fuel system integrity, Cummins Inc. has increased the requirements for free water and emulsified water removal. 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 Cummins Filtration™ and most other major filter manufacturers meet or exceed these requirements.

Cummins Inc. recommends that a fuel-water separator be installed on all Cummins® engines, and strongly recommends using Cummins Filtration™ fuel-water separators that utilize Stratapore™ filter media. These StrataPore™ filters provide high efficiency removal of harmful particles and both free and emulsified water.

Fuel-water separators should be checked on a daily basis and drained into an appropriate disposal container when free water is noted. If water is indicated by a water-in-fuel (WIF) sensor, it should be drained immediately to prevent damage to the fuel system components. Water should not be allowed to fill the bowl.

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

CAUTION

If the water level in the fuel water separator is allowed to reach the fuel filter element, water can be forced through the filter and cause corrosion and failure of sensitive components in the fuel system.

Fuel Filter Maintenance

Fuel filters must be changed periodically to prevent restriction of fuel flow from the fuel tank to the fuel pump. Fuel restriction will increase over time as sediment gets collected in the filter media. Sediment could possibly consist of rust, dirt, dust, oxidation products, and biological growth.

Change fuel filters as recommended by the appropriate Cummins® Owner's Manual or Operation and Maintenance Manual. When operating under severe conditions, additional fuel filter changes can be required. To determine if this is necessary, fuel filter restriction must be checked. Refer to the appropriate Cummins® Service Manual for fuel filter restriction checking procedures. After checking the restriction a few times, a maintenance schedule for fuel filter changes can be established for each type of operation.

Fuel Cleanliness

This section explains the importance of fuel cleanliness to the successful operation of Cummins® Engines.

Modern fuel systems have been developed to reduce emissions and fuel consumption, and improve engine performance. These high pressure systems operate at pressures approaching 2100 bar [30,500 psi] and with component match clearances typically from 2 to 5 microns for injectors. At these pressures, very small, hard particles are potential sources of fuel system malfunction.

Excessive contamination of diesel fuel can cause premature clogging of diesel fuel filters and/or premature wear of critical fuel injection system parts. Depending on the size and nature of the particles, this can lead to:

Reduced component life
Component malfunction
Fuel system and/or engine failure
Increased exhaust emissions.
Determining fuel cleanliness requires measuring both the size and number of particles per size class in the fuel, i.e. the particle size distribution. The International Standards Organization (ISO) has developed a protocol for expressing the level of contamination by coding the size distribution called ISO 4406.

ISO 4406 cleanliness codes are expressed as a series of three numbers (#/#/#), which correspond respectively to the number of particles greater than 4, 6, and 14 microns. For example, the numbers in the ISO 4406 rating of 18/16/13 translate to:

18 - Up to 2,500 particles larger than 4µm (per mL of fuel)
16 - Up to 640 particles larger than 6µm (per mL of fuel)
13 - Up to 80 particles larger than 14µm (per mL of fuel)

Engine builders and fuel injection equipment manufacturers have found that the particles greater than 4 microns and greater than 6 microns are particularly critical to the durability of the fuel injection system. They also recognize that the fuel systems must be robust to hard particles smaller than 4 microns that are difficult to filter out, even with the finest filtration. To maximize the efficiency and effectiveness of filtration, Cummins Inc. has adopted the recommendation of the World Wide Fuel Charter that fuel supplied to engines meet the ISO 4406 code of 18/16/13 maximum for respectively 4, 6, and 14 micron particle sizes.

Cummins Inc. recommends that if the fuel does not meet the ISO cleanliness code of 18/16/13 in bulk storage, additional filtration be applied before the fuel is delivered to the equipment's fuel tank. A Cummins® Distributor or Cummins Filtration™ representative can supply hardware and additional filtration guidance and can recommend countermeasures such as improved fuel quality from the fuel supplier, and/or better fuel handling, storage, dispensing, and fuel tank cleaning techniques.

Tank Vent Filtration

Particles in the 4 to 6 micron size range require laboratory equipment to identify, yet can do significant damage to high pressure fuel systems when the cleanliness of the fuel in the tank exceeds the ISO 4406 code 18/16/13 maximum. Cummins Inc. recommends that all fuel tanks be fitted with a tank vent filter (of at least 98.7 percent efficient at 10 micron) to prevent dirt from entering the tank as the fuel level drops. One such filter is manufactured by Wiggins and is available through your Cummins® and Cummins Filtration™ Distributor.

