Biodiesel Fuel Management
Best Practices for Transit

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Public transportation systems play a key role throughout the country not only in providing vital services to citizens but also in the environmental quality of our communities. Transit systems nationwide are seeking out new technologies in order to increase US energy independence and reduce emissions by switching to biodiesel in diesel buses.

This report discusses the benefits and challenges to the transit industry of using biodiesel. It provides information on the characteristics of biodiesel and biodiesel blends and discusses best practices for the procurement, blending, storage and use of biodiesel.

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Abbreviations and Acronyms

ASTM	American Society for Testing and Materials
B100	100% biodiesel
B20	20% biodiesel, 80% petroleum diesel
B5	5% biodiesel, 95% home heating oil
BTU	British thermal unit
CFPP	Cold filter plugging point
CI	Compression ignition
CO	Carbon monoxide
CO_2	Carbon dioxide
DOE	United States Department of Energy
ECRA	Energy Conversation Reauthorization Act of 1998
EPA	United States Environmental Protection Agency
EPAct	Energy Policy Act of 1992
GVWR	Gross vehicle weight rating
HC	Hydrocarbon
MSDS	Material Safety Data Sheet
NBB	National Biodiesel Board
NORA	National Oil heat Research Alliance
NO_x	Nitrogen Oxide
NPAH	Nitrated polyaromatic hydrocarbons
NREL	National Renewable Energy Laboratory
OEM	Original Equipment Manufacturers
PM	Particulate matter
Ppm	Parts per million
SO_2	Sulfur dioxide
ULSD	Ultra low sulfur diesel
VOC	Volatile organic compound
BOL	Bill of lading
COA	Certificate of Analysis

Executive Summary

The demand for energy security and environmentally friendly public policy has grown in recent years. Consumers are seeking energy efficient products in all areas of American life from light bulbs to biofuels. Demand for these products continues to grow, as consumers increasingly recognize the impact our choices have on the environment. Security concerns arising from our dependence on foreign oil has further increased interest in domestic alternatives. These environmental and security factors have led to a period of extraordinary growth in the biodiesel industry.

Public transportation systems play a key role throughout the country in providing vital services to citizens and in the environmental quality of our communities. Transit systems nationwide are seeking out new technologies to reduce emission and increase energy efficiency. Because of the unique role of transit systems within our nationwide transportation system, their efforts provide a tremendous opportunity to explore new technologies and to disseminate information about improving air quality and reducing dependence on foreign oil. One option being tried by transit agencies is switching to biodiesel to fuel their diesel buses. Biodiesel has been used in city bus fleets in Cedar Rapids, Iowa; Cincinnati, Ohio; St. Louis, Missouri, and the list is growing.

This document seeks to explain the benefits and challenges of biodiesel. It provides those in the petroleum industry supply chain and those they serve with information ranging from storage to shipping of biodiesel fuels. It also discusses best practices that will help ensure the quality of the biodiesel product.

Biodiesel can have significant environmental benefits. Neat biodiesel (100% biodiesel) reduces carbon dioxide emissions by more than 75% over petroleum diesel. A blend of 20% biodiesel reduces carbon dioxide emissions by 15%.[1]

Use and handling of biodiesel is similar to petroleum diesel. It operates in conventional engines, typically without engine modifications, and it does not require substantial changes to fueling infrastructure. Biodiesel has similar properties to petroleum diesel and the two fuels can be, and often are, blended.

While the properties of biodiesel are similar to petroleum diesel, it is important to be aware of differences, and to use good management practices to ensure successful handling and operation when using biodiesel or blends. This handbook discusses the differences and explains how they should be managed. With the use of good management practices, biodiesel and biodiesel blends can contribute to our energy security, while reducing our impact on the environment.

[1] "Biodiesel Benefits." www.eere.energy.gov: Alternative Fuels Data Center.

Introduction

Crude oil, natural gas, refined products and petrochemicals are all sold in commodity markets. Commodities are mass-produced, unspecialized products that are highly fungible, having characteristics so similar that they are interchangeable. The "commodity" label often makes differentiating one product from another challenging. Differentiating between products is critical as the fuels industry moves towards alternative and enhanced products. As this shift occurs, both consumers and the petroleum industry will realize key differences and benefits.

Biodiesel is gaining popularity in America. It is a clean-burning, alternative fuel derived from domestic, renewable resources such as fats and oils. Biodiesel is made through a process called transesterfication. The process of converting vegetable oils or animal fats into biodiesel is a chemical reaction that uses an alcohol, such as methanol, and a catalyst, such as sodium hydroxide.

Biodiesel can be used as a replacement or supplement for petroleum-based heating oil and diesel fuel. Biodiesel does not require any special handling or storage facilities because it can be splash blended with heating oil and diesel fuel in any concentration. However, splash blending should eventually be transitioned to a more reliable electronically managed blending methodology to ensure optimum blending. (This will be addressed later in this manual.) The use of biodiesel, even at higher blends, does not necessarily require any major modifications to conventional vehicle or home heating oil systems. (Minor modifications might be required to ensure material compatibility.)

In its neat form, biodiesel offers significant environmental benefits. Biodiesel contains virtually no sulfur. Furthermore, according to a U.S. Environmental Protection Agency (EPA) report issued in October 2002, burning neat biodiesel (B100) reduces the emissions of particulate matter and carbon monoxide by almost 50% and unburned hydrocarbons by almost 70%. However, there is a slight increase in the nitrogen oxides (NOx) emissions, but blending reduces NOx emissions to a negligible amount. Research indicates that NOx emissions for B20 blends and lower in diesel engines may be the same or lower than that of petrodiesel alone, depending on the testing protocol and application. Further work is ongoing in this area. In open flame applications, where NOx results are more dependent upon fuel oxygen level rather than in-cylinder temperatures, B20 shows significant NOx reductions on the order of 10 to 20% according to testing done at Brookhaven National Laboratory while maintaining the reductions in other emissions normally observed in diesel engines.

Biodiesel has fully completed health effects testing requirements of the 1990 Federal Clean Air Act Amendments. Any product marketed as biodiesel must meet the high standard set by the ASTM.

Beyond environmental benefits, biodiesel is vital to maintaining America's national security and reducing this country's dependence on imported oil. The United States accounts for

approximately 24%[2] of world-wide petroleum consumed, according to the US Department of Energy. Continued dependence (58% in 2006 according to EIA) on imported oil in a volatile geopolitical environment has the potential to create an economic and security crisis. More efficient utilization of domestic surpluses of vegetable oils and waste fats, as well as the development of specialized crops, could reduce U.S. dependence on imported oil and increase national security.

Cost and availability has been most frequently cited as a barrier to widespread use of biodiesel. Biodiesel initially was not meant to compete with generic petroleum products such as diesel fuel and heating oil. It enabled petroleum companies to maintain market share with EPACT (Energy Policy Act of 1992) fleets that were transitioning to alternative fuels, such as compressed natural gas, to comply with government regulation. Biodiesel has made headway in new markets as an alternative and/or supplement to diesel and heating oil applications. This has caused the economics of these products to be weighed against one another. The biodiesel blenders' tax credit is also a key market driver since it provides biodiesel and petroleum handlers access to a credit for each gallon of biodiesel blended with on- and off-road diesel fuel as well as heating oil. Download the most recent copy of the U.S. Internal Revenue Service guidance document, which describes the program in detail at http://www.irs.gov/pub/irs-pdf/p510.pdf.

The IRS has published updated versions of Form 637 and Form 720. These forms are available by going to the Forms and Publications page of the IRS website, www.irs.gov. A direct link to that page is http://www.irs.gov/formspubs/lists/0,,id=97817,00.html.

Form 637 is the registration application that all biodiesel producers and blenders must complete. (Note: Becoming officially registered may take a considerable amount of time. Planning accordingly to meet the deadlines prescribed by the IRS is critical. For information about the registration process and timing, contact your local IRS field office.)

Form 720 is the Quarterly Federal Excise Tax Return. Entities utilize this form to report and pay federal excise tax.

The biodiesel industry could see significant growth over the next few years. Several factors such as the emergence of ultra low sulfur diesel (ULSD) regulations, the biodiesel mixture credit program and potential integration into the heating oil pool will be drivers to increased use of biodiesel. Technology will play a major role in lowering the cost of biodiesel production and finding alternative higher value uses for the primary byproduct, which is glycerin.

This guide has been developed for the petroleum industry supply chain and those that they serve, such as the transit industry. It will provide a broad range of information relating to liquid fuel storage, blending and shipping and field use of diesel fuel, biodiesel fuel and blends of both. Suggested quality practices will be discussed that will ensure a positive working experience for fleet managers nationwide. Because biodiesel will primarily be a blend stock for diesel fuel and heating oil we have included an equal amount of data on generic fuels and fuel additives. It is

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[2] July 2007 Monthly Energy Review. Energy Information Administration. http://www.eia.doe.gov. August 2007

imperative that sound housekeeping practices be incorporated and adhered to throughout the supply chain in order to achieve positive results with both middle distillates and biodiesel fuels.

General Fuel Management Practices

Fuel quality characteristics in the United States have undergone a number of changes that severely impact fuel suppliers' operations and profitability as well the fleet user's operational experience with the fuel. The most recent change impacting fuel quality has been the introduction of ultra low sulfur diesel fuel. Technology demands and processing changes have seriously impacted the use and storage of No. 1 and No. 2 fuels. Guidelines that have been in place for 50 years require fuels to pass a limited number of tests which are designed to measure fuel performance under controlled conditions with very tolerant engine and storage systems.

The limited number of tests that make up the specifications do not cover many physical properties severely impacting storage and operations today. This is evidenced by the Engine Manufacturers Association (EMA) pump grade specification. Emissions regulations are rapidly changing and will continue to drive changes in diesel fuel composition and specifications. Changes will include restrictions on certain fuel components, such as sulfurs and aromatics, which have an unfavorable effect on exhaust emissions. However, they do not currently address the negative impact on certain fuel characteristics, nor do they address the consequences that poor fuel quality and contaminants will have on new, sophisticated engine technologies.

This chapter includes a brief summary of contaminants and fuel components, which could potentially be present in your fuel. Additionally, an assessment of the causes and effects of poor fuel performance has also been included for your review.

Common Contaminants Found in Diesel Fuel

- Water
- Particulates (gums, dirt, fuel degradation material, sludge)
- Surfactants
- Microorganisms
- Peroxides

Entrained Water

One of the most favorable characteristics of middle distillates is its natural ability to shed water, thus preventing fuel/water emulsions. However, many diesel fuels have recently shown a disastrous tendency to absorb and hold large quantities of water. These fuel/water emulsions greatly reduce the effectiveness of fuel/water separators and can rapidly plug fuel filters. Typical causes of excessive entrained water levels include microbial activity, surfactants, alcohols, particulates, and poorly designed additives.

Free Water

Poor housekeeping is probably the largest contributor to the free water problem. Water enters bulk fuel tanks via condensation, carry-over from the fuel distribution system, and leakage through the fill cap, spill containment valve or piping. When water bottoms are allowed to build

up, significant quantities of water may be pumped into vehicle fuel tanks causing deleterious operational effects.

Moisture promotes microbial activity, fuel/water emulsions, rust, and corrosion. The more water is dispersed in fuel or in the fuel system, the greater the tendency for ice crystals to form and grow when the fuel temperature falls below the freezing point of water. Even in warm weather, water could lead to poor combustion. Even worse, it could contribute to injector failure.

Particulates

The most commonly recognized particulate contaminants found in diesel fuel are rust, dirt and sludge. However, both diesel and biodiesel fuels can form their own solid particulate contamination as they undergo complex chemical changes known as oxidation and polymerization. In addition to oxidation, certain microbes grow in fuel and the microbes' waste products contribute to the overall particulate contamination.

Particulates become trapped in filter surfaces, tank walls, and fuel lines. The result is shortened fuel filter life, dirty fuel tanks, clogged lines and plugged screens. Recently, many fleets have seen fuel filters plugged with "black goop," which can be caused by the particulates that are filtered out of the fuel as they oxidize. The fuel filter may not trap finer particulates, which will cause fuel system wear. This might include injector spray hole erosion; plunger damage and premature fuel pump wear. Issues such as nozzle, filter and strainer plugging can result in unscheduled service call for home heating systems.

Surfactants

Surfactants are substances that reduce the surface tensions of fuel/water and thereby promote fuel/water emulsions. These surface-active compounds come from various sources, including refinery treatment chemicals, naturally occurring materials not removed from the crude oil, pickup from other products in the distribution system, poorly formulated additives, lube oil blended into the fuel, and even microorganisms.

Fleet operators need to pay attention to surfactants because they are instrumental in causing slow water settling in fuel storage tanks. Operators should work to prevent the coalescing of water by fuel/water separators. Surfactants will also disperse microorganisms, rust, dirt and water throughout the fuel system. Certain types of surfactants actually cause fuel filter restriction by giving the fuel an electrical charge.

Microbial Contamination

The most common means by which microbes enter the fuel system is through air drawn into the tank as fuel is dispensed or used. Other sources of contamination may include ground water encroachment, portable fuel transfer piping or hoses, or through the fuel delivery process.

Bacteria and fungi form biomass as they reproduce, which may accumulate at any place in the fuel system where microscopic droplets of water exist. Common points of accumulation are the fuel/water interfaces, tank surfaces and filters. Metabolic waste and dead cells accumulate and

they settle out as sludge. Particulates will be drawn out with diesel fuel if sufficient sludge builds up. That can cause the filters and orifices to clog. Filter and line plugging results more often from biofilm formation on transfer line walls and filter surfaces.

Reduced filter life often goes unrecognized in many operations where chronic microbial contamination goes undetected. The problem's existence is often only recognized after biomass is inhibited and the consequent longer filter life is achieved. Occasionally catastrophic failures, such as engine shut down due to fuel starvation, provide convincing evidence of the importance of microbial contamination control.

One of the more sinister aspects of the filter-plugging problem is that often the biofilm is nearly transparent and goes unnoticed. Microbial induced corrosion can severely damage main storage tanks, vehicle tanks and fuel lines. This is usually noticed when catastrophic failures occur.

Engine wear is another effect of flow restriction. Non-uniform flow causes variation in combustion within cylinders, increased piston wear rates and increased torque on camshafts all translating to higher maintenance costs. ULSD will have most of the natural microbial inhibitors removed by the hydro processing needed to get to 15 ppm sulfur. This will allow microbes to thrive at an accelerated rate compared to today's fuels. Biodiesel, like ULSD, also is virtually sulfur free which makes it an equal candidate for microbial contamination if systems are not regularly maintained.

Poor housekeeping starts the microbial process. Petroleum handlers need to implement a thoughtful storage tank management program to reduce exposure to this challenging fuel quality issue.

Peroxides

The refining process used to produce low sulfur fuel can lead to unexpected consequences. The increased tendency for some severely hydro treated fuels to form high peroxide levels is an area of significant concern. These levels can be high enough as to be incompatible to fuel system components. Peroxide formation in severely hydro treated aviation fuel has been recognized for some years. There have been field experiences of fuel system elastomers hardening and cracking from exposure to high peroxide levels in aviation fuel. This has led to the specification for limiting peroxides in some military fuels and requirements for the addition of anti-oxidants if the fuel contains hydro treated components.

Initial research compiled by Advanced Fuel Solutions found that a large number of low sulfur diesel fuels may have had a tendency to form high levels of peroxides which would necessitate attention. In fact, it was suggested that high peroxide levels could damage fuel system components. Ongoing evaluation by a national chemical manufacturer validated it is not UNLESS the fuel is stored for a longer than normal period of time (>6 weeks).

Fuel Economy

Diesel fuel is one of the top three expenses for a fleet, and today's fleet managers are under greater financial pressure then ever before to reduce fuel costs. Fuel economy becomes more important as the price of fuel

goes up. Crude oil was trading between $70 - $75 per barrel when this report was written, a significant milestone in energy prices which is why fleets are using detergent packages to arrest operational degradation caused by poorly performing fuel injectors. This strategy may help maintain fuel economy through optimization of combustion.

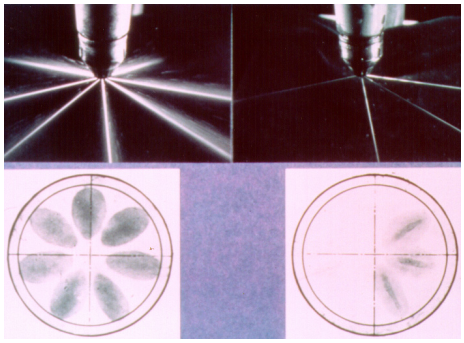
Engine deposits are formed in the combustion chamber as a by-product of combustion. Small amounts of deposits can degrade the spray pattern, which is vital for maximum combustion efficiency. Diesel detergents, at the correct treat rate, can help remove existing deposits and prevent new deposits from forming. The net benefits are in the return of lost fuel economy and power, and lower emissions.

Primary Function of Diesel Detergents

According to Cummins, preventing formation of, and removing existing, deposits (coking) caused by fuel recombination/decomposition results in optimal fuel spray pattern being maintained (as demonstrated in the Cummins L-10 IDT and numerous other engine depositing tests.) Other tests are being evaluated, but the measure of heavy duty performance remains the L-10.

Benefits of detergent packages include:

- Better fuel economy.
- Better bottom line.
- Reduced wear in the upper cylinder.
- Reduction/prevention of ring deposits.
- Restoration of horse power/torque.
- Reduction of combustion noise.
- Reduction of emissions and black smoke.
- Reduced maintenance of injector system and extended vehicle life.



EMA Recommended Premium Fuel Properties

Joint EMA/TMC Pump Grade Specification for Premium Diesel Fuel specification

The Engine Manufacturers Association has made very clear statements on the type of fuel quality they desire for optimum performance. Additives can help to economically achieve those specifications. The complete text and additional information on this specification can be found at www.enginemanufacturers.org. Please see *Appendix 2* for EMA Consensus Position.

Fuel Stability

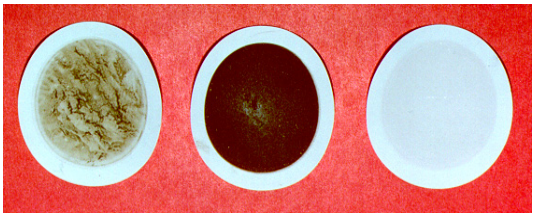
Today's commercially available fuel can deteriorate through oxidation and complex chemical changes between hydrocarbons and various organic compounds naturally present in fuel.

Fuel composition, environmental factors and time directly influence the rate at which these processes proceed. Diesel fuel is increasingly being used as a coolant for high-pressure fuel injection systems, which can thermally stress the fuel. Thermal stress is often responsible for fuel

degradation and the formation of sediments, which can cause fuel flow to be restricted through filters and injection systems.

The sediments are products of the complex chemical changes between oxygen, hydrocarbons and other organic compounds. These products can cause fuel system damage and performance deterioration in the field. This might include, for example, deposit formation on the injectors and in the combustion chamber and filter plugging. Accelerated Stability (ASTM D6468, Octel F21) is a test method that determines the relative instability of a fuel subjected to a thermal degradation process. The significance of the test lies in the fact that a similar environment is created as the fuel used to cool the injectors returns "hot" to the fuel tank. This test is currently one of the test methods specified by the NCWM for defining a "Premium Diesel Fuel."

In the test, the fuel is passed through a filter pad to trap any solid material that might already be present in the fuel prior to heating. The fuel is then subjected to a heating process that accelerates chemical reactions naturally occurring in unstable fuels. The newly created fuel degradation by-products, in the form of insoluble gums and solid particulate matter, are then trapped as the fuel is passed through another clean filter pad.



The pads are evaluated using a photometer's percent reflectance. The lower the percent reflectance, the heavier and larger the deposits. For proper performance, a fuel should not have a percent reflectance less than 80% after aging for three hours at a temperature of 302° F (150° C). In biodiesel, fuel aging and oxidation can lead to high acid numbers, high viscosity, and the formation of gums and sediments that clog filters.

Lubricity in Today's Fuels

Lubricity is described by the ability of a fluid to minimize friction between – and minimize damage to – surfaces in relative motion under loaded conditions. Diesel fuel injection equipment relies on the lubricating properties of diesel fuel. Shortened life of engine components such as fuel injection pumps and unit injectors can usually be attributed to very low fuel lubricity.

Today's on road diesel fuel encounters increasingly deeper hydrodesulfurization in order to meet lower sulfur targets. The hydro treating and hydro cracking processes remove naturally occurring polar fuel components that afforded relatively effective protection. The transition to ULSD fuel in 2006 made these problems worse as it relates to lubricity. Resolving lubricity deficiencies can be achieved by using, a 1% to 2% blend of biodiesel or using one of the widely available commercial lubricity additives.

A lubricity improver or low blends of biodiesel will restore the boundary lubrication between metallic parts in critical fuel system components by forming a protective layer on the metal surfaces. Lubricity is currently measured in the lab with a High Frequency Reciprocating Rig

(HFRR). HFRR became the ASTM standard to measure fuel lubricity in all fuels once the January 1, 2005 specification took effect. The fuel must meet a wear scar of 520 mm.

Low Temperature Operability

Cold weather continues to present challenges for diesel operability. Part of the solution to achieve winter operability has been a diesel user's reliance on a combination of kerosene blending and commercially available fuel additives. Before the transition to ULSD the rule of thumb had been that for every 10% of kerosene blended with generic diesel fuel a gain of 1° F to 3° F drop in the operability value would be achieved. Today ULSK does not perform as well to help improve the winter operability of diesel fuels. ULSK like ULSD undergoes the same refining processing to reduce the sulfur to <15 ppm levels making both diesel and kerosene a challenge to optimize for winter operability conditions while continuing to suffer from historical supply and economic volatility, fuel economy penalties and challenged lubricity levels.

Kerosene blending has additional operational concerns making it less desirable than other commercially available options. Increased cost differentials between diesel and kerosene pricing as well unpredictable availability makes kerosene a volatile cold flow reduction strategy during winter months. Decreases in fuel economy noted with kerosene blending are also a noted downside to winter blending that fleets have dealt with for decades, which is the opposite of the benefits of using a proven commercially available winter fuel cold flow additive to achieve cold weather operational goals.

Cold flow additives have proven to be more cost effective in optimizing winter performance when compared to blending with kerosene and likely will not be subjected to the volatile pricing and supply concerns associated with kerosene. Seasonal winter diesel additives properly administered at the wholesale fuel rack level contain advanced chemical wax modifiers and de-icing compounds designed to provide reliable winter operability without compromising fuel economy. Many fleets that attempt to use additives in the downstream, however, are challenged to administer them in a cost effective manner due to the lack of automated injection systems. These type of additives need to be proportionally blended and added to the fuel before the fuel meets it's posted cloud point or they will be unreliable.

Nucleation technology, advanced copolymers, and wax anti-settling additives are only a few of the solutions you may choose from to address cold flow challenges. Additionally, cold flow chemistry can be adjusted through injection system optimization to gain enhanced winter performance in your specified region of the nation. The latest in technology combined with laboratory services is the trouble-free way to assure:

- Reliable operation of equipment.
- Proper engine power and fuel efficiency.
- Lower fuel costs.

ULSD fuel has proved to be a challenge at the fleet level due to its increased levels of wax concentration as well as the speed with which the wax precipitates from the diesel fuel. This has created a greater demand for new cold flow improver technologies, which national chemical manufacturers continue to improve upon, in this second year of ULSD availability. It is imperative that fleet managers get the most reliable data on the cold flow properties of their generic diesel fuel before beginning to blend their biodiesel stock.

It is highly recommended to challenge your present and future additive counselors on the performance of the chemistry which they offer. The best recommendation one could make to an interested fleet manager seeking guidance on optimizing the fleet to perform in cold weather is to secure a few quarts of generic fuel or if biodiesel blends are to be used, a finished sample of the appropriate blend. Ask your additive representative to submit both a small sample of the proposed formula following the recommendations and run several of the following tests to see for yourself what the performance of these elixirs are before submitting your equipment to a field test.

Suggested Low Temperature Operability Tests

These tests were developed to help determine when a fuel would no longer be operationally acceptable for certain applications. The main concern for diesel users is the Cold Filter Plugging Point test and Low Temperature Flow Test. Both tests can help determine the lowest temperature at which a diesel vehicle could operate.

Cold Filter Plugging Point ºC (CFPP) D6371, I.P. 309)

This ASTM test method is used to predict the low temperature operability limits of a fuel. The test is used to determine the temperature at which wax crystals precipitate out of a diesel fuel and plug equipment filters. This information is used to determine the temperatures (above the CFPP) at which a fuel is expected to give trouble free flow within a fuel system.

Low Temperature Flow Test (ASTM D4539)

The Filterability of Diesel Fuels by Low-Temperature Flow Test (LTFT) estimates the filterability of diesel fuels in some automotive equipment at low temperatures. At temperatures below the LTFT, operability problems may begin to develop.

Biodiesel Basics

Biodiesel is an alternative fuel product that is manufactured from vegetable oils, recycled cooking greases, or animal fats. This alternative fuel product is created through a unique manufacturing process, which converts the oils and fats to long chain mono alkyl esters. The resulting product, B100, must adhere to the requirements of latest revision of ASTM D6751, which at time of this publication's release is ASTM D 6751-07a.

Biodiesel is legally registered as a fuel and fuel additive with the United States Environmental Protection Agency (EPA) and is a legal fuel for commerce. The EPA registration is not dependent on the feedstock and includes biodiesel made from most animal fats, vegetable oils, and greases. Raw or refined vegetable oil, or recycled grasses that have not undergone the conversion to biodiesel ARE NOT BIODIESEL, and should not be used as such. Biodiesel is the only alternative fuel that has complied with a four-year, $2.2 million health effects testing regimen required by Section 211(b) of the 1990 Clean Air Act Amendments.

Biodiesel is a very versatile fuel that can be used as a substitute or additive for many petroleum-based products. Biodiesel and/or biodiesel blends have been proven effective as lubricity additives and for use in home heating systems, automotive engines, and other equipment designed to use diesel fuel. Biodiesel has many advantages as an alternative fuel:

Advantages of Biodiesel

- Renewable
- Energy efficient
- Positive environmental characteristics: nontoxic, biodegradable, suitable for environmentally sensitive areas
- Interchangeable in most diesel equipment (minor adjustments may be necessary)
- Global warming emission reductions (CO_2, SO_2, CO, HC, and soot)
- Domestically produced from agricultural or recycled resources
- Easy handling
- Variety of applications (blend stock for diesel fuel, heating oil, etc.)
- Easy to transition in and out without presenting disruption to your operations.

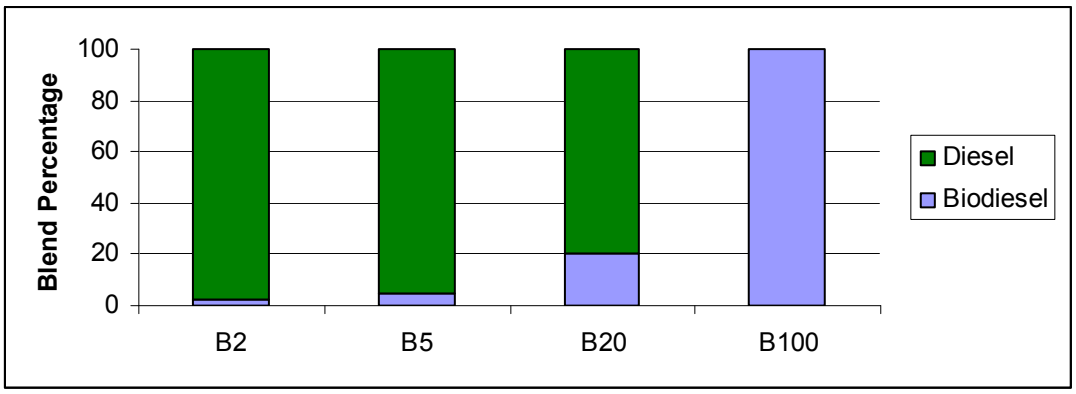
Blend Name: (Bxx) vs. % Biodiesel

Biodiesel can be used in its pure form (B100) or as a blend (Bxx) with traditional petroleum products. The blend is identified using B followed by the percentage of biodiesel in the finished product. Common blends include B2, a 2% biodiesel blend, which is often used for added lubricity; and B20, a 20% biodiesel blend, which is the minimum blend level that can be used by fleets covered by the Energy Policy Act of 1992. B20 is popular because of its balance of cost, cold weather performance, materials compatibility, and solvency issues.

The National Oil heat Research Alliance (NORA) has embraced a 2% to 5% blend of biodiesel over the next three years into conventional home heating oil following four-and-a-half years of technical review. Testing has been done on blends up to 20% with positive environmental and operational results. The industry is more receptive to lower blends due to fuel economics, supply

capabilities and neat biodiesel solvency at least until more technical data can be amassed to address these issues.

Figure 1: Biodiesel Blends by Percentage



Pure Biodiesel (B100) can be used as a blending agent or as a pure fuel in diesel applications. B100 has the following key physical properties:

- It contains less than 15 ppm sulfur.
- It contains no aromatics.
- It has a high cetane level (47+).
- It is biodegradable.
- It is non-toxic.
- It has a high flashpoint (higher than 260° F).
- It has a comparable BTU value (8% less than No. 2 diesel).

B100 used as either a blending agent or as a pure fuel must meet the requirements as listed by ASTM D6751-07a.

Table 1: Requirements for Biodiesel Blend Stock as Listed in ASTM D6751-07a

Property	ASTM Method	Limits	Units
Flash Point	D93	130.0 min.	Degrees C
Water and Sediment	D2709	0.050 max	% vol.
KinematicViscosity,40C	D445	1.9 - 6.0	mm2/sec.
Sulfated Ash	D874	0.020 max.	% mass
Sulfur (S 15 grade)	D5453	0.0015 max.	ppm
Sulfur (S 500 grade)	D5453	0.05 max.	ppm
Copper Strip Corrosion	D130	No. 3 max.	ppm
Cetane	D613	47 min.	
Cloud Point	D2500	Report Customer	Degrees C
*Carbon Residue	D4530*	0.050 max.	% mass
Acid Number	D664	0.50 max.	mg KOH/gm
Free Glycerin	D6584	0.020 max.	% mass
Total Glycerin	D6584	0.240 max.	% mass
Phosphorus Content	D4951	10 max	ppm
Distillation Temperature, Atmospheric Equivalent Temperature, 90% Recovered	D1160	360 max	Degrees C
Combined Na/K	EN 14538	5 ppm	ppm
Combined Ca/Mg	EN 14538	5 ppm	ppm
Oxidation Stability	EN 14112	3 min	hours
***Workmanship**	See below		

*Carbon residue, 100% of sample
*Workmanship, free of un-dissolved water, sediment & suspended matter
Bold criteria = BQ-9000 "Critical Specification Testing once production process under control.
Note: A considerable amount of experience with a B20 blend exists in the United States.

Although B100 can be used, blends higher than B20 should be evaluated on a case-by-case basis until further knowledge is available. Modifications of individual limiting requirements may be agreed upon between purchaser, seller and manufacturer to meet special operating conditions.

The above tests are based on the most recent revisions of ASTM D6751, D6751-07a at time of publishing this document, which ensures the quality of the biodiesel (B100) and its blends. Currently, the ASTM has no defined standards for the various biodiesel blends. However, it is expect that ASTM will have these standards in place in the near future. Please reference the ASTM website atwww.astm.org for updates to these standards.

Color and Odor

Biodiesel will not have one specific color or odor. Both these properties depend on a number of factors including the feedstock and manufacturing process. Therefore, biodiesel can meet ASTM D6751-07a and have a variety of odors and colors. Initiate a testing process if you are concerned that the fuel may not smell or look right. However, if there is a concern over color or odor, refer to *Table 2* for industry specifications to monitor.

Table 2: Key Fuel Specifications to Monitor

Fuel	Biodiesel	Petrodiesel
Standard	*ASTM D 6751-07a*	*ASTM D 975*
Specifications to Monitor	Flash Point	Cetane number/index
	Acid Number	Cloud Point
	Free glycerin	Pour Point
	Total glycerin	CFPP
	Water and Sediment	Water & Sediment
	Cloud Point	Sulfur
	Sodium & Potassium	Lubricity
	Oxidation Stability	

Biodiesel Energy Content

Biodiesel contains the highest British Thermal Unit (BTU) content of any alternative fuel. Biodiesel contains 8% less energy per gallon than No. 2 diesel and 12.5% less energy per pound. Unlike with diesel fuel, the composition, blending, and refining methods have no significant impact on the energy content of B100. Biodiesel made from most of the common feedstock will have the same impact on fuel economy power and torque. The difference in power, torque and fuel economy can be noticeable when using B100. As the proportion of biodiesel within the fuel blend is decreased (B20) these differences become less apparent. Specific BTU values can be found in *Table 3*.

Table 3: BTU Values

Fuel	Btu/lb	Btu/gal
#2 Diesel	18,300	129,050
Biodiesel (B100)	16,000	118,170

Cold Flow Properties

Table 4: Cold Flow Properties

B100 Fuel[3]	Cloud Point		Pour Point		Cold Filter Plug Point	
	F	C	F	C	F	C
Soy Methyl Ester	36	2	30	-1	28	-2
Canola Methyl Ester	27	-3	25	-4	25	-4
Lard Methyl Ester	57	14	52	11	52	11
Edible Tallow Methyl Ester	68	20	55	13	57	14
Inedible Tallow Methyl Ester	73	23	46	8	50	10
Yellow Grease 1 Methyl Ester	108	42	54	12	52	11
Yellow Grease 2 Methyl Ester	46	8	46	8	34	1

B100 should be stored at temperatures at least 15° F higher than the cloud point. Generally, storage temperatures of 45° F to 50° F are acceptable for most B100. However, some B100 fuels may require higher storage temperatures. These temperature requirements make most underground storage facilities adequate, but aboveground fuel systems should be protected with insulation, agitation, heating systems or other methods depending on the climate. These precautions should also be taken with piping, tanks, pumping equipment, vehicles or any other equipment, vehicles or any other equipment used for the transport or storage of the fuel.

Commercially available cold flow additives have had negligible effect on biodiesel produced in the United States. The effectiveness of the additives varies greatly depending on the type of biodiesel and the processing that it has undergone. The cold flow additives currently in commercial use have been used much more successfully with biodiesel blends. For further information review the additive section of this manual or contact your incumbent additive counselor for guidance on additive applicability for your specific blend.

Cetane Number

All B100 fuels meeting the ASTM D6751-07a standard must have a cetane number above 47. Therefore, biodiesel has a higher cetane number than most U.S. diesel fuel, which will provide easier starting, quieter operation, and a more complete burn resulting in lower emissions.

Stability[4]

Degradation of biodiesel follows two main chemical processes; hydrolysis and oxidation. Hydrolytic instability is a result of exposure of the biodiesel to water, which may increase the acidity of the biofuel which directly increases the rate of degradation of the biodiesel. The second driver of instability is oxidative instability which is a result of both the biodiesel and petroleum diesel being exposed to atmospheric oxygen which results in formation of peroxides.

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[3] Handling and Use Document, 2nd Addition, Department of Energy/DOE/GO-102006-2288, March 2006, page 18.

[4] Biodiesel Market Concerns and Solutions, PLMR 2007-01 Issue 2, 4/2007, Innospec Fuel Specialties, Littleton, CO.

These peroxides undergo subsequent transformation to produce alcohols, aldehydes, ketones, and carboxylic acids. This transformation then becomes the catalyst to form gums and polymers which can be detrimental to engine components. The final driver in fuel instability is thermal instability; generally biofuels in the absence of oxygen and water are thermally stable. However prolonged storage at elevated temperatures can cause an increase in rates of other degradation processes (Microbial, Hydrolytic, and Oxidative) and results in enhanced instability.

Short-term storage (one to four months) of B100 has been very successful with little or no stability problems. The ASTM D4625 data suggests that biodiesel can be stored safely for eight months to a year depending on the type of fuel and the stability of that fuel.. Any fuel stored for more than six months may warrant the use of antioxidants and should be tested periodically for acid number, viscosity and sediments.

Today specific stabilizing additives are widely available that will address biodiesel instability. It is recommended that you contact your additive counselor for application recommendations.

Tips on Ensuring Biodiesel Stability[5]

- **Know the level of saturation of your biodiesel.** The lower the level of saturation the more likely the fuel will oxidize. Saturated fatty acids are stable, and each time the level of saturation decreases the stability of the fuel goes down by a factor of ten.
- **Do not store B100 in clear totes in the summer.** Heat and sunlight will accelerate the oxidation process.
- **Do not store B100 for long periods of time in systems containing reactive materials.** Certain metals such as copper, brass, bronze, lead, tin, and zinc will serve to accelerate the degradation process and form even higher levels of sediment than would be formed otherwise. Metal chelating additives may reduce the negative impact of the presence of these metals.
- **Know how your fuel is processed.** Bleaching, deodorizing or distilling oils and fats before or as a part of the biodiesel process can remove natural antioxidants, which will lessen fuel stability.
- **Keep oxygen away from fuel.** By limiting the fuel's exposure to oxygen the risk of fuel oxidation can be greatly reduced or eliminated. This will increase the storage life of the biodiesel.
- **Antioxidants protect stability.** Antioxidants, whether natural or incorporated as an additive can significantly increase the stability of biodiesel.
- **B100 Microbial Contamination.** Biocides are recommended for conventional and biodiesel fuels wherever biological growth in the fuel has been a problem. If biological contamination is a problem water and sediment contamination must be controlled.

[5] Tyson, Shaine. 2004 Biodiesel Handling and Use Guidelines. Department of Energy/NREL. DOE/GO 102004. September 2004: Page 21-23.

In some cases, the cleaning effect or solvency of B100 has been confused with gums and sediments that could form over time in storage as fuel ages. Tests of the acid number and the viscosity should be performed to determine the cause of the sediment. If these numbers are within ASTM specifications the sediment is most likely the result of the solvency of B100.[6]

B100 Solvency

Biodiesel is comprised of methyl esters. Methyl esters are mild solvents and have been used as low volatile organic compound cleaners for years. Thus, B100 may dissolve the accumulated sediments in diesel storage and engine fuel tanks. Dissolved sediments can plug fuel filters and cause fuel injector failure. Therefore, if biodiesel will be used or stored, the following considerations should be made:[7]

1. Carefully **clean the tanks and fuel system** where any sediments or deposits may exist. Petroleum handlers should be evaluating bulk storage tanks regardless of possible biodiesel storage and distribution to ensure fuel quality preservation of conventional distillates is maintained.
2. Be prepared for the possibility of some **filter clogging** and more **frequent filter changes** until the system has been cleaned of old sediments. Once the system is cleaned the filter change interval should return to normal intervals.
3. **Wipe biodiesel spills** from painted surfaces immediately as it will dissolve some paints.

These effects are greatly reduced or eliminated in blends of 20% or less. (B20, B5, B2, etc.) B20 filter changes happen in 2% of cases when first starting up, B2 has seen no changes to filter performance. For those petroleum organizations planning on using an older diesel fuel or heating oil tank with years of accumulated sediment (tank bottoms) it is highly recommended to clean bottoms before introducing neat biodiesel.

B100 Material Compatibility[8]

B100 may degrade some hoses, gaskets, seals, elastomers, glues and plastics with prolonged exposure. Natural or nitrile rubber compounds, polypropylene, polyvinyl, and Tygon materials are particularly vulnerable. More testing is being done to extend this list of vulnerable materials. Most elastomers used after 1993 and are compatible with B100 (Viton/Teflon.) Contact the equipment vendor to determine compatibility with fatty acid methyl esters before handling or using neat biodiesel (B100.).

Biodiesel blends of 20% or less have shown a much smaller effect on these materials. The effects are virtually non-existent in low-level blends such as B2. Normal monitoring of hoses and gaskets for leaks is sufficient when handing blends of B20.

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6 Tyson, Shaine. 2004 Biodiesel Handling and Use Guidelines. Department of Energy/NREL. DOE/GO 102004. September 2004: Page 25

7 "Biodiesel Myths and Facts." National Biodiesel Board: www.biodiesel.org, 2001

8 "B100 Material Compatibility." National Biodiesel Board: www.biodiesel.org, December 1997.

Teflon, Viton, and Nylon have very little reaction to biodiesel and are among the materials that can be used to update incompatible equipment. B100 suppliers and equipment vendors should be consulted to ensure the most recent findings on compatibility. It is highly recommended that bulk biodiesel fuel handlers speak with hose suppliers to source hoses that are compatible with neat biodiesel.

Most tanks designed to store diesel fuel will be adequate for storing B100. Acceptable storage tank materials include aluminum, steel, fluorinated polyethylene, fluorinated polypropylene, Teflon, and most fiberglasses.

Brass bronze, copper, lead, tin, and zinc may catalyze the oxidation process of biodiesel creating fuel-insoluble gels and salts. Lead solders and zinc linings should be avoided, as should copper pipes, brass regulators, and copper fittings. Affected equipment should be replaced with stainless steel, carbon steel, or aluminum. **Blends of B20 and lower reduce the impact of material compatibility issues.** (For a more comprehensive list of materials visit www.biodiesel.org, click fuel facts, click materials of construction).

Underwriters Laboratory and other certification organizations are currently evaluating biodiesel material compatibility. Please reference UL's website for up-to-date list of approved products, http://www.ul.com/

Table 5: Summary of Hardness and Swell Characteristics

Material	Effect of Biodiesel
Teflon	Little change
Nylon 6/6	Little change
Nitrile	Hardness reduced 20%
	Swell increased 18%
Viton A401-C	Little change
Viton GFLT	Little change
Fluorosilicon	Little change in hardness
	Swell increased 7%
Polyurethane	Little change in hardness
	Swell increased 6%
Polypropylene	Hardness reduced 10%
	Swell increased 8-15%

Enhanced Lubricity[9]

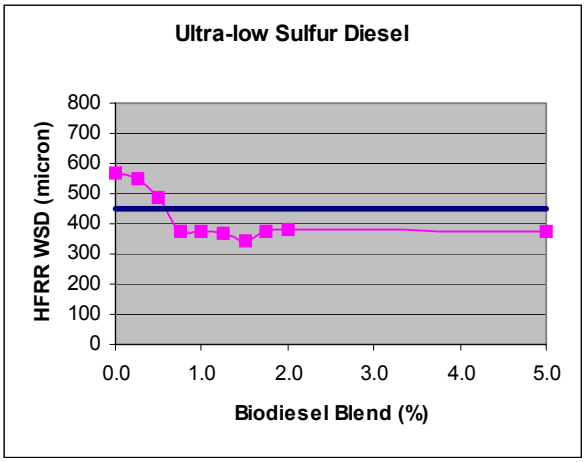
Historic Data on Lubricity

Lubricity describes how a fuel lubricates the fuel system and engine. Enhanced lubricity benefits equipment and will lead to fewer system problems and longer equipment life.

[9] Howell, Steve. MARC-IV LLC. "Lubricity Test at William Pipeline Laboratory." 1999

Traditionally diesel fuel was lubricated primarily with sulfur. However, the combustion of sulfur leads to sulfur dioxide – the primary component of acid rain. This environmental concern led policymakers to require sulfur reductions in diesel fuel by 2006.

Figure 2: Lubricity of ULSD/Biodiesel Blends



Historic lubricity testing has demonstrated that biodiesel is extremely effective in increasing the lubricity in diesel fuel. Blends containing less than 1% biodiesel have shown significant increases in fuel lubricity. B2 has been shown to have up to 66% more lubricity than No. 2 diesel fuel. These graphs depict the lubricity effects of biodiesel on various pilot batches of ultra low sulfur diesels. **Blends of 2% biodiesel have been proven adequate in most cases.**

Current Lubricity Testing

Existing information on biodiesel impact with ULSD is very positive, even with the poorest quality fuels. The NBB is conducting a survey of current market ULSD (fall of 2007) with a wide variety of ultra low sulfur diesel fuels. That survey is still in progress at the time of the this report but preliminary results show similar lubricity improvements as was demonstrated previously: The addition of 2% biodiesel to any diesel fuel appears sufficient to bring even the poorest lubricity diesel fuel into stringent Fuel Injection Equipment manufacturers recommendations.

Cold Weather Performance

Biodiesel cold weather properties require careful attention when dealing with the product in cold climates. It is extremely important to be familiar with the cold weather properties of both biodiesel and the generic diesel intended for blending before handling the fuels.

Blends of biodiesel will impact cold weather operability in direct relationship to the independent base analysis of the fuels being blended to create B2, B5 and B20. Therefore, the cold filter plugging point, cloud point and pour point of both D975 and ASTM D6751-07a generic fuels requires the attention of the blender.

The same precautions taken with petrodiesel can be used to insure trouble-free operations with biodiesel. Traditional cold weather solutions for diesel work well with biodiesel except for commercial cold flow additives designed for conventional diesel. These solutions include kerosene blending, block and filter heaters and indoor garaging of vehicles when possible. Although some additive suppliers claim to have products that work with biodiesel, it is more likely that these products impact the generic diesel cold flow characteristics and not the neat biodiesel.

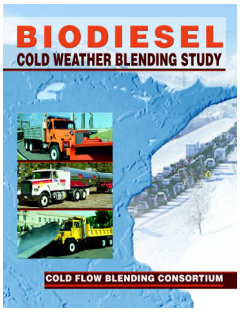
Terminal companies that are storing biodiesel in its neat form will need to heat their tanks, piping and associated delivery equipment to accommodate the pour point of biodiesel. The pour point varies by feedstock.[10] Today the most common biodiesel feedstock being used to manufacture ASTM D 6751 biodiesel has been soy which has a cloud point of 36° F and a pour point of 30° F. Keeping the biodiesel heated to 50° F to 60° F is recommended until it can be determined that it has been satisfactorily blended into the distillate product.

It is vital to adhere to the lowest operating temperature of the diesel fuel (CFPP or LTFT) prior to accepting blends of biodiesel. When compared to conventional diesel fuel, B20 could decrease operational temperatures by 7° F to 10° F. However, this value will be totally dependent on the biodiesel feedstock being used. As a user of diesel fuel and biodiesel blends you are ultimately responsible for advising your supplier what operability value you are seeking. For example, if you need to operate to -10F in January and February your supplier will need to ensure that the base diesel which is blended with biodiesel is a minimum of -20F before blending in the 20% biodiesel.

Anticipating that a temperature compromise of up to 10F is likely (with soy based biodiesel, more if tallow, grease or palm is used) you would then net down to -10F as a blended fuel. Your supplier will need to source the most desirable base stock (based on the fuels cold filter plugging point) blended with a combination of kerosene and a judicious dose of a competent and proven cold flow additive designed to reduce the generic fuel operability which will make room for the biodiesel percentage.

Biodiesel and Original Equipment Manufacturers (Warranties)

All diesel engine companies warranty the product they make - engines. They warranty their engines for "materials and workmanship." If there is a problem with an engine part or with engine operation due to an error in manufacturing or assembly within the prescribed warranty period, the problem will be covered by the engine company.



Typically, an engine company will define what fuel the engine was designed for and will recommend the use of that fuel to their customers in their owner's manuals.

Engine companies do not manufacture fuel or fuel components. Therefore, engine companies do not warranty fuel - whether that fuel is biodiesel or petrodiesel fuel. Since engine manufacturers warranty the materials and workmanship of their engines, they do not warranty fuel of any kind. If there are engine problems caused by a fuel (again, whether that fuel is petrodiesel fuel or biodiesel fuel) these problems are not related to the materials or workmanship of the engine, but are the responsibility of the fuel supplier and not the engine manufacturer. Any reputable fuel supplier (biodiesel, petrodiesel, or a blend of both) should stand behind its products and cover any fuel quality problems if they occur.

[10] Biodiesel Cold Weather Blending Study. Cold Flow Consortium, July 2005, page 19.

Therefore, the most important aspect regarding engine warranties and biodiesel is whether an engine manufacturer will void its parts and workmanship warranty when biodiesel is used, and whether the fuel producer or marketer will stand behind its fuels should problems occur.

Most major engine companies have stated formally that the use of blends up to B20 will not void their parts and workmanship warranties. This includes blends below 20% biodiesel, such as the 2% biodiesel blends that are becoming more common. Some engine companies have already specified that the biodiesel must meet ASTM D-6751 as a condition, while others are still in the process of adopting D-6751 within their company or have their own set of guidelines for biodiesel use that were developed prior to the approval of D-6751. It is anticipated that the entire industry will incorporate the ASTM biodiesel standard into their owner's manuals over time. Check with your engine manufacturer for their current warranty information. (Websites for some engine manufacturers are provide in Appendix 9.)

The National Biodiesel Board, the trade association for the biodiesel industry, has formed the National Biodiesel Accreditation Commission (NBAC) to audit fuel producers and marketers in order to improve the quality of biodiesel production and handling throughout marketing channels in the U.S. NBAC issues a 'Certified Biodiesel Marketer' seal of approval for biodiesel marketers that have met all requirements of fuel accreditation audits. The purpose of this seal of approval is to provide added assurance to customers, as well as engine manufacturers, that the biodiesel marketed by these companies meets the ASTM standards for biodiesel.

With biodiesel that meets the D-6751 specification, there have been over 50 million miles of real-world operation with B20 blends in a wide variety of engines, climates, and applications.[11] The steps taken by the biodiesel industry to work with the engine companies and to ensure that fuel meets the newly accepted ASTM standards provides confidence to users and engine manufacturers that their biodiesel experiences will be positive and trouble-free.

Taxes and Incentives

A number of tax incentive programs have been implemented which will benefit the biodiesel industry. The IRS has published on its website the various forms associated with the Volumetric "Blender" Tax Credit. Forms are available by going to the Forms and Publications page of the IRS website, www.irs.gov. A direct link to Form 637 is http://www.irs.gov/pub/irs-pdf/f637.pdf. This form is the registration application that all biodiesel producers and blenders must complete. Official registration may take a considerable amount of time so planning accordingly to meet IRS deadlines is critical. For more information, contact the local IRS field office.

The Small Agri-Biodiesel Producer Tax Credit was established as part of the Energy Policy Act of 2005. This tax credit program is a volumetric based income tax credit for the production of agri-biodiesel (biodiesel made from first-use vegetable oils and first-use animal fats). At time of

[11] *Diesel Distributors Sell Soybean-Based Fuels Direct to Farmers.* NBB Press Release August 30, 2001.

publication, this credit has been extended to December 31, 2010 and can be found at http://www.irs.gov/pub/irs-pdf/f8864.pdf

The Alternative Fuel Refueling Infrastructure Tax Credit was also established as part of the Energy Policy Act of 2005.[12] This tax credit program provides a tax credit for the installation of certain qualifying fueling infrastructure that dispense alternative fuel, including biodiesel blends B20 and higher.

Environmental and Safety Information[13]

Acute Oral Toxicity/Rates – Biodiesel is nontoxic. The acute oral LD 50 (lethal dose) is greater than 17.4 g/Kg body weight. Table salt (NaCI) is nearly 10 times more toxic, by comparison. However, as with all fuels, biodiesel should be handled with care.

Skin Irritation – Humans – A 24-hour human patch test indicated that undiluted biodiesel produced a very mild irritation. The irritation was less than the result produced by a 4% soap and water solution.

Aquatic Toxicity – A 96-hour lethal concentration for bluegill of biodiesel grade methyl esters was greater than 1000 mg/L. Lethal concentrations at these levels are generally deemed "insignificant," according to the National Institute of Occupational Safety and Health (NIOSH) guidelines in its Registry of the Toxic Effects of Chemical Substances.

Biodegradability – Biodiesel degrades about four times faster than petroleum diesel. Within 28 days, pure biodiesel degrades 85% to 88% in water. Dextrose, a test sugar used as the positive control when testing biodegradability, degraded at the same rate. For example, blends of 20% biodiesel and 80% diesel fuel degrade twice as fast as No. 2 diesel alone.

Flash Point – The flash point of a fuel is defined as the lowest temperature at which the vapor above a combustible liquid can be made to ignite in air. The biodiesel flash point is more than 260° F, well above petroleum-based diesel fuel's flash point, which is about 125° F. Testing has shown the flash point of biodiesel blends increases as the percentage of biodiesel increases. Therefore, biodiesel blended with ULSD is safer to store, handle, and use than diesel fuel.

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12 "Small Agri-Biodiesel Producer Tax Credit." Energy Policy Act of 2005, Section 1345.

13 Environmental and Safety Information Sheet. National Biodiesel Board, http://www.nbb.org/pdf_files/Environment_Safety.pdf.

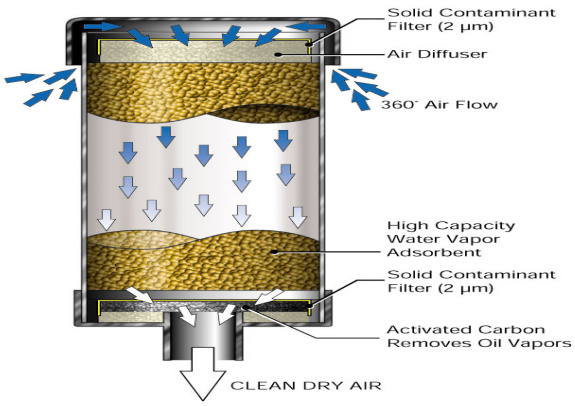
Housekeeping for Biodiesel and Middle Distillates[14]

It is imperative to ensure an optimum storage environment for all fuels. Air, water and insoluble materials in the fuel itself are the three primary contaminants that can affect fuel. Controlling these contaminants will minimize their effect on the fuel, whether middle distillates, biodiesel or a blend of both.

Air

Air will enter through the vent pipe to displace fuel in the tank as it is emptied. The excess air in the tank may lead to increased oxidation, particulate contamination, and increased water levels. These contaminants affect both the stability and quality of the fuel. In order to limit the effects of air, it is recommended that fuel handlers do not store fuels without stabilizers for long periods of time in partially empty tanks. The use of desiccant filters to reduce moisture and particulate contamination might also be considered.

Figure 3: Air Flow Diagram



Water

Both free and entrained water accelerate corrosion and fuel degradation. Free water may enter bulk fuel tanks via condensation, carry-over from the fuel distribution system, and leakage through the fill cap, spill containment valve, or piping. Microbial activity, surfactants, alcohols, particulates, and poorly designed additives may be the cause of entrained water problems. In addition to the accelerated breakdown of the fuel product, water also creates a fertile growing environment for microbial contamination. Poor tank design has made complete removal of water nearly impossible. Therefore, it is important to take steps to reduce it. Mechanical engineers can determine strategies for optimizing tank farms for those that may be experiencing water contamination.

Fuel Contaminants

Stored fuel may form insoluble materials which plug filters, foul injectors and form combustion system deposits which all promote fuel system corrosion. Fuel often is contaminated with sand, salt, dirt and other particles through the delivery process. Poor housekeeping practices will increase operational headaches, which ultimately will result in more time and money spent. Sticking tanks periodically with water-finding paste and addressing accumulating water by drawing down water levels in tanks will go a long way in preserving the quality of stored fuels.

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[14] Interview with Howard Chesneau. President, Fuel Quality Services Inc., Flowery Branch, Georgia. Edited ASTM STP-1005, Distillate Fuel Contamination Storage and Handling. 1987. Serves as speaker for SAE, Edited Chapter 3, Manual 45, ASTM. Serves on Board of Directors for International Association of Storage and Handling.

Later in this publication there is a comprehensive listing of additive components designed to address specific deficiencies inherent in stored liquid fuels of all types (Addressing Fuel Quality Deficiencies with Additives). The deficiencies listed do not affect just biodiesel. Petroleum handlers have for decades faced numerous quality challenges resulting from poor storage and handling of fuels. The listing of additives is not meant to recommend any specific brand additive, only the component which many additive manufacturers and distributors may use to resolve the deficiency from which your fuel may be suffering.

Storage Tank Challenges

Distribution chain storage tanks present a challenging maintenance process for fuel handlers. Improper placement of water draw-off can lead to accumulation of water in the system. Lack of attention to water evaluation may exacerbate this problem. Electronically or physically sticking the tanks with water-finding paste before and after each fuel delivery is a must.

Maintaining Fuel Quality

- Specify ASTM approved fuels only. (See appendix) ASTM D975 (generic diesel) ASTM D396 (heating oil) and ASTM D6751-07a (biodiesel)
- Reference cold weather performance and other special needs prior to ordering. (Please refer to the section on Fuel Properties.)
- Be proactive with general housekeeping practices.
- Execute a monthly or quarterly fuel analysis program to ensure the safe keeping of fuels.
- Adhere to BQ-9000 program directives. www.bq-9000.org

Key Points for Transporting Biodiesel[15]

- Use aluminum, carbon steel, or stainless steel containers during transport.
- Implement proper inspection and/or washout of transport.
- Check for previous load carried and any residuals.
- Food products or raw vegetable oil, gasoline, and lubricants are not acceptable residuals.
- Make sure there is no residual water in transport.
- Make sure hoses and seals are clean and compatible with B100.

[15] Tyson, Shaine. 2004 Biodiesel Handling and Use Guidelines. Department of Energy/NREL: DOE/GOV–102004-1999, September 2004, page 27.

- Determine the need for insulation or method of heating the transport if shipping during winter months.

Placards are a critical source of hazard information. They are part of an internationally harmonized system of communicating the dangers inherent in the transportation of hazardous materials. They also play a critical role in communicating the presence of hazardous materials to emergency responders, transport workers and regulatory enforcement personnel in the event of an incident.

Current placarding requirements are diamond-shaped (square-on-point) signs that are used to identify shipments of hazardous materials. When the use of placards is required, they must be placed on both ends and both sides of trucks, railcars, and intermodal containers that carry hazardous materials. They are coded by color and contain symbols and numbers that designate the hazard class or division of the hazardous material being shipped. For bulk and certain non-bulk shipments, a four-digit hazardous material identification number may be on the placard or on an accompanying orange panel or a white square-on-point sign.[16]

Placards are required for the transportation of hazardous materials, based on the type and quantity of material. Federal law defines hazardous material as:

"A substance or material that the Secretary of Transportation has determined is capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and has designated as hazardous under…Federal hazardous materials transportation law." [17]

Hazardous materials are broken into nine hazard classes:[18]

1. Explosives
2. Gases
3. Flammable and combustible liquids
4. Flammable solids, spontaneously combustible materials, and dangerous when wet materials
5. Oxidizers and organic peroxides
6. Toxic (poison or poisonous) material and infectious substances
7. Radioactive materials
8. Corrosive materials
9. Miscellaneous dangerous goods (HMR, Title 49 CRF Part 172.504)

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16 "Role of Hazardous Material Placards in Transportation Safety and Security." Executive Summary. U.S. Department of Transportation, Research and Special Programs Administration. January 15, 2003.

17 HMR, Title 49 CRF Part 171.8

18 Role of Hazardous Material Placards in Transportation Safety and Security." U.S. Department of Transportation, Research and Special Programs Administration. January 15, 2003. Page 6.

Placards are necessary if the flash point is under 200° F. Placards would not be required for raw vegetable oil or neat biodiesel (B100) because the flash point for biodiesel is 266° F. In lieu of testing each blend for flash, distributors of B20 or other blends should use the existing placards 1993 or 1223, to cover themselves. For the biodiesel producer interested in the one gallon of diesel into the 999 gallons of biodiesel (a 99.9% blend) it is unlikely that the biodiesel should to be adulterated to the point of pushing it down under the 200 F range, hence making placarding these blends (for tax purposes) not necessary.

The HMIS/NFPA Hazard Rating – which is shown in the right corner of our sample MSDS sheet on biodiesel (Appendix 1) – is 0-1-0 (1) being the fire rating (0), for health risk, and (0) for reactivity. Standard No. 2 fuel oil or diesel is 1-2-1. This placard blue/red/yellow symbol has nothing to do with the Hazmat placarding system. The HMIS/NFPA Hazard Rating is about the Occupational Safety and Health Administration and the National Fire Protection Agency.

Key Points for Storage of Biodiesel

- Acceptable storage tank materials include aluminum, steel, fluorinated polyethylene, fluorinated polypropylene, Teflon, and most fiberglass.[19]
- Do not store B100 for long periods of time in systems containing reactive metals.[19]
- B100 should be stored at temperatures at least 10° F higher than the cloud point. Generally, storage temperatures of 45° F to 50° F are acceptable for most B100, although some B100 fuels may require higher storage temperatures. Therefore, most underground storage facilities are adequate, but aboveground fuel systems should be protected with insulation, agitation, heating systems or other methods, depending on the climate.[20]

- B100 is a mild solvent, so carefully clean the tanks and fuel system where any sediments or deposits may exist. Prepare for more frequent filter changes while the system is cleaned. [21]
- UL Test Certification of National Foam's Aer-O-Foam XL-3, approved for extinguishing Biodiesel Fuel Fires. Fire tests were conducted in accordance with UL Standard 162, Safety for Foam Equipment and Liquid Concentrates, 7th edition revised, 9-8-1999.
- Both Kolor Kut and Sar Gel water finding pastes are effective at detecting water in biodiesel and biodiesel blends. Use of stick and water finding paste is absolutely the most effective tank management protocol available. Tanks should be evaluated before and after each fuel receipt to ensure that no water arrived with the fuel delivery.[22]

- API RP 1637 color marking system has been established for B100 and associated blends. This marking system helps designate the contents of tanks and piping which carries it to

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19 "Materials Compatibility." National Biodiesel Board, www.biodiesel.org.

20 Biodiesel Cold Weather Blending Study. NBB and the Cold Flow Consortium, July 2005, page 6.

21 Biodiesel Myths and Facts. National Biodiesel Board, www.biodiesel.org. 2001

22 Nazzaro, Paul and Hoon Ge. Water Finding Paste and Biodiesel Blends. Advanced Fuel Solutions and MEG Corp. Hoon Ge. August 2006.

the loading rack. API has approved the following symbol for use with biodiesel and biodiesel blends: Yellow hexagon outer bank with bronze hexagon inside with either white or back font for designated blends as well as B100. These colors will be used at the service station level as well.

Blending B-100

The chemical makeup of biodiesel makes it compatible for blending with any kind of distillate. The blending can occur in any ratio with petroleum diesel from additive levels to 100% biodiesel. The blend is identified using B followed by the percentage of biodiesel in the finished product in "Bxx" form. Common blends include B2, a 2% biodiesel blend, which is often used for added lubricity, and B20, a 20% biodiesel blend, which is the minimum blend level that can be used by fleets covered by the Energy Policy Act of 1992.

Preparing to Blend Biodiesel

- Establish storage and injection points suitable for larger terminals, smaller jobbers, and some retail outlets.
- Evaluate each terminal individually because different requirements will be necessary to ensure seamless operation at each terminal.
- Coordinate with biodiesel suppliers for best delivery methods and scheduling when sizing tank capacity.
- Address on-site storage challenges for biodiesel.

Blending Strategies

Splash Blending

Biodiesel and diesel fuel are loaded separately. Mixing of the products occur as the fuel is agitated through blending of each fuel, as well as agitation during transport and delivery to the end user. It is recommended that because biodiesel is slightly heaver than conventional distillates it be loaded second when top loading to eliminate the biodiesel from settling to the bottom of the blending tank. When bottom loading is utilized, the fuel flow may be adequate to load either fuel first with no negative consequences due to the minor viscosity differentials.

In-Tank Blending

Biodiesel and diesel are loaded separately – or in some cases simultaneously through different incoming sources – but at a high enough fill rate that the fuels sufficiently mix so that no further agitation is necessary.

In-Line Blending

Biodiesel is added to a stream of diesel fuel as it travels through a pipe or hose. The blending occurs as the two products move through the pipe or once the fuel is loaded into its receiving vessel.

Rack Blending

Injected directly at the rack into the tank truck, similar to adding performance fuel additives and red dye.

Biodiesel is fully compatible with petroleum diesel, and therefore blending biodiesel is not difficult. However, regardless of the blending strategy, it is important to understand some of the significant characteristics of biodiesel. Some of these characteristics are:

- **Biodiesel is heavier than diesel fuel.** Biodiesel has a specific gravity of 0.88 compared to No. 2 diesel at 0.85 and No. 1 diesel at 0.80. It is therefore recommended that the generic distillate fuel be in the tank prior to introducing the biodiesel. Biodiesel should be blended on top of the petroleum diesel when splash blending.
- **Biodiesel has a high pour point.** It may be necessary to heat the biodiesel depending on the outside temperature to ensure flow prior to the introduction of the generic distillate portion of the blend.
- **Blends will not separate in the presence of water.** Execute proactive tank management to prevent other problems caused by excess water.

Cold Weather Blending

Biodiesel has a pour point of approximately 30° F and therefore requires heating to ensure flow prior to the introduction of the generic distillate portion of the biodiesel blend. The cold flow performance of the finished product may be impacted between 3° F and 10° F for a B20 blend, less for B2 and B5, once the biodiesel is blended into the generic distillate. Knowing what is being purchased – based on fuel specifications provided by the fuel supplier as it relates to the generic percentage of the biodiesel blend – is critical. The lower the winter operability temperatures of the generic distillate that will be blended with the biodiesel, the more reliable the blended fuel will be in different regions.

Blended fuels can be stored below ground in most climates. Above ground storage for both generic distillates and biodiesel should be protected with insulation, agitation, kerosene blends, heating systems or other measures if freezing weather is common. These precautions should also be used to protect tank piping and pumping equipment. These cold weather preparatory recommendations are equally important when storing conventional distillates as well as biodiesel and biodiesel blends.

Generic distillates are commonly loaded onto fuel trucks at oil terminals at temperatures as low as 19° F. Fuel handlers will be blending cold diesel fuel with warm biodiesel when biodiesel

requires heat protection to at least 10° F above the cloud point of the fuel.[23] Input has been solicited from fuel handlers as to independent blending strategies in an effort to develop recommended "best practices" to achieve successful blending and distribution.

While some feedback indicates no problems with fuel temperature differentials, other information suggests fuel handlers have seen the saturated compounds in the biodiesel crystallize and plug fuel filters and lines. The effects have been similar to generic distillate fuel that see temperatures equal to or lower than its cloud point. To circumvent the potential for this problem, it is recommended that the following guidelines be observed when blending biodiesel with generic distillates:

Cold Weather Blending Guidelines

- Blend the biodiesel with 50% kerosene prior to introducing it into the final fuel mixture. Make sure that the kerosene is above 45° F, if possible.
- Absolutely know the cloud point, cold filter plugging point and pour point of the generic diesel fuel product prior to blending. This will help determine the possible effect of the biodiesel blend on the key winter operability characteristics post blending. If the process is begun with inferior generic distillate cold weather specifications, the result will end with an inferior biodiesel blended fuel as well.
- Seek higher blending speeds through gravity distribution or mechanical agitation, at least 75 gallons per minute to full rack velocity, which can be as high as 650 gallons per minute. Hand mixing – pouring one fuel into another – is not suggested in cold climates. Alternatively, once the truck has been loaded at a bulk terminal the product could then be pumped or gravity dropped into the end users' fuel storage tanks. This blend strategy has proven successful. (Note: Optimum blending of fuels results from appropriate terminal blending under automated equipment utilization.)
- Neat biodiesel should not be kept on a truck overnight prior to delivery.
- Many fuel users and distributors currently use cold winter diesel fuel additives to improve winter handling characteristics of diesel fuel. No commercial diesel fuel additive has to date been found effective in modifying the cold weather specifications of neat biodiesel. However, commercial additives are available to treat the generic distillate portion of the blend, which can aid in reducing the cold weather characteristics of the fuels' pour point and cold filter plugging point. That will benefit the biodiesel blend by working solely on the distillate fuel characteristics. (Remember that the lower the pour point, cloud point and cold filter plugging point of the distillate fuels the better the biodiesel blend will be.)
- It is imperative that cold weather distillate additives be added to the fuel before the fuel reaches its cloud point. It is also essential that the additive get into the fuel when agitation is available through the chosen blending strategy. As with biodiesel blending, an additive requires equal blending attention to ensure that it is distributed evenly throughout the tank to obtain optimum winter performance characteristics.
- Only use fuels that meet ASTM specifications. Biodiesel needs to meet or exceed ASTM D6751 while generic diesel must meet or exceed ASTM D975. Absolutely do not blend fuels that do not meet the respective specifications.

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[23] Biodiesel Cold Weather Blending Study. Cold Flow Consortium, July 2005, Page 2.

- Become acquainted with the local fuel-testing laboratory in the region before a problem arises. Ask the laboratory to provide pre-labeled testing kits to use when submitting samples for quality testing evaluations.
- Stick all tanks storing biodiesel, generic distillates, and combinations for both fuels for water by using a gauge stick and water-finding paste, which is available at petroleum supply houses.
- It is recommended that 30-micron filters be used on filters utilized for fuel pumping islands whenever possible. Winter conditions frequently cause fuel to haze when fuels reach posted cloud points, and the entrained moisture tends to freeze causing premature filter plugging. Operators of vehicles using 5-micron or 6-micron filters should consider switching to a large micron filter during extreme winter conditions.
- Water-fuel separators need to be checked at the time vehicles are being fueled and must be serviced as often as necessary.

Infrastructure considerations[24]

There will not be a best single way to blend B2 to B100 by using one method for the complete range at the loading rack. Utilize current assets the best way possible. Select storage and blending options that are appropriate and can be supported by existing equipment.

To accommodate B2 to B5 with product flow rates of 600 gallons per minute the pump and supply line will handle the demand of the total volume for all load arms with sufficient pressure. Blend ratios in this range will require a larger injection point – typically a two-inch opening. Consideration must also be given to power requirements for the larger motors required for this blending ratio.

B2 to B5 distributed with a product flow of 600 gallons per minute will require a meter and valve rated for 12 GPM minimum while B5 will require a 30 GPM system. These ranges are achievable with current high capacity meter-based injectors found in many terminals nationwide. High capacity meter-based injectors will allow accurate control and metering up to 5% blending.

Blending biodiesel in ratios of 10% and above will require a higher level of infrastructure to achieve this goal. B10 and above will be more invasive as it pertains to physical space required by this equipment. However, this blend percentage will be achieved by using sequential blending with or without automation or preset ratio blending depending on automation only. (See below)

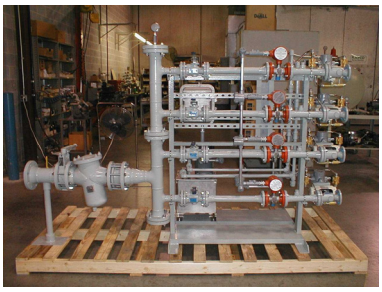
Sequential blending means basically loading one product at a time using the same meter for both products – biodiesel and generic rack diesel. Both products can also use one common control valve. However, a block valve for each product will be necessary.

[24] Paul Hinkle, ASI Engineering, Broken Arrow, Oklahoma, Paul J. Nazzaro, Advanced Fuel Solutions, Inc. A collaboration on infrastructure development, 2006

Sequential blending typically is the least intrusive and least expensive to add to existing terminal infrastructure. It is really a matter of adding a new product to a loading lane at the truck terminal facility. The ultimate result is enabling a terminal operator to load multiple products at one loading position or at different rack positions through different loading arms.

Preset true ratio blending enables terminal operators to load both products (biodiesel/diesel fuel) at the same time. One meter and control valve per product is required and the blend stays proportional and blends throughout the complete load.

Preset batch ratio blending activates both products simultaneously and is loaded at the same time. Like the preset true ratio concept, one meter and control valve per product is required but flow ratios are not controlled proportionally. That means the product with the lesser volume may finish substantially earlier than the larger product volume.



Blending systems like a 4-arm blender engineered to work with rack presents can be built to work within your specific space requirements. They are normally designed in a horizontal configuration, but often are designed in vertical configurations to fit in tighter space requirements.

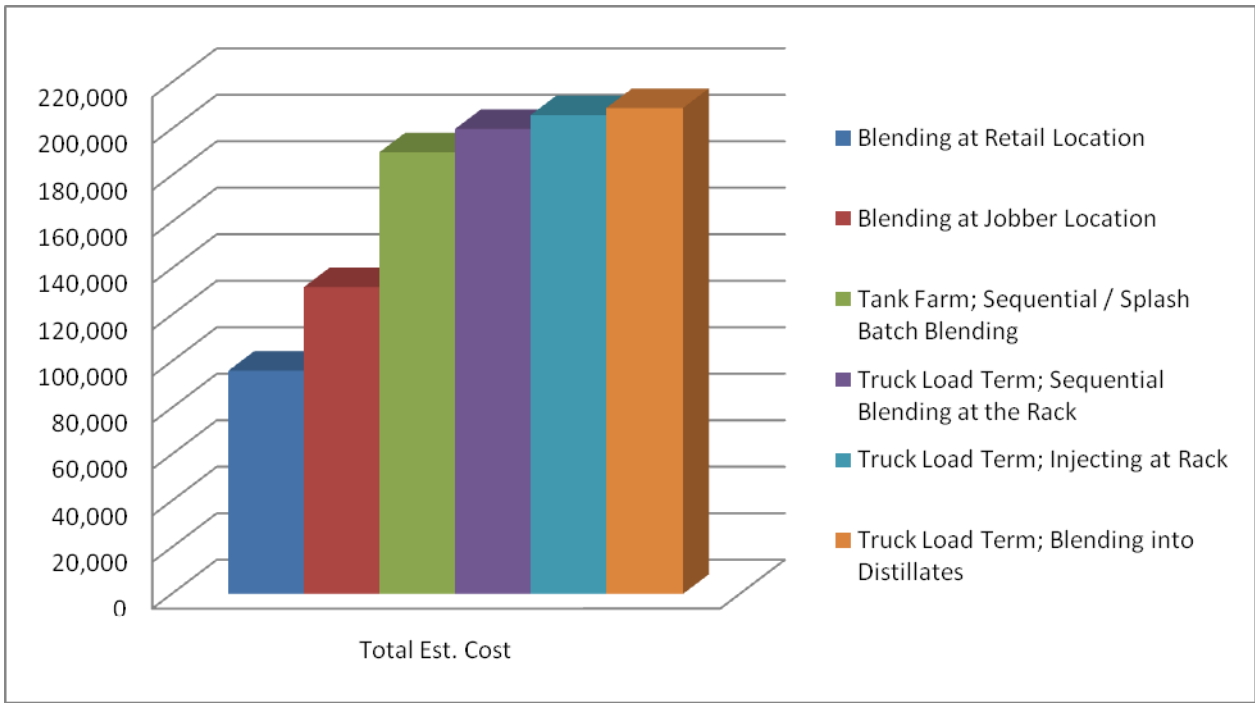
V-Port ball valves allow for more accurate controls of the product stream at different rates and are enabled with hydraulic actuators. Again, if space restrictions at terminals are an issue, multiple arms per bay blenders can be designed and installed at the end of each respective truck bay to accommodate tight spots.

Distribution goals should be determined prior to developing infrastructure upgrade plans to successfully blend biodiesel into generic fuel streams. There are many mechanical engineering companies strategically located throughout the nation that are qualified to tour facilities and make recommendations on how best to accomplish intended goals.

Each blending method (and its required infrastructure) has many positives and negatives. The blending method must fit to both current and future needs, while remaining cost effective. Shown below is an analysis of each of the blending options, positive and negative aspects as well as an approximate cost analysis based on actual nationwide installations.

NOTE: Recommendations based on recent installations managed by ASI Engineering, a Broken Arrow Oklahoma mechanical engineering company. The following recommendations and values are based on experiences which ASI encountered with field projects over the past several years. It is highly recommended that these recommendations and values be used only as guidelines during developmental processes. It is a good practice to seek the guidance of a reputable engineering company to develop solutions to individual situations.

Figure 4: Estimated Cost Comparisons of Biodiesel Infrastructure Options



Recommendations for Blending at Retail Locations (Option 1)

- Injecting into distillate at retail locations without automation systems and other limitations.
- This system is currently used at many retail outlets to inject cold flow improver into fuel.
- Allows for accurate reconciling of blended fuel.
- This system adds the Biodiesel automatically and proportionately as the fuel is dropped into the storage tanks at the retail outlet from the transport.
- Can be accessed remotely by modem.

Positives
• Most economical for small scale operations
Negatives
• Numerous moving parts, one system per location • Minimal documentation • More hands-on involvement • No method to test and make corrections to blend

Pricing			
	Tank Sized for 500K Gallons Month		
1	10,000 Gallon Double Wall AST includes level gauges, valves, etc.		$50,000
1	Dual Pump/ Motor Skid		$14,000
1	Injector per storage tank		$6,000
1	Tank fill adapter, meter, valves, etc.		$4,500
1	Insulation for tank		$4,000
1	Tank Heaters		$7,500
	Mixer not needed, pump will circulate		
1	Installation of complete system/storage tank includes mech., elec., and civil/tank		$10,000
	Total		**$96,000**

Recommendations for Blending at Jobber Locations (Option 2)

- Injecting into distillates at jobber locations without automation systems and other limitations.

Positives			
• Economical			
Negatives			
• Requires human involvement during blending process • Potential for inaccurate loads • Minimal documentation of loads			
Pricing			
	Tank Sized for 500K Gallons / Month		
1	10,000 Gallon Double Wall AST includes level gauges, valves, etc.		$50,000
1	Biodiesel Loading/Metering Skid (30 GPM)		30,000
1	Insulation for tank		$10,000
1	Tank Heaters		$9000
1	Concrete Pad for tank		$8,000
1	Installation of tank and equipment		$25,000
	Total		**$132,000**

Recommendations for Tank Farm Blending Sequential / Splash Batch Blending (Option 3)

Positives			
• Cost effective and operationally sound. • Allows Biodiesel to be transferred into distillate tankage when all distillate is to be blended with Biodiesel. • Biodiesel can be loaded directly into the storage tank prior to, during, or after delivery. • For optimum blending the Biodiesel can be injected proportionally into the distillate pipeline upstream of tankage. • Minimal capital investment allows accurate accountability with the ability to perform lab analysis on, and make corrections to the actual blend before loading transports.			
Negatives			
• All distillate in selected storage tanks has been blended and cannot be sold as unblended to locations not desiring Biodiesel blended distillate, i.e. exporting. • The tank may need to be circulated to maintain suspension of Biodiesel depending on turnover duration and temperature of fuel.			
Pricing			
	Tank Sized for 1.5M Gallons / Month		
1	30,000 Gallon AST (Vertical or Horizontal)		$60,000
1	Heated and Insulated		$20,000
1	Foundation		$15,000
1	Insertion Heaters		$9000
1	Feed Pump for Biodiesel (20 GPM P/D)		$20,000
1	Flow Meter (20 GPM) 4-20 mA for Biodiesel		$3,000
1	Mainline Flow Meter		$5,000
1	Misc. Valves, Check Valves, etc.		$3,000
1	Installation Construction		$55,000
	Civil, Mechanical, and Electrical		
	Total		**$190,000**

Recommendations for Truck Loading Terminals Sequential Blending at the Rack (Option 4)

Positives

- Cost effective / operationally sound strategy to blending individual loads.
- Allows Biodiesel to be loaded and metered at a flexible proportionate rate, with the fuel loading afterward. Allows use of existing automation systems to perform the blending, monitoring, and reconciling of the fuel mixture.
- Allows rate changes to be easily performed in programming without future equipment upgrades specific for this product.
- Allows for Independent storage for the unadditized fuel to be loaded either with or without Biodiesel.
- If Biodiesel is desired, fuel volume will be selected as normal by the driver with a selection of grade for Biodiesel.
- The Biodiesel will be loaded into the truck first by volume entered in the presets, and the distillate will be added at the end of the load proportionately. This will be done by the existing automation system using the same loading arm.
- Similar to the method commonly used for ethanol and mid-grade.
- Operates by installing a Biodiesel line connection into the fuel loading line.
- Flow will be controlled by a control valve and meter pulses to the automation system or accuload.

Negatives

- B100 requires heat and insulation to all injection points and may slow loading time at some locations, but by small amounts.

Pricing

	Tank Sized for 1.5M Gallons / Month		
1	30,000 Gallon AST (Vertical or Horizontal)		$60,000
1	Heated and Insulated		$20,000
1	Foundation		$15,000
1	Insertion Heaters		$9,000
	Feed Pump for Biodiesel (20 GPM P/D)		$20,000
1	Flow Meter (20 GPM) 4-20 mA for Biodiesel		$3,000
1	Control Valve		$5,000
1	Misc. Valves, Check Valves, etc.		$3,000
1	Installation Construction		$55,000
	Civil, Mechanical, and Electrical		
1	Automation Upgrade/Bay		$10,000
	Total		**$200,000**

Recommendations for Truck Loading Terminals Injecting at the Rack (Option 5)

- Biodiesel is blended as a normal fuel additive proportionately as the fuel is loaded.

Positives			
• Terminal operators will be familiar with this type of system operation and maintenance.			
Negatives			
• Blend rates up to 5% proportional maximum optional. • Higher rates desired must slow loading of product. • Typically this is most affordable.			
Pricing			
	Tank Sized for 1.5M Gallons / Month		
1	50,000 Gallon AST (Vertical or Horizontal)		$80,000
1	Dual pump/motor skid w/ 8-10 GPM pumps		$14,000
1	Concrete Pad/ Containment		$15,000
1	Insertion Heaters		$9,000
1	Tank Farm Equipment Installation		$40,000
1	Insulate AST		$25,000
1	Injector, Tubing, Valves, etc. per load arm		$8,000
1	Installation Injector Equipment/Load Arm		$5,000
1	Includes electrical		
	Options:		
1	Automation Upgrade/ Programming per Bay		$10,000
	Total		**$206,000**

Sequential Blender Recommendations for Truck Loading Terminals Blending into Distillates (Option 6)

- Splash blending and wild stream blending to the rack.
- Goal Accomplished by adding the same equipment as for sequential blending
- Splash blending allows the biodiesel to be loaded concurrently with the distillate through a common load arm.

Positives			
• Minimal interference with normal operations using equipment common in all terminals. • Fuel is mixed throughout load while loading into transport.			
Negatives			
• Installation and maintenance costs are increased versus sequential blending.			
• B100 requires heat & insulation to all blend connections.			
Pricing			
	Tank Sized for 1.5M Gallons / Month		
1	30,000 Gallon AST (Vertical or Horizontal)		$60,000
1	Heated and Insulated		$20,000
1	Foundation		$15,000
1	Insertion Heaters		$9000
1	Heated and Insulated 2” Line to the Rack		$10,000
1	Feed Pump for Biodiesel (20 GPM P/D)		$9,000
1	Flow Meter (20 GPM) 4-20 mA for Biodiesel		$3,000
1	4” Control Valve		$5,000
1	Misc. Valves, Check Valves, etc.		$3,000
1	Installation Construction		$65,000
	Civil, Mechanical, and Electrical		
1	Automation Upgrade/Bay		$10,000
	Total		**$209,000**

Equipment Summary

There are several flexible options for meeting blending requirements for biodiesel. Each option has several pros and cons as well as different budgeting implications.

Each terminal operator dictates the selected strategy. The strategy should be based on the needs of the operator, the goals of the operation, and the constraints of the budget. Future flexibility should also be considered.

Sizing storage tanks and controlling cold weather handling characteristics of biodiesel comprise the majority of installation costs.

All costs outlined within this document are subject to change without notice. Publication contributors projected costs as of September 2004. Mechanical engineering contractors can provide more site-specific quotations.

Conclusion

Environmental concerns and a desire to increase U.S. energy independence are encouraging transit agencies to look for alternatives to diesel fuel. Biodiesel is a promising alternative that requires little, if any, modifications to today's engines. However, transit agencies considering the use of biodiesel need practical information on how to procure, handle, and use it. The report provides transit agencies with best practices, including a fleet fuel procurement checklist (in Appendix 3), to help them determine how to add biodiesel to their current operations and how to avoid potential problems.

Appendix 1: Material Safety Data Sheet

1. CHEMICAL PRODUCT

General Product Name: **Biodiesel**
Synonyms: Methyl Soyate, Rapeseed Methyl Ester (RME),
Methyl Tallowate
Product Description: Methyl esters from lipid sources
CAS Number: Methyl Soyate: 67784-80-9; RME: 73891-99-3;
Methyl Tallowate: 61788-71-2

2. COMPOSITION/INFORMATION ON INGREDIENTS

This product contains no hazardous materials.

3. HAZARDS IDENTIFICATION

Potential Health Effects:

INHALATION:
Negligible unless heated to produce vapors. Vapors or finely misted materials may irritate the mucous membranes and cause irritation, dizziness, and nausea. Remove to fresh air.
EYE CONTACT:
May cause irritation. Irrigate eye with water for at least 15 to 20 minutes. Seek medical attention if symptoms persist.
SKIN CONTACT:
Prolonged or repeated contact is not likely to cause significant skin irritation. Material is sometimes encountered at elevated temperatures. Thermal burns are possible.
INGESTION:
No hazards anticipated from ingestion incidental to industrial exposure.

4. FIRST AID MEASURES

EYES:
Irrigate eyes with a heavy stream of water for at least 15 to 20 minutes.
SKIN:
Wash exposed areas of the body with soap and water.
INHALATION:
Remove from area of exposure; seek medical attention if symptoms persist.
INGESTION:
Give one or two glasses of water to drink. If gastro-intestinal symptoms develop, consult medical personnel. (Never give anything by mouth to an unconscious person.)

5. FIRE FIGHTING MEASURES

Flash Point (Method Used): 130.0° C min (ASTM 93)
Flammability Limits: None known
EXTINGUISHING MEDIA:
Dry chemical, foam, halon, CO_2, water spray (fog). Water stream may splash the burning liquid and spread fire.
SPECIAL FIRE FIGHTING PROCEDURES:
Use water spray to cool drums exposed to fire.
UNUSUAL FIRE AND EXPLOSION HAZARDS:
Oil soaked rags can cause spontaneous combustion if not handled properly. Before disposal, wash rags with soap and water and dry in well ventilated area. Firefighters

should use self-contained breathing apparatus to avoid exposure to smoke and vapor.

6. ACCIDENTAL RELEASE MEASURES SPILL CLEAN-UP PROCEDURES

Remove sources of ignition, contain spill to smallest area possible. Stop leak if possible.
Pick up small spills with absorbent materials such as paper towels, “Oil Dry”, sand or dirt.
Recover large spills for salvage or disposal. Wash hard surfaces with safety solvent or
detergent to remove remaining oil film. Greasy nature will result in a slippery surface.

7. HANDLING AND STORAGE

Store in closed containers between 50°F and 120°F.
Keep away from oxidizing agents, excessive heat, and ignition sources.
Store and use in well ventilated areas.
Do not store or use near heat, spark, or flame, store out of sun.
Do not puncture, drag, or slide this container.
Drum is not a pressure vessel; never use pressure to empty.

8. EXPOSURE CONTROL /PERSONAL PROTECTION

RESPIRATORY PROTECTION:
If vapors or mists are generated, wear a NIOSH approved organic vapor/mist respirator.
PROTECTIVE CLOTHING:
Safety glasses, goggles, or face shield recommended to protect eyes from mists or
splashing. PVC coated gloves recommended to prevent skin contact.
OTHER PROTECTIVE MEASURES:
Employees must practice good personal hygiene, washing exposed areas of skin several
times daily and laundering contaminated clothing before re-use.

9. PHYSICAL AND CHEMICAL PROPERTIES

Boiling Point, 760 mm Hg:>200°C Volatiles, % by Volume: <2
Specific Gravity (H_2O=1): 0.88 Solubility in H_2O, % by Volume: insoluble
Vapor Pressure, mm Hg: <2 Evaporation Rate, Butyl Acetate=1: <1
Vapor Density, Air=1:>1
Appearance and Odor: pale yellow liquid, mild odor

10. STABILITY AND REACTIVITY

GENERAL:
This product is stable and hazardous polymerization will not occur.
INCOMPATIBLE MATERIALS AND CONDITIONS TO AVOID:
Strong oxidizing agents
HAZARDOUS DECOMPOSITION PRODUCTS:
Combustion produces carbon monoxide, carbon dioxide along with
thick smoke.

11. DISPOSAL CONSIDERATIONS

WASTE DISPOSAL:
Waste may be disposed of by a licensed waste disposal company. Contaminated
absorbent material may be disposed of in an approved landfill. Follow local, state and
federal disposal regulations.

12. TRANSPORT INFORMATION

UN HAZARD CLASS: N/A
NMFC (National Motor Freight Classification):
PROPER SHIPPING NAME: Fatty acid ester
IDENTIFICATION NUMBER: 144920
SHIPPING CLASSIFICATION: 65

13. REGULATORY INFORMATION:

OSHA STATUS:
This product is not hazardous under the criteria of the Federal OSHA Hazard Communication Standard 29 CFR 1910.1200. However, thermal processing and decomposition fumes from this product may be hazardous as noted in Sections 2 and 3.

TSCA STATUS:
This product is listed on TSCA.
CERCLA (Comprehensive Response Compensation and Liability Act):
NOT reportable.

SARA TITLE III (Superfund Amendments and Reauthorization Act):
Section 312 Extremely Hazardous Substances:
None
Section 311/312 Hazard Categories:
Non-hazardous under Section 311/312
Section 313 Toxic Chemicals:
None

RCRA STATUS:
If discarded in its purchased form, this product would not be a hazardous waste either by listing or by characteristic. However, under RCRA, it is the responsibility of the product user to determine at the time of disposal, whether a material containing the product or derived from the product should be classified as a hazardous waste,
(40 CFR 261.20-24)

CALIFORNIA PROPOSITION 65:
The following statement is made in order to comply with the California Safe Drinking Water and Toxic Enforcement Act of 1986. This product contains no chemicals known to the state of California to cause cancer.

14. OTHER INFORMATION:

This information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any other process. Such information is to the best of the company's knowledge and believed accurate and reliable as of the date indicated. However, no representation, warranty or guarantee of any kind, express or implied, is made as to its accuracy, reliability or completeness and we assume no responsibility for any loss, damage or expense, direct or consequential, arising out of use. It is the user's responsibility to satisfy himself as to the suitableness and completeness of such information for his own particular use.

Appendix 2: EMA Consensus Position

EMA Consensus Position: Joint EMA/TMC Pump Grade Specification for Premium Diesel Fuel

Purpose

This Consensus Position is intended to define premium diesel fuel marketed commercially at retail fueling stations and truck stops.

It is the belief of the Engine Manufacturers Association (EMA) and The Maintenance Council (TMC) that equipment users look to premium diesel fuel at the pump as a significant opportunity for improving fuel-related performance issues or solving problems related to fuel. As such, premium diesel fuel should be a fuel broad in scope, offering improvements in many areas so as to satisfy the needs of as many end users as possible. The recommendations in the attached table are intended to produce performance benefits that are noticeable to equipment users.

This diesel fuel recommendation is considered to be "premium" insofar as it may assist in improving the performance and durability of engines currently in use and those expected to be produced prior to 2004. It is not intended to enable engines to meet any emissions standard or, in general, to improve exhaust emissions. Nor does it preclude centrally fueled fleets from negotiating with their fuel supplier for fuel that they feel fits their unique needs. It is intended as a "living document" in that, as other needs or test procedures are identified, the recommendation will be upgraded.

The most significant aspects of this Consensus Position are its requirements for a minimum fuel lubricity, increased cetane number, improved cold weather performance, detergency, thermal stability, minimum energy content, and specifications regarding overall fuel "cleanliness". These properties, described in detail below, should help address many current customer satisfaction issues.

Significance and use of the recommended properties:

API Gravity or Energy Content

API Gravity is a measure of a fuel's density – or weight per gallon. The higher the API gravity, the less a gallon of fuel weighs and the less energy it contains. API gravity of diesel fuel has a profound effect on engine power. As a general rule, a 3% to 5% decrease in the thermal energy content will result in roughly the same percentage decrease in engine power. Use of fuels with higher API gravity will also result in higher fuel consumption – lower miles per gallon. Our recommendation includes a maximum API gravity based on equipment the user needs to maintain engine power, while minimizing fuel consumption. As an alternative, this Consensus Position includes an equivalent minimum energy content specification to help ensure acceptable performance.

Low Temperature Operability

Several tests are commonly used to characterize the low temperature operability of diesel fuel. These are Cloud Point, Low Temperature Flow Test (LTFT), and Cold Filter Plugging Point (CFPP). Among these, the LTFT provides the best overall correlation with field performance. However, for fuel without additives, Cloud Point and LTFT correlate very well. Since Cloud Point is more practical as a quality control test, it is listed as the primary recommendation. ASTM does not recommend CFPP as an indicator of low temperature operability. However, if data emerges to show universal correlation with the recommended procedures for all vehicle types, EMA/TMC will consider including that procedure in a future version of this Consensus Position.

Actual temperature targets should be adjusted monthly based on latitude using ASTM D975 10^{th} percentile minimum ambient temperature data. EMA and TMC agree with the Canadian approach in recommending 2.5 percentile temperature for cold flow properties as providing the necessary protection for a "premium" grade fuel. Since 2.5 percentile data is not available in the United States, setting the recommended level 4° C below the 10^{th} percentile is designed to approximate the 2.5 percentile level of protection.

Cetane Number/Cetane Index

Cetane number is a relative measure of the interval between the beginning of injection and auto ignition of the fuel. Cetane number is a year-round concern. A higher number means a shorter delay interval. Fuels with low cetane numbers will cause hard starting, rough operation, noise and increased smoke opacity. Current commercial fuel cetane requirements may not adequately address these customer satisfaction issues.

Generally, diesel engines will operate better year-round on fuels with cetane numbers above 50, compared to fuels with cetane numbers of the national average of approximately 45. Fuel suppliers may increase the cetane number through the refining process or the blending of combustion ignition-improving additives.

Cetane index approximates fuel ignition quality through correlation with other fuel properties. Since it is not affected by the use of combustion improver additives, cetane index estimates the fuel's base cetane number.

Lubricity

Lubricity describes the ability of a fluid to minimize friction between – and damage to – surfaces in relative motion under loaded conditions. Diesel fuel injection equipment relies on the lubricating properties of the fuel. Shortened life of engine components such as fuel injection pumps and unit injectors usually can be attributed to a lack of fuel lubricity, which is a concern for engine manufacturers. ASTM D975 does not adequately address this property.

Additional lubricity information can be found in the Society of Automotive Engineers (SAE) Technical Papers 952372, "ISO Diesel Fuel Lubricity Round Robin Program" and 981363, "Continued Evaluation of Diesel Fuel Lubricity by Pump Rig Tests." SAE can be contact at www.sae.org or (412) 776-4841.

Detergency

Some diesel fuels that do not contain detergents have a tendency to form carbon deposits on certain fuel injectors. It has generally been found that low sulfur fuels and thermally unstable fuels have a greater tendency to form these deposits. Detergent additives will prevent carbon deposits, which interfere with fueling and fuel spray patterns, from forming.

Dirty injectors will invariably give rise to higher smoke levels in all equipment. It can limit power by restricting flow in some equipment. Diesel fuel detergency is measured using the L10 Injector Deposit Test. Passing limits for the tests are shown in the attached table. These limits are expressed in terms of a CRC rating for injector cleanliness and flow loss criterion.

Please refer to Cummins L10 Injector Depositing Test to Evaluate Diesel Fuel quality SAE Paper for further support and explanation of the detergency issue.

Water and Sediment

Diesel fuel should be clear in appearance and free of water and sediment. The presence of these materials generally indicates poor fuel handling practices. Water and sediment can shorten filter life or plug fuel filters which can lead to engine fuel starvation. In addition water can promote fuel corrosion and microbial growth. For that reason, we recommend separate analysis and maximum levels.

The level of water specified in the attached table is within the solubility level of water in fuel and does not represent free water.

ASTM D6217 is the preferred test method that covers the determination of the mass particulate contamination in middle distillate fuels by filtration. However, since D6217 is a newer test that might not be accessible to all, D2276 and D5452 are also included in the specification.

A quick field test for visually checking water and sediment is ASTM D4176. If free water or sediment is observed, laboratory testing should be conducted to determine when the recommendations specified in the attached table are being met.

Bacteria and Fungus

This represents an additional specification designed to minimize fuel contamination that has resulted from the presence of free water in transport, storage or vehicle tanks. Microbes do not live in fuel; they live in the interface that forms between the fuel and free water. The presence of microbes can cause operational problems, corrosion, and sediment build-up in diesel fuel systems. Note, however, the absence of microbes in fuel received at filling stations does not ensure the absence of microbes in fuel storage tanks or vehicle fuel systems.

Accelerated Thermal Stability

Diesel fuel should be stable under normal storage and use conditions. Unstable fuel will darken and form black particulate materials that will cloud fuels and create gum residues in the fuel system. The accelerated thermal stability test is intended to predict the resistance of fuel to degradation at normal engine operating temperature and to provide an indication of overall fuel stability.

Distillation

This property provides a measure of the temperature range over which a fuel volatilizes or turns to a vapor. Volatility is one of the primary factors that distinguish No. 1 fuel from No. 2 fuel. No. 1 diesel typically has greater volatility than No. 2. The highest temperature recorded during distillation is called the end point. However, because it is difficult to measure and duplicate a fuel's end point, the fuel's 90% to 95% distillation point is commonly used. The 95% distillation is the preferred point since it is not difficult to repeat and because it is closer to the fuel's end point than the 90% point currently measured in D975. Additionally, reporting the 10% distillation and 50% distillation points is recommended because they are part of the cetane index calculation. Equipment in applications that operate at low loads and frequent idle periods should benefit from a lower end point.

Sulfur

To assist diesel engine manufacturers in meeting mandated limits for particulate matter in diesel engine exhaust; sulfur content is limited by U.S. federal law to 0.05% for diesel fuel used in on-highway applications.

Copper Corrosion

The copper strip corrosion test indicates potential compatibility problems with fuel system components made of copper alloys such as brass or bronze. The limit requires that the fuel not darken these parts under the test conditions.

Flash Point

The flash point temperature of diesel fuel is the minimum temperature at which the fuel will ignite (flash) on application of an ignition source under specified conditions. Flash point varies inversely with the fuel's volatility. Flash point minimum temperatures are required for proper safety and handling of diesel fuel. Due to its higher flash point temperature, diesel fuel is inherently safer than many other fuels, such as gasoline.

Aromatics

This property is listed simply as a reminder that there are both federal and state limitations on diesel fuel aromatics content.

Kinematic Viscosity

Viscosity affects injector lubrication and fuel atomization. Fuels with low viscosity may not provide sufficient lubrication for the precision fit of fuel injection pumps or injector plungers, which may result in leakage or increased wear. Fuels that do not meet viscosity requirements can lead to performance complaints. Fuel atomization is also affected by fuel viscosity. Diesel fuels with high viscosity tend to form larger droplets on injection that can cause poor combustion and increased exhaust smoke.

Rams bottom Carbon Residue

The Rams bottom Carbon Residue test is intended to provide some indication of the extent of carbon residue that result from the combustion of a fuel. The limit is a maximum percentage of deposits by weight.

Ash Content

Ash is a measure of the amount of metals contained in the fuel. High concentrations of these materials can cause injector tip plugging. Combustion deposits and injection system wear. Soluble metallic materials cause deposits while abrasive solids will cause fuel injection equipment wear and filter plugging.

EMA Consensus Position

JOINT EMA/TMC PUMP GRADE SPECIFICATION FOR PREMIUM DIESEL FUEL

PROPERTY	TEST METHOD	RECOMMENDED VALUE
API GRAVITY***	D287*	39 MAX.
or		
BTU CONTENT***, GROSS	D2382	136,000 MIN.
CLOUD POINT, ^{o}C	D2500	4o C BELOW 10th percentile minimum ambient temperature
or		
LTFT	D4539	4o C BELOW 10th percentile minimum ambient temperature
CETANE INDEX	D4737	45 MIN.
CETANE NUMBER	D613	50 MIN.
LUBRICITY	D6078	3100g. MIN.
or	D6079	0.45mm dia. wear scar, max. @ 60oC
DETERGENCY	L10 - Injector	CRC Rating </= 10
	Deposit Test	% Flow Loss </= 6
WATER, PPM	D1744	200 MAX.
SEDIMENT, G/M3	D6217	10 MAX.
or		
SEDIMENT, MG/L	D2276 or 5452	10 MAX.
BACTERIA & FUNGUS	**	0 cfu/ml
ACCELERATED THERMAL STABILITY	OCTEL, F21	80% Reflectance
DISTILLATION, ^{o}C:	D86	
10%		REPORT
50%		REPORT
90%		332 MAX.
95%		355 MAX.

SULFUR, WT %	D2262	0.05 MAX. OR LEGAL
COPPER CORROSION	D130	3b MAX.
FLASH POINT, ^{o}C***	D92	52oC MIN. OR LEGAL (38 ^{o}C for winter)
AROMATICS, VOL.%	D1319	LEGAL
VISCOSITY, cST.@ 100F (40oC)***	D445	1.9 - 4.1 (1.7 for winter)
RAMSBOTTOM RESIDUE, %	D524	0.15 MAX.
ASH CONTENT, % WT.	D482	0.01 MAX
APPEARANCE	D4176	2 or less and no visible free water or sediment

*Numbers preceded by a 'D' refer to ASTM Standards; ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959

** Appropriate test procedures for bacteria and fungus are available from the American Society from Microbiology (ASM), 1325 Massachusetts Ave. N.W., Washington D.C.

*** In Extreme cold climate conditions described by ASTM 10th percentile temperatures below -10C in December, January, and February, the gravity, BTU, flash point and viscosity specification may be waved and the flash point and viscosity may deviate to the indicated values to achieve the desired cold flow

Technical Statement on the Use of Biodiesel Fuel in Compression Ignition Engines

Introduction

The Engine Manufacturers Association (EMA) is an international membership organization representing the interests of manufacturers of internal combustion engines. In 1995, EMA published a “Statement on the Use of Biodiesel Fuels for Mobile Applications.” Since that time, there has been increased worldwide interest in reducing reliance on petroleum-based fuels and improving air quality. This has led many stakeholders – including engine manufacturers – to continue investing in alternative, renewable fuels – including biodiesel fuels – as a substitute for conventional diesel fuel. In addition, recent government proposals in the United States and Europe have called for incentives or mandates to increase the production and use of renewable fuels.

The current statement, which takes into consideration additional laboratory and field research, conducted since the publication of the 1995 statement, sets forth EMA’s position on the use of biodiesel fuels with current engine technologies. It should be noted that only limited data are available regarding the use of biodiesel with those technologies that have been, or are about to be, introduced to meet the U.S. Environmental Protection Agency’s (EPA) 2004 heavy duty on-highway emission standards. Moreover, because of the absence of available data, the current

statement does not address the potential use of biodiesel fuels with advanced emission control technologies, including after-treatment systems designed for future ultra-low emission engines.

Biodiesel

Biodiesel fuels are methyl or ethyl esters derived from a broad variety of renewable sources such as vegetable oil, animal fat and cooking oil. Esters are oxygenated organic compounds that can be used in compression ignition engines because some of their key properties are comparable to diesel fuel. "Soy Methyl Ester" diesel (SME or SOME), which is derived from soybean oil, is the most common biodiesel in the United States. "Rape Methyl Ester" diesel (RME) derived from rapeseed oil, is the most common biodiesel fuel in Europe. Collectively, these fuels are sometimes referred to as "Fatty Acid Methyl Esters" (FAME). A process called transesterfication produces Biodiesel fuels. In transesterfication, in various oils (triglycerides) are converted into methyl esters through a chemical reaction with methanol in the presence of a catalyst, such a sodium or potassium hydroxide. The by-products of this chemical reaction are glycerol's and water, both of which are undesirable and need to be removed from the fuel along with traces of methanol, unreacted triglycerides and catalyst, such as sodium or potassium hydroxide. Biodiesel fuels naturally contain oxygen, which must be stabilized to avoid storage problems. Although biodiesel feedstock does not inherently contain sulfur, sulfur may be present in biodiesel fuel because of contamination during the transesterfication process and in storage.

Biodiesel Specifications

Biodiesel is produced in a pure form (100% biodiesel fuel, referred to as B100 or neat biodiesel) and may be blended with petroleum-based diesel fuel. Such biodiesel blends are designated as Bxx, where xx represents the percentage of pure biodiesel contained in the blend. Examples include B5 and B20.

Several standard-setting organizations worldwide have recently adopted biodiesel specifications. Specifically, ASTM International recently approved a specification for biodiesel referenced as D6751. In addition, German authorities have issued a provisional specification for FAME under DIN 51606. Europe's Committee for Standardization (CEN) is in the final stages of setting a technical standard for biofuels to be referred to as EN 14214.

The European specifications include more stringent limits for sulfur and water, as well as a test for oxidation stability, which is absent from the current ASTM specification. Depending on the biomass feedstock and the process used to produce the fuel, B100 fuels should meet the requirements of either ASTM D6751 or an approved European specification, such as DIN 51606 or EN 14214 (once adopted). In addition, it should be noted that the National Biodiesel Board has created the National Biodiesel Accreditation Commission to develop and implement a voluntary program for the accreditation of producers and marketers of biodiesel. The commission has developed a standard titled "BQ-9000, Quality Management System Requirements for the Biodiesel Industry," for use in the accreditation process.

Biodiesel Blends

Public and private bodies recently have taken positions regarding the use of biodiesel blends. For example, the U.S. Energy Policy Act of 1992 (EPAct) was amended in 1998 to allow covered fleets to use biodiesel to fulfill up to 50 percent of their annual alternative fuel vehicle (AFV) acquisition requirements. Under EPAct's Biodiesel Fuel Use Credits provisions, covered fleets are allocated on biodiesel fuel use credit – the equivalent of a full vehicle credit – for each 450 gallons of B100 purchased and consumed. Such credits are awarded only if the blended fuel contains at least 20 percent biodiesel (B20) and is used in new or existing vehicles weighing at least 8,500 pounds. No credits are awarded for biodiesel used in vehicles already counted as an AFV.

However, during the same period a consortium of diesel fuel injection equipment manufacturers (FIE Manufacturers) issued a position statement concluding that blends greater than B5 can cause reduced product service life and injection equipment failures. According to the FIE Manufacturers' Position Statement, even if the B100 used in a blend meets one or more specifications, "the enhanced care and attention required to maintain the fuels in vehicle tanks may make for a high risk of noncompliance to the standard during use." As a result, the FIE Manufacturers disclaim responsibility for any failures attributable to operating their products with fuels for which the products were not designed. Based on current understanding of biodiesel fuels and blending with petroleum based diesel fuel, EMA members expect that blends up to a maximum of B5 should not cause engine or fuel system problems, provided the B100 used in the blend meets the requirements of ASTM D6751, DIN 51606, or EN 14214. If blends exceeding B5 are desired, vehicle owners and operators should consult their engine manufacturer regarding the implications of using such fuel.

Engine Operation, Performance and Durability

The energy content of neat biodiesel fuel is about 11 percent lower than that of petroleum-based diesel fuel on a per gallon basis, which results in a power loss in engine operation. The viscosity range of biodiesel fuel is higher than that of petroleum-based diesel fuel (1.9 to 6.0 centistokes versus 1.3 to 5.8 centistokes), which tends to reduce barrel/plunger leakage and thereby slightly improve injector efficiency. The net effect of using B100 is a loss of approximately 5 percent to 7 percent in maximum power output. The actual percentage power loss will vary depending on the percentage of biodiesel blended into the fuel.

Any adjustment to the engine in service to compensate for such power loss may result in a violation of EPA's anti-tampering provisions. To avoid such illegal tempering, as well as potential engine problems that may occur if the engine is later operated with petroleum-based diesel fuel, EMA recommends that users not make such adjustments. Neat biodiesel and higher percentage biodiesel blends can cause a variety of engine performance problems, including filter plugging, injector coking, piston ring sticking and breaking, elastomer seal swelling and hardening/cracking, and severe engine lubricant degradation.

At low ambient temperatures, biodiesel is thicker than conventional diesel fuel, which would limit its use in certain geographic areas. In addition, elastomer compatibility with seals, hoses, gaskets, and wire coating should be monitored regularly. There is limited information about the effect of neat biodiesel and biodiesel blends on engine durability during various environmental conditions. More information is needed to assess the viability of using these fuels over the mileage and operating periods typical of heavy-duty engines. See: "Diesel Fuel Injection Equipment Manufacturers Common Position Statement on Fatty Acid Methyl Ester Fuels as a Replacement or Extender for Diesel Fuels." (May 1, 1998)

Emission Characteristics

In October 2002, the EPA released a draft report titled, "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions." The draft technical report can be found on the EPA website: http://www.epa.gov/otag/models/biodsl.htm. Use of neat biodiesel and biodiesel blends in place of petroleum-based diesel fuel may reduce visible smoke and particulate emissions, which are of special concern in older diesel engines in non-attainment areas. In addition, B100 and biodiesel blends can achieve some reduction in reactive hydrocarbons (HC) and carbon monoxide (CO) emissions when used in an unmodified diesel engine. Those reductions are attributed to the presence of oxygen in the fuel. Oxygen and other biodiesel characteristics, however, also increase oxides of nitrogen (NOx) in an unmodified engine. As a result, B100 and biodiesel blends produce higher NOx emissions than petroleum-based diesel fuel. As such, EMA does not recommend the use of either B100 or biodiesel blends as a means to improve air quality in ozone non-attainment areas.

Storage and Handling

Biodiesel fuels have shown poor oxidation stability, which can result in long-term storage problems. When biodiesel fuels are used at low ambient temperatures filters may plug and the fuel in the tank may thicken to the point where it will not flow sufficiently for proper engine operation. Therefore, it may be prudent to store biodiesel fuel in a heated building or storage tank, as well as heat the fuel systems' fuel lines, filters, and tanks. Additives also may be needed to improve storage conditions and allow for the use of biodiesel fuel in a wider range of ambient temperatures.

To demonstrate their stability under normal storage and use conditions, biodiesel fuels tested using ASTM D6468 should have a minimum of 80 percent reflectance after aging for 180 minutes at a temperature of 150° C. The test is intended to predict the resistance of fuel to degradation at normal engine operating temperatures and provides an indication of overall fuel stability. Biodiesel fuel is an excellent medium for microbial growth. Inasmuch as water accelerates microbial growth and is naturally more prevalent in biodiesel fuels than in petroleum-based diesel fuels, care must be taken to remove water from fuel tanks. The effectiveness of using conventional anti-microbial additives in biodiesel is unknown. The presence of microbes may cause operational problems, fuel system corrosion, premature filter plugging, and sediment build-up in fuel systems.

Health and Safety

Pure biodiesel fuels have been tested and found to be nontoxic in animal studies. Emissions from engines using biodiesel fuel have undergone health effects testing in accordance with EPA Tier II requirements for fuel and fuel additive registration. Tier II test results indicate no biologically significant short-term effects on the animals studied other than mirror affects on lung tissue at high exposure levels. Biodiesel fuels are biodegradable, which may promote their use in applications where biodegradability is desired – for example, marine or farm applications. Biodiesel is as safe in handling and storage as petroleum-based diesel fuel.

Warranties

Engine manufacturers are legally required to provide an emissions warranty on their products – which are certified to EPA's diesel fuel specification. They also typically provide commercial warranties. Individual engine manufacturers determine what implications the use of biodiesel fuel has on the manufacturers' commercial warranties. It is unclear what implications the use of biodiesel fuel has on emissions warranty, in-use liability, anti-tampering provisions and the like. As noted above, more information is needed about the impact of long-term use of biodiesel on engine operations.

Economics

The cost of biodiesel fuels varies depending on the base stock, geographic area, variability in crop production from season to season, and other factors. Although the cost may be reduced if relatively inexpensive feedstock – such as waste oils or rendered animal fat – is used instead of soybean, corn or other plant oil, the average cost of biodiesel fuel nevertheless exceeds that of petroleum-based diesel fuel. That said, users considering conversion to an alternative fuel should recognize that the relative cost of converting an existing fleet to biodiesel blends is much lower than the cost of converting to any other alternative fuel because no major engine, vehicle, or dispensing system changes are required.

EMA Conclusions

Depending on the biomass feedstock and the process used to produce the fuel, B100 fuels should meet the requirements of either latest revisions of ASTM D6751 or an approved European specification.

Biodiesel blends up to a maximum of B5 should not cause engine or fuel system problems, provided the B100 used in the blend meets the latest revisions of ASTM D6751 which as of this publication release is ASTM D 6751-07a, DIN 51606, or EN 14214. Most engine manufactures approve up to a B5 blend and possibly higher blends, engine manufacturers should be consulted when transitioning to biodiesel.

Biodiesel blends may require additives to improve storage stability and allow use in a wide range of temperatures. In addition, the conditions of seals, hoses, gaskets, wire coating, dispenser and vehicle fuel filters should be monitored regularly when biodiesel fuels are used

Although the actual loss will vary depending on the percentage of biodiesel blended in the fuel, the net effect of using B100 fuel is the loss of approximately 5 percent to 7 percent in maximum power output.

Historically B100 and biodiesel blends have reduced PM, HC and CO emissions and increase NOx compared with petroleum-based diesel fuel used in an unmodified diesel engine. However through more recent testing by National Renewable Energy Laboratory results show that NOx emissions are neutralized by utilizing B100 or biodiesel blends. Conversely NOx is reduced in heating oil applications consistent with the blend of biodiesel being used.

Biodiesel fuels have generally been found to be nontoxic and are biodegradable, which may promote their use in applications where biodegradability is desired.

Individual engine manufacturers determine what implications the use of biodiesel fuel has on the manufacturers' commercial warranties.

Although several factors affect the cost of biodiesel fuel, its average cost may exceed that of petroleum-based diesel fuel. However, the relative cost of converting an existing fleet to biodiesel blends is much lower than the cost of converting to other alternative fuels.

Appendix 3: Biodiesel Quality Assurance Program for the Fleet[25]

How to Buy Fuel

When purchasing bulk fuels, ask for the fuel specifications. Verify that the fuel properties are suitable for the intended use. If you are buying diesel fuel in the winter you should know what the documented cold weather characteristics are so that you can prepare accordingly for local climate conditions. Problem free fuel performance begins by demanding ASTM benchmarked fuels. Once you have obtained a quality fuel you must keep the fuel "on-spec." In other words, at the same ASTM quality as you originally received it. Ensuring that your fuel storage tanks are free of contamination, (most notably, free of water) is a positive step in preserving the quality specifications of the fuel which you have purchased.

An additional way to guarantee that you are starting with quality product is to obtain your biodiesel from BQ-9000 accredited producers or certified fuel marketers. Look for this symbol of quality. It is always an excellent idea to execute a simple field inspection of incoming fuel for cleanliness and haze which could indicate the presence of water or wax (in cold weather). Suspended water in fuel may result in water in all stages of fuel distribution system. Inspect regularly with all bulk quantities of fuel before accepting it for delivery. The purpose of this visual inspection is to prevent accepting fuel that may be currently impaired with contaminants and water. It is highly recommended that fleet managers regardless of the equipment secure a copy of the Fuel Quality and Performance Guide which contains step by step instructions covering fuel procurement, acquisition, storage and usage to begin to build a proactive fuel management program for his/her independent operation.

[25] Fuel Quality and Performance Guide, A troubleshooting checklist for diesel fuel, biodiesel and Bioheat users. Publication is sponsored by the United States Soybean Council and the Soybean Check off program, 2006, available through the National Biodiesel Board.

Figure 5: Example of Distillate Fuel Haze Rating Standard Using ASTM Clear and Bright Test

Pass, Pass, Fail, Fail, Fail, Fail

Fleet Fuel Purchasing Checklist

A great deal of information pertaining to biodiesel, diesel fuel and heating oil issues have been addressed throughout this comprehensive publication on fuel quality. In the end a professional fleet manager must assume responsibility to provide a clean storage tank to ensure a positive user experience with the fuel which you purchase.

Pre-Buy Considerations

1. Secure a reliable and trustworthy fuel distributor who takes time to discuss his/her company credentials and how they will benefit your operations.
2. Request that delivery personnel present at time of off-loading copies of BOL, (bill of lading) detailing type of fuel and quantity as well COA, (certificate of analysis) representing that the fuel is meeting ASTM specifications, (D6751, D975, D396 or specific blends of each).
3. When executing your supply agreement make sure that delivery personnel stick your storage vessel before and after the drop noting water accumulation on the delivery slip.
4. Regardless if you are purchasing biodiesel blended diesel fuel or generic diesel fuel specify during your negations what specific cold weather parameter you will require during the winter season. Be specific; if you wish to operate at -20F in January and February make sure that your supplier is capable of optimizing your blend to eliminate the guess work of your actual operability point. If you remember to specify your fuels cold flow values you will not need to labor over the type of feedstock that your distributor is accessing (biodiesel) to blend with your generic fuel, (remember the feedstock variables discussed on page 23.

Post-Buy Considerations

1. Have a company employee stick the storage vessel prior to the delivery and immediately following to confirm sticking values generated by truck delivery personnel, compare results with driver noting any discrepancies.
2. Retrieve (2) quart container running samples off the truck prior to off-loading into the storage vessel. Keep them available for possible analysis should fuel quality issues arise. Hold samples through the second re-supply of the tank. In the event testing is required offer your fuel supplier a sample of the retains so that they may round robin (exact tests) to eliminate technician error.
3. If any accumulated water is recognized remove it immediately, bulk storage, saddle tanks and water fuel separators.
4. Keep a log book of all inbound shipments as well water accumulation where appropriate.

Following these simple steps prior to and immediately following receipt of your fuel deliveries will ensure that you will reduce unscheduled vehicle downtime

Appendix 4: ASTM D 6751-07a

Biodiesel (B100)

Property	ASTM Method	Limits	Units
Flash Point	D93	130.0 min.	Degrees C
Water and Sediment	D2709	0.050 max	% vol.
KinematicViscosity,40C	D445	1.9 - 6.0	mm2/sec.
Sulfated Ash	D874	0.020 max.	% mass
Sulfur (S 15 grade)	D5453	0.0015 max.	ppm
Sulfur (S 500 grade)	D5453	0.05 max.	ppm
Copper Strip Corrosion	D130	No. 3 max.	
Cetane	D613	47 min.	
Cloud Point	D2500	Report Customer	Degrees C
*Carbon Residue	D4530*	0.050 max.	% mass
Acid Number	D664	0.50 max.	mg KOH/gm
Free Glycerin	D6584	0.020 max.	% mass
Total Glycerin	D6584	0.240 max.	% mass
Phosphorus Content	D4951	10 max	ppm
Distillation Temperature, Atmospheric Equivalent Temperature, 90% Recovered	D1160	360 max	Degrees C
Combined Na/K	EN 14538	5 ppm	ppm
Combined Ca/Mg	EN 14538	5 ppm	ppm
Oxidation Stability	EN 14112	3 min	hours
***Workmanship**	See below		

*Carbon residue, 100% of sample

*Workmanship, free of undissolved water, sediment & suspended matter

Bold criteria = BQ-9000 “Critical Specification Testing once production process under control.

Appendix 5: ASTM D 396

Heating Oil

Property	ASTM Method	Limits	Units
Flash Point	D93	38 min.	Degrees C
Water and Sediment	D2709	0.050 max	% vol.
KinematicViscosity,40C	D445	1.9 - 3.4	$mm^2/sec.$
Ash	D482	----------	% mass
Sulfur (Grade No.2)	D129	0.50 max.	% mass
Sulfur (Grade No. 2- Low Sulfur)	D2622	0.05 max.	% mass
Copper Strip Corrosion	D130	No. 3 max.	
Cetane	D613	----------	Degrees C
Pour Point	D97	-6	Degrees C
Cloud Point	D2500	----------	% mass
or			
LTFT/CFPP	D4539/D6371	----------	
Density, 15C	D1298	876	kg/m^3
Ramsbottom Carbon Residue	D524	0.35 max.	mg KOH/gm
Cetane Index	D 976	----------	
or			
Aromaticity	D1319	----------	% vol.
Distillation Temperature, 90% Recovered	D86	282-338	Degrees C

Appendix 6: Addressing Fuel Quality Deficiencies with Additives[26]

Many of the additives available for use in the middle distillates have the ability to affect either directly or indirectly, fuel properties and emission requirements of diesel engines
The various additives, their use, and their effects will be addressed in the following sections.

Cetane improvers are almost universally alkyl nitrates. They are used in variable concentrations based on the starting cetane value of the fuel being treated. Historically, the lower the cetane value the more challenging and expensive it will be to obtain desirable goals. For example, elevating a 40 rating to a 50 rating will be more costly than transitioning from 45 rating to a rating of 50. Up to a certain rating level, around 45 to 50, increasing the cetane number generally will improve starting, reduce smoke, noise, HC and CO emissions, and improve fuel economy.

The cetane number is measured using a cetane engine but estimates on cetane index are often used in the absence of an engine. Cetane index is based on physical properties and does not respond to cetane improver, which is its major disadvantage. It is also important that increasing the cetane value does not become an obsession because cetane values that are too high will cause thermal stability problems with the same fuel. This is an instance of more not being better.

Stability improvers have historically been nitrogen-based organic compounds that retard the oxidation and polymerization processes involving pyrrole and sulfur containing materials in both diesel fuel and heating oil. With the introduction of low sulfur diesel fuel in 1993, the hydro treating used to reduce sulfur has improved diesel fuel stability relative to color and sediment formation. However, some severely hydro treated fuels and the soon to arrive ultra low sulfur diesel fuel >15 ppm may tend to form peroxides during storage. That in turn requires some of these key additive compounds to maintain expected performance specifications. Stability improvers directly affect distillate performance by controlling formation of gums and insoluble's, which can block fuel filters and nozzles. That can cause restricted fuel flow and distorted spray patterns both in fuel injectors and burner nozzles. ASTM D2274 is currently used to determine oxidation stability to meet some diesel fuel specifications. Most often the ASTM D 6468 test method is used. This test predicts storage stability as does D2274, but also predicts thermal stability and is popular in the United States because it is quick. Thermal stability is important because of increasing hot fuel recirculation temperatures. Other lower temperature, one-term tests are also used to assess storage stability in laboratory evaluations such as the Octel-Starreon F31-81 test.

Biocides are used to deter growth of microorganisms in diesel fuel storage tanks, particularly in the water bottoms and on the vessel walls. These microorganisms can plug fuel lines on filters, stabilize emulsions and accelerate both gum formation and corrosion. Filter plugging is the first phenomenon observed but by the time that occurs, the other problems of emulsions, gum and corrosions may already be in advanced stages. Because of their relatively high cost and the concern of microbes developing immunity, biocides are not used on a continuous basis. They are most often only added on an as-needed basis, but are sometimes added quarterly or seasonally. Biocides are regulated because many of them are used in applications involving human contact.

[26] Innospec Fuel Specialties, Littleton, Colorado, 2006

If used properly, biocides are effective in controlling biological growth and the problems they introduce. An adjunct to their use is good housekeeping, including minimizing tank water bottoms.

Corrosion inhibitors provide protection to the entire system that comes into contact with the treated diesel fuel or heating oil. This includes refinery storage facilities, transportation vessels including pipelines, terminal storage tanks and end use vehicles. The inhibitor follows the fuel since all modern corrosion inhibitors are fuel soluble. Most inhibitors are based on some type of dimmer acid and, as such, are susceptible to salt formation and loss by extraction when contacted by caustic water carried over from the cracked stock treatment system. Good housekeeping is essential. By inhibiting corrosion, the chance of filter plugging by corrosion products is minimized and, of even greater value, the life of storage tanks and pipelines is substantially extended. As will be discussed later, corrosion inhibitors can also provide lubricity benefits by a mechanism similar to that which is responsible for corrosion inhibition.

Metal Deactivator is an additive of universal application in the petroleum industry. It is of value in all stocks from gasoline to lube oil, and from diesel fuel to home heating oil. It provides color and oxidation stability in diesel fuel. Its primary value is in chelating copper ions and preventing them from catalyzing gum forming oxidation reaction, which is abundant in heating oil. Pound for pound it is the most valuable additive for finishing petroleum products. As little as 1 mg/L can protect against copper ion contamination and boost the efficacy of antioxidants in the fuel.

Cold Flow Improvers are used seasonally to allow maximum performance in cold climates. They are the additives with the highest visibility in that their absence or failure to function will cause operational shutdown. The action of cold flow improver is to lower the operability temperature to either the pour point or cold filter plugging point. This is accomplished by interfering with or modifying the growth of wax crystals, which can pass through fuel filters.

In their absence, large wax crystals form which entrap the liquid fuel and creating non-filterable gel. Nearly all cold-flow improvers are based on ethylene/vinyl acetate copolymers known as EVAs. However, there are many variations involving other co-monomers in the chain or the use of anti-settling or anti-flocculation co-additives or the use of heavy wax modifiers. The combination of this unique cold flow system is quite formidable and capable of kerosene blending.

Treat level ranges are determined by region and temperature values as well as on how waxy the fuel is and the lowest operating temperature required. The most basic performance tests are pour point and cloud point, which represent the severity extremes. Many prefer the cold filter plugging point (CFPP, IP309) or the lowest temperature filterability test (LTFT, ASTM D4539) which are intermediate in severity between pour point and cloud point and also seem to correlate better with vehicle operating temperature requirements.

Anti-Haze Additives are sometimes added to diesel fuel packages to control possible water haze problems created by the addition of detergent. In other cases, the refiner may require the anti-haze or additive package to improve haze performance beyond that of untreated fuel. There is occasionally a request for spot treatment to settle water in a storage tank.

Anti-haze additive promotes rapid and clean separation of water dispersed in your middle distillates. In addition, it can minimize the thickness of any emulsion, which may form at the fuel/water bottom interface. This in turn allows the maximum amount of clear fuel to be pumped and also allows water bottoms to be drawn off without putting hydrocarbons in the water treating system.

Smoke Suppressants are categorized as combustion improvers. Smoke consists mainly of carbon particles or agglomerates plus associated condensed fuel. Smoke suppressants are organ metallic compounds generally of manganese, iron and barium. Barium used to be the most popular but is losing ground because of toxicity concerns. However, few if any of these products are currently used in the United States because of government registration limitations and because their use may actually increase particulate matter weight.

Cetane improver is also a type of combustion improver. Cetane improvers work by decomposing during combustion to produce free radicals, thereby enhancing the chain initiation rate of the diesel fuel and improving ignition characteristic. More recently, interest has focused on combustion improvers composed of a compound of copper, manganese or alkaline earth metals.

These improvers are intended to catalyze the combustion process by reducing the ignition temperatures. This would result in more complete combustion and, consequently, reduce emission levels. These types of additives could become increasingly important if particulate traps are employed where they would catalyze the combustion of deposited carbon to promote filter or trap regeneration. Products of this nature commonly have an increased cost in the range of .035 cents to .040 cents per gallon above conventional distillates.

Detergents for middle distillates are currently one of the more high profile additives used in the United States. Many markets are using detergent treatments to create a premium diesel fuel and home heating oil although the definition of premium diesel fuel is still the subject of much debate. Detergents are nitrogen based organic compounds, typically amines, amides or succinimides. They are used in varying percentages depending on the demands created by market drivers.

An effective detergent used at the correct concentration not only keeps injectors and oil burning nozzles clean but also can remove pre-formed deposits. By maintaining a clean injection system the diesel engine and oil burner will maintain lower emissions and continue to operate at peak efficiency. The distinction between keep – clean and clean – up is a gradual one. The detergent concentration therefore provides the basis for effective maintenance or improvement in emissions and economy in diesel powered engines.

Conductivity Improvers are different than the other additives under discussion in that they do not provide a fuel quality or engine performance benefit. These additives provide for electrostatic safety in the use and handling of diesel fuel and/or heating oil. When fuels are pumped or filtered, they develop a charge, which must be able to migrate through the bulk fuel to container wall, and that accumulated charge will cause a spark in the vapor space. If the vapor space has an explosive ration of air and fuel vapor, then an explosion can occur.

For that reason, it is important to provide a path for charge to migrate through the fuel by adding to the conductivity improver. Since conductivity increases proportionately with temperatures, use concentrations recommended by the fuel additive supplier. Grounding all vessels and transfer lines must be carefully maintained and safe-pumping procedures must also be followed.

Dyes are currently used in the United States to differentiate between on-highway diesel fuel, which is subject to a highway tax, and off-road and heating fuel, which are not taxed. There is very little difference between the two fuels, the main difference being that there is, of course, no cetane number specification on heating oil.

They can therefore be used interchangeably and dye is added to protect the tax revenue for the government. The most effective application of dye is to add it with the least costly fuel since blending of the cheaper fuel into the more expensive fuel would be most noticeable if the cheaper fuel is the one that is dyed.

In this case, when the heating oil or off-road diesel fuel is dyed in the United States the Internal Revenue Service stipulates the solvent Red 164 must be used at a strength equivalent to 11.1 mg/L of solvent. This a solid reference dye but nearly all refiners in the United States have converted to liquid dyes for ease of handling and to eliminate dusting exposure. Liquid dyes are available that are equivalent in shade but an up-treat is necessary to accommodate the strength difference between solid and liquid dyes. Like middle distillates, any biodiesel being blended into diesel fuel for off-road use must also be dyed in accordance with the information provided.

Deicers are used in diesel fuel in cold climates and low temperature seasons to prevent water that settles out of the diesel fuel from freezing. Diesel fuel leaves the refinery saturated with water, which could be up to 150 mg/L depending on the temperature and aromatic content of the diesel fuel. As the fuel cools, some of the dissolved water drops out of the solution. If it is allowed to freeze it could plug fuel line filters and starve the engine for fuel.

To prevent these water bottoms from freezing, refiners or marketers can elect to use a deicer or actually an anti-icer. Glycol ethers are quite effective and can be used to safely address moisture concerns.

Lubricity Additives have been used successfully for many years in jet fuel to solve fuel pump wear problems. Initially, the U.S. Military criterion was to require 50% more than the minimum necessary to control corrosion. More recently, lubricity tests have received some levels of general recognition and the jet fuel requirements are now also based on performance in the ball-on-cylinder lubricity evaluator (BOCLE). Tests have been developed that are being used in the industry such as scuffing load BOCLE and the high frequency reciprocating rig (HFRR).

At time of publication the chosen lubricity test chosen by by ASTM is the HFRR, ASTM D 6079. ASTM D 975 includes a <520 wear scar and is required for custody exchange no matter whether low sulfur diesel or ultra low sulfur diesel. The Engine Manufacturers of America require <460 wear scar under the D 6079 test standard

Sulfur compounds in diesel fuel convert to sulfate when combusted and these represent a major contribution to particulate matter. When hydro treating to reduce sulfur, the naturally occurring lubricity component in diesel is destroyed. Some acidic corrosion inhibitors have proven effective in providing lubricity and are widely used today to provide both features. In some cases, ester type additives have been adopted to address real and perceived needs for increased concentration of lubricity improver.

Anti Foaming additives are added to diesel fuel to prevent or reduce foaming especially during fueling. There are two principal advantages to the use of anti-foam: 1) The user will not get diesel fuel on their hands if foam is prevented from coming up and out of the filter nozzle; and 2) By preventing this foam-up, more fuel can be put into the tank at each fill up.

It is in the refiner's interest to take advantage of these benefits. Anti-foams are widely used in Europe. Diesel fuels are less viscous and lower boiling in the United States. Both those qualities tend to reduce foaming tendencies. This reduced tendency to foam, along with the fact that truckers use most diesel fuel in the United States, makes de-foaming less necessary. As a result, anti-foams are rarely used in the United States.

Summary of General Distillate Fuel Additives[27]

Cetane Improvers

- Easier starting
- Reduced smoke
- Less noise
- Reduce HC (Hydrocarbons) and CO (Carbon Monoxides) and NOx
- Improve fuel economy

Stability Improvers

- Historically nitrogen-based organics
- Best to add to cracked components
- Stability measured by ASTM D2274 and ASTM D 6468 method and F31 for home heating oil
- Reduces unscheduled service calls in home heating oil market segment

Biocides

- Usually nitromorpholines, triazines or boranes
- Used to control growth of microorganisms
- Decreases filter plugging, gum formation, and emulsions

[27] Innospec Fuel Specialties, Littleton, Colorado, 2007

- Used when needed or routinely but not continuously
- Not a substitute for good housekeeping and minimizing water bottom

Corrosion Inhibitors

- Most inhibitors are dimmer acids, transitioning to ester based
- By controlling corrosion, filter plugging is reduced and tank and pipeline life are extended
- Performance evaluated by NACE TM 0172 or ASTM D665

Metal Deactivator

- Pound for pound the most versatile additive available
- Based on salicyladehyde and diaminopropane
- Use concentration range 1-6 mg/L
- Chelates ionic copper and other metals
- Provides color protection and retards gum formation
- Also extends antioxidant effectiveness

Cold Flow Improvers

- Used seasonally to provide cold weather flow
- Functions by interfering with wax crystal growth
- Typical composition is ethylene vinyl acetate copolymer
- Use level depends on wax content and temperature
- Tests used are pour point, cloud point, cold filter plugging point and low temperature filterability test

Anti-Haze Additives

- Used to aid separation of fuel from water bottom
- Difficult to predict field result from lab test

Smoke Suppressants

- Smoke is mostly carbon particles plus condensed fuel
- Suppressants work by inhibiting cracking reactions
- Composition is generally based on metal salt
- Cetane improver is another type of combustion improver designed to reduce emissions
- More recent combustion improvers designed to reduce emissions
- Intended to catalyze combustion process
- May also promote filter or trap regeneration

Detergents/Dispersants

- Adopted in United States to create premium diesel and now premium heating oil
- Joint ASTM/NCWM committee created premium definition
- Clean injectors help maintain low emissions and good fuel economy

Conductivity Improvers

- Reduces electrostatic charge accumulation
- Reduces incidents of spark discharge
- Use concentration 1 mg/L to 2 mg/L in moderate climates
- Cold temperature may require up to 5 mg/L
- Goal is to provide minimum 50 pS/m conductivity

Dyes

- Used to differentiate fuels from one another, taxable or not
- Preferable to add to less expensive fuel
- Most dyes are azo compounds but some are anthraquinones
- Treat leave range from 5 mg/L up to 25 mg/L for gasoline and up to 25 mg/L for diesel

Deicers

- Used to prevent freezing of separated water
- Prevents fuel line and filter plugging
- Composition is generally glycol ether
- Used concentration is about 50 mg/L

Lubricity Additives

- Used to control wear in fuel delivery systems
- More critical issues with low sulfur fuels
- Hydro treating reduces sulfur and natural lubricants
- A must in <15 ppm Ultra Low Sulfur Fuel

Anti-Foam Additive

- Used to prevent foam during refueling
- Maximizes fuel drops, eliminates run outs, decreases delivery costs
- Foam-up prevents topping off tank
- Not widely used in the United States

Appendix 7: Diesel Fuel Properties – for #2 LSD/ULSD

D 975 – 06b vs. EMA FQP-1A

Property	ASTM Method	ASTM D975 Specifications	EMA *Guidelines* FQP-1A	NCWM Premium Diesel Definition *Recommendations*
Flash Point	D93	≥ 52ºC [≥ 125.6ºF]	≥ 52ºC [≥ 125.6ºF]	-
Appearance	D4176	-	≤2 & no visible free water or sediment	-
Water & Sediment	D2709	≤ 0.05% vol.	≤ 0.05% vol.	-
Water ppm	D1744	-	200 max	-
Sediment G/M^3 max	D6217 or D2276 or D5452	-	10 max	-
Distillation	D86		-	-
90% vol. recovered minimum temp.		≤ 300ºC [572ºF]		
90% vol. recovered maximum temp.	D86	≤ 356ºC [672ºF]	≤ 332ºC [≤629ºF]	-
95% vol. recovered maximum temp.	D86	-	≤ 355ºC [≤675ºF]	-
Kinematic Viscosity @ 40ºC	D445	1.9 – 4.1 cSt	1.9 – 4.1 cSt (1.7 for winter)	-
Ash	D482	≤ 0.01% mass	≤ 0.01% mass	-
Sulfur	D2662, D4294	≤ 0.05 % mass	≤ 0.05 % mass or legal	-
Ultra Low Sulfur Diesel	D5453	≤ 0.0015 % mass	-	-
Copper strip corrosion rating	D130	≤ 3	≤ 3b	-
Cetane Number	D613	≥ 40	≥ 50	≥ 47
OR - Calculated Cetane Index [may be used in lieu of cetane number]	D4737	≥ 40	≥ 45 (or does not apply)	-
Aromatics	D1319	≤ 35 % vol.	Legal	-
Low Temperature Operability by Cloud Point, LTFT, or CFPP	D2500 D5733 D4539 D6371	Recommend meeting ASTM D975 10th percentile minimum ambient air temperature	Seasonal – 4ºC below 10th percentile minimum ambient air temperature	Seasonal meet the ASTM D 975 10th percentile minimum ambient air temperature by D 2500 or D 4539
Ramsbottom Carbon Residue on 10% Bottoms	D524	≤ 0.35% mass max	≤ 0.15% mass max	-
API Gravity	D4052 D 287	-	39.0 max	-
Energy Content	D2382	-	136,000 min	-
Detergency, L10-IDT Rating	Cummins	-	≤10.0 Rating	
		-	≤ 6.0% Flow Loss	
Accelerated Stability	D6468 Octel F21-61	-	-	≥ 80% reflectance @ 180 minutes
Lubricity - HFRR	D6079	≤ 520 microns	≤ 450 microns	≤ 520 microns

U.S. Ultra Low Sulfur Diesel Fuel Properties

Engine manufacturers support the introduction and use of ultra low sulfur diesel fuel (i.e. fuel <15 ppm sulfur using ASTM D2622). The U.S. Environmental Protection Agency has adopted regulations establishing requirements for the introduction of ULSD. Meanwhile, many refiners are introducing ULSD fuel earlier than required and states, other jurisdictions, and users are considering incentive programs for its early introduction. In all such cases, engine manufacturers support uniform and consistent properties for ULSD fuel. In order to facilitate such uniformity, the Engine Manufacturers Association recommends that at a minimum all diesel fuel, including ULSD fuel, meet the requirements of ASTM D975 as well as the following additional performance requirements:

Cetane

Using ASTM D613, ULSD fuel should have a minimum cetane number of 40. Alternatively, to ensure a minimum cetane number of 40, ULSD should have a minimum cetane index of 42.5 using ASTM D4737-96a.

Lubricity

Using the SL BOCLE test method (ASTM D6078), ULSD fuel should demonstrate minimum lubricity of 3100 grams. Using the HFRR test method (ASTM D6079), the maximum lubricity of ULSD should be 450 micrometers at a temperature of 60° C.

Thermal Stability

Using ASTM D6468, ULSD fuel should have a minimum of 70 percent reflectance after aging for 180 minutes at a temperature of 150° C. Finally, in considering ULSD fuel properties, it is also important to recognize the need to maintain the cleanliness of ULSD from the time it leaves the refinery until it is delivered to the vehicle. Use of a filter smaller than five (5) microns at the point where the fuel is dispensed into the vehicle helps to assure the needed cleanliness.

Appendix 8: Information Resource Websites

National Biodiesel Board
www.biodiesel.org
800-841-5849

- BQ-9000 Accreditation Commission
  www.bq-9000.org
  573-635-3893

- Steel Tank Institute
  www.steeltank.com

- U.S. Environmental Protection Agency (EPA)
  www.epa.gov

- Petroleum Equipment Institute
  www.pei.org

- Thomas Register
  (To search for local labs in your area or testing equipment companies)
  www.thomasnet.com

- Biodiesel Magazine Industry Directory
  www.biodieselmagazine.com
  www.biodieselindustrydirectory.com

- National Renewable Energy Laboratory (NREL)
  2004 Biodiesel Handling & User Guidelines
  http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/tp31892.pdf

ASTM International Standards Worldwide, www.astm.org

Energy Information Agency, www.eia.doe.gov

Appendix 9: Engine Manufacturers' Biodiesel Statements

Manufacturer	Biodiesel Information
Case IH	http://www.caseih.com/highlights/highlights.aspx?navid=121&recordid=193&RL=ENNA
Caterpillar	http://www.cat.com/cda/components/fullArticle?m=37675&x=7&id=149474
Cummins	http://www.everytime.cummins.com/every/news/release99.jsp
Detroit Diesel	http://www.biodiesel.org/pdf_files/OEM%20Statements/2005_DDC_Statement.pdf
Fairbanks Morse	http://www.fairbanksmorse.com/file_system/fairbanksmorseengineapproves100biodiesel_copy_1.pdf
Ford Motor Company	https://www.fleet.ford.com/showroom/environmental_vehicles/biodiesel_vehicles.asp
General Motors	http://www.gm.com/explore/fuel_economy/altfuel/index.jsp
Honda	http://corporate.honda.com/images/banners/environment/Honda_2007_North_American_Environmental_Report.pdf
International	http://www.biodiesel.org/pdf_files/OEM%20Statements/2005_May_OEM_International.pdf
Isuzu	http://www.isuzucv.com/faqs/AlternativeFuel2004081110.html
John Deere	http://www.deere.com/en_US/rg/infocenter/infoevents/pr/2007/biodiesel.html
Kubota	http://www.biodiesel.org/pdf_files/OEM%20Statements/2006_OEM_kubota.pdf
Mack	http://www.biodiesel.org/pdf_files/OEM%20Statements/2007_OEM_MACK.pdf
Mercedes-Benz	http://www.mbusa.com/campaigns/alternative-fuels/index.do
New Holland	http://www.newhollandmediakit.com/index.cfm?fuseaction=newsreleases.DisplayNewsReleases&NewsID=166
UD Trucks/Nissan Diesel	http://www.biodiesel.org/pdf_files/OEM%20Statements/2006_Nissan.pdf
Volkswagen	http://www.biodiesel.org/pdf_files/OEM%20Statements/2005_OEM_VW%20US%20Biodiesel_Statement_5_16_05.pdf
Volvo	http://www.biodiesel.org/pdf_files/OEM%20Statements/2005_Volvo_Truck_Corporation.pdf