Fundamentals of Biodiesel

Four (4) Continuing Education Hours
Course #ME1275

Approved Continuing Education for Licensed Professional Engineers

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Course Description:

The Fundamentals of Biodiesel course satisfies four (4) hours of professional development.

The course is designed as a distance learning course that overviews biodiesel and biodiesel blends and practical guidelines for using in place of standard diesel.

Objectives:

The primary objective of this course is to enable the student to understand biodiesel and biodiesel blends, its characteristics, storage and safety issues, and procedures for using in compression-ignition engines and boilers.

Grading:

Students must achieve a minimum score of 70% on the online quiz to pass this course. The quiz may be taken as many times as necessary to successful pass and complete the course.

A copy of the quiz questions are attached to last pages of this document.

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Fundamentals of Biodiesel

Introduction

This course is a guide for those who blend, distribute, and use biodiesel and biodiesel blends. It provides basic information on the proper and safe use of biodiesel and biodiesel blends in engines and boilers, and is intended to help fleets, individual users, blenders, distributors, and those involved in related activities understand procedures for handling and using biodiesel fuels.

Biodiesel is manufactured from plant oils, animal fats, and recycled cooking oils and has several advantages. Biodiesel:

- Is renewable
- Displaces petroleum-derived diesel fuel
- Can be used in most diesel equipment with no or only minor modifications
- Can reduce global warming greenhouse gas emissions
- Is compatible with new technology diesel engines (NTDE) and emissions control devices
- Can reduce tailpipe emissions from older vehicles, including air toxics
- Is nontoxic, biodegradable, and suitable for sensitive environments
- Is produced domestically from agricultural or recycled resources.

In this course, biodiesel refers to the fuel produced from renewable sources that meets ASTM International (ASTM) Standard D6751-15cε1 (the latest standard for biodiesel used as a blendstock). A number following the letter "B" indicates the percent by volume (vol%) of biodiesel in a gallon of fuel; the remainder of the gallon can be No. 1 or No. 2 diesel, kerosene, Jet A, JP8, heating oil, or any other distillate fuel. Pure (or neat) biodiesel is also known as B100.

Biodiesel is most commonly used as a blend with petroleum diesel. At concentrations of up to 5 vol% (B5) in conventional diesel fuel, the mixture will meet ASTM D975 diesel fuel specification and can be used in any application as if it were neat petroleum diesel; for home heating oil, B5 will meet the ASTM D396 home heating oil specification.[1] At concentrations of 6% to 20% (B6 to B20), biodiesel blends can be used in many applications that use diesel fuel with minor or no modifications to the equipment, although not all engine manufacturers have approved these blends for use in their equipment. B6 to B20 blends are covered by ASTM Specification D7467-15cε1. Biodiesel can even be used as a fuel in its neat form (B100) if proper precautions are taken. Appendix A shows a sample Safety Data Sheet for biodiesel.

Commonly used blends are limited to B20 in the United States because this level provides a good balance between material compatibility, cold weather operability, performance, and emission benefits, as studied. B20 is also the minimum blend level allowed for compliance with the Energy Policy Act of 1992 (EPAct), which requires the use of renewable fuels and/or alternative fuel vehicles (AFVs) by certain covered fleets. Equip-

ASTM International (*astm.org*) is a consensus-based volunteer standards group that comprises experts across numerous industries. Committee D02, Petroleum Products, Liquid Fuels, and Lubricants, covers biodiesel, diesel, and heating oil specifications (in addition to many other products). Membership in D02 includes engine and fuel injection equipment companies, fuel producers, and fuel users. ASTM standards are recognized in the United States by most government entities. Specifications are living documents and may be updated frequently to reflect the most current needs of the industry. Any ASTM method or specification will include a number and a year, such as D6751-15cε1. This means the most current version of the method was published in 2015; a letter after the year indicates that more than one modification has been published in a given year. It is up to users to ensure they are using the most up-to-date version of a test method or specification.

1. The ASTM standard for B100 to be used as a blend stock is D6751. Diesel fuel is defined in ASTM D975. ASTM D396 defines heating oils. A-A-59693A defines B20 for military use.

ment that can use B20 includes diesel engines, fuel oil and heating oil boilers, and turbines.

Higher blend levels such as B50, and B100 require special handling and may require equipment modifications. These issues can potentially be managed with heaters and/or changing engine seal and gasket materials. Consult your engine or combustion equipment manufacturer for further information about procedures before using biodiesel blends higher than B20.

Biodiesel Basics

This section provides a basic overview of biodiesel. You can also refer to Section 9 (Frequently Asked Questions) for answers to general questions from your management, customers, or reporters. Technical details about many aspects of biodiesel are provided in Sections 3 to 8.

What is Biodiesel?

Biodiesel is a diesel replacement fuel for use in diesel engines. It is manufactured from plant oils (e.g., soybean oil, cottonseed oil, canola oil, corn oil); recycled cooking greases or oils (e.g., yellow grease); or animal fats (beef tallow, pork lard); and various combinations of these feedstocks. Used cooking oils are mostly plant based, but may also contain animal fats. Used cooking oils are both recycled and renewable.

As biodiesel production and use increase, new feedstocks are being developed and may soon be introduced into the market. Some examples include pennycress, camelina, cuphea, brown grease, and various strains of algae. Although there is little biodiesel from these feedstocks currently available, there is great potential for these feedstocks to supplement the current feedstock supply.

The biodiesel manufacturing process converts oils and fats into chemicals called long-chain mono alkyl esters, or biodiesel. These chemicals are also referred to as fatty acid methyl esters (FAME), and the process is referred to as esterification. Figure 1 provides a simplified diagram of the esterification process. Roughly speaking, 100 pounds of oil or fat are reacted with 10 pounds of a short-chain alcohol (usually methanol) in the presence of a catalyst (usually sodium hydroxide or potassium hydroxide) to form 100 pounds of biodiesel and 10 pounds of glycerin (or glycerol). Glycerin is a sugar and is a co-product of the biodiesel process.

Biodiesel is a legally registered fuel and fuel additive with the U.S. Environmental Protection Agency (EPA). The EPA registration is feedstock and process agnostic and includes all biodiesel that meets the ASTM biodiesel specification, ASTM D6751.[2]

Straight Vegetable Oil and Other Products

Raw or refined plant oils, fats, or recycled greases that have not been processed