Stand-by and Emergency Power Generation

Engines intended to supply stand-by or emergency power present unique situations for fuel quality and cleanliness. These engines are not used frequently, and therefore could possibly require special considerations for fuel handling and storage.

The engine manual discusses the specific procedures for maintaining the engine in a state of readiness. This section is concerned with the fuel supply.

Fuel tanks must be inspected and maintained to avoid contamination of the fuel by either water or dirt. Consult with your fuel supplier for qualified persons or laboratories in your area to help with monitoring of the fuel supply. Samples can be taken from the top, middle, and bottom of the tank every 6 months and checked for cleanliness and biological contamination, as well as to make sure the fuel still meets the specifications in Table 1 of this service bulletin.

Long term storage (in excess of 6 months) is not recommended unless the fuel has been stabilized by the fuel supplier and there is a monitoring program in place. Periodic testing of the engine is recommended to be performed frequently enough and long enough to make sure that the fuel supply is replenished and stays fresh.

Duplex Fuel Filtration Systems

Stand-by and emergency generators can be called upon to run for hundreds of hours in case of emergency. Such critical operations could possibly wish to install a duplex fuel filtration system. These systems allow rapid switching to fresh fuel filters. It is recommended that such service occur while the engine is shut down briefly. A Cummins® or Cummins Filtration™ Distributor can advise on the proper installation for a particular engine and location.

Fuel Tank Care and Maintenance

Tank cleaning is a major operation which requires complete draining of the tank, and should only be done by professionals. It is therefore carried out infrequently, normally on the schedule of several years coinciding with (statutory) inspection and maintenance requirements. Good housekeeping can help extend periods between tank cleanings.

Water bottom measurements can be made on an appropriate time interval (via automatic gauging or regular tank dipping with water finding paste) and water can be removed when necessary. This is important since any water and sediment can be stirred up when the tank is filled. Cummins Inc. recommends waiting a minimum of one hour per foot of fuel depth before dispensing fuel after a delivery. If water and sediment are observed, additional setting time is one way of bringing the fuel back into specification.

It is virtually impossible to stop water from entering the supply chain; therefore, good housekeeping is essential. Hardware, tanks, and pumping systems should be routinely inspected and maintained. Fuel should be checked periodically for contamination by water to ensure that there is no free water present in the fuel entering the engine, and dissolved (emulsified) water does not exceed 200 ppm.

Cummins Inc. recommends that if the fuel does not meet the ISO 4406 cleanliness code of 18/16/13 in bulk storage, additional filtration be applied before the fuel is delivered to the engine. A Cummins® or Cummins Filtration™ Distributor can supply hardware and additional filtration guidance.

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 the problem is understood, the less difficult the process of finding a solution becomes. Determining whether a low power complaint is due to fuel filter plugging 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, 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 D6371). The temperature at which fuel will no longer flow is the Pour Point (ASTM D97). At the pour point, most of the fuel is still liquid, although it is very thick or viscous and trapped in a honeycomb-like 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, filters, 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 with engine coolant temperature below the minimum specification found in the applicable engine Owner's Manual. This can result in fuel dilution of the lubricating oil, carbon build up in the cylinder, cylinder head valve sticking, and/or reduced performance.

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 additives will or will 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 can require fuel warmers in addition to additives. Although other additives are available that can provide some benefits, Cummins Filtration™'s Fleet-tech™ Winter Conditioner and Turbo Diesel All Season Fuel Additives are the only fuel additives recommended by Cummins Inc. 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 Cummins Filtration™ to raise the temperature of the inlet fuel.

Fuel Filter Heater - The Cummins Filtration™ 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 5).

Table 5: Fuel Filter Heaters

Watts	Cummins Filtration™ Part Number
300	3836029-S

A Cummins Filtration™ kit, Part Number 3837317-S, adapts the heater to most fuel filter heads with 1 in-14 threads. Use to the following fuel filter list to identify fuel filter heads with 1 in-14 threads. 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 Cummins Filtration™ kit, Part Number 3832054-S, adapts to FS-1251 filter.

Thermo-Blend™ - The Cummins Filtration™ 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 [109°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).
Thermo Blend FM, Part Number 3310630 - The Cummins Filtration™ Thermo Blend FM fuel warmer combines the return fuel heating principle with a special filter head. When used with Cummins® Part Number 3315843 (Cummins Filtration™ 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 Cummins® engines with the 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, [39 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]).

Cummins Filtration™ Winter Conditioner Base and Turbocharger Diesel All Season Fuel Additives are the only additives recommended by Cummins Inc. 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, rather than 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 micro-organisms. These micro-organisms, 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 micro-organisms begin to grow and reproduce. The rate of growth depends on how well the environment suits the particular micro-organism's needs.

The growth of a large colony of micro-organisms 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 micro-organisms can cause is corrosion due to the acid by-products some of them produce. It is also possible, if the micro-organisms 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:

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.
Black or brown "stringy" material suspended in tank water bottoms.
Swelling or blistering of any rubber surface (washers, hoses, connectors, and so forth) that comes in contact with fuel.
Sludge or slime deposits on filter surfaces.
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 micro-organisms 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 Inc. 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.

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 lntertech, Inc., P.O. Box 255, Bedford, MA 01730 U.S.A.
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 micro-organisms is not possible because these organisms can enter the fuel through many different routes.

Growth of these micro-organisms 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 micro-organisms will kill the micro-organisms, but it will not eliminate the filter plugging they can be causing. The water and sludge containing the micro-organisms 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 micro-organisms. Finally, the addition of a water-soluble or universally-soluble biocide can be continued for at least several months to be sure the micro-organisms 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 will 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 37

Fuel Discoloration (Black Fuel)

In some Cummins® engines, normal operation can cause the diesel fuel in the engine and fuel tank to appear dark or black in color. Discoloration of the fuel can be caused by either: engine lubricating oil mixing with the fuel during operation, the formation of asphaltenes, or the degradation of fuel from storage.

Mixing of engine lubricating oil

In some fuel systems, engine lubricating oil and diesel fuel are used in close proximity to each other for lubricating and sealing purposes. This interface is a function of fuel pump and/or injector design. Under certain operating conditions, a small amount of lubricating oil can mix with the diesel fuel and be returned to the tank, causing the fuel to appear dark in color. It takes a very small amount of lubricating oil (less than 0.1 percent) to cause the fuel to become visibly darkened. This small amount of oil in the fuel will have no adverse affects on engine performance, durability, reliability, or emission levels.

Asphaltene formation

This phenomenon is common for fuel systems that operate at very high fuel pressures and temperatures. The high temperature fuel that is not injected into a combustion cylinder is returned to the fuel tank. As the fuel is recirculated and exposed to the same high pressures

and temperatures during continuous operation, asphaltenes begin to form larger clusters of insoluble materials that can lead to fuel discoloration. If these formations of asphaltenes grow large enough, they will be captured by the filter element and can lead to high filter restriction and shortened filter life.

Asphaltene formation due to fuel overheating can be aggravated by a lack of fuel coolers, improperly sized fuel tanks, inadequate mixing of return fuel between tanks, low fuel levels, or installation of the fuel tank that prevents dissipation of heat. If an engine or fuel system cooling issue is suspected, the cooling systems must be inspected and modified as necessary to comply with Cummins® requirements. Existing fuel filters could possibly need to be resized or additional filtration could possibly need to be added to increase contaminant holding capacity. Consult a local Cummins® Authorized Repair Location for guidance in fuel filter selection and cooling system issues. Refer to the “Additives” section of this service bulletin for a listing of Cummins Filtration™ Asphaltene Conditioners.

Degradation of fuel from storage

Refer to the “Microbial Contamination of Diesel Fuel” section of this service bulletin.

Darkening of diesel fuel due to the mixing of lubricating oil or asphaltene formation does not indicate a manufacturing defect or other warrantable malfunction, and is a function of normal operation. Customers should continue using the equipment as is, unless the discoloration has resulted from fuel overheating, fuel contamination, or if fuel filter life is being reduced and causing operational difficulties with the equipment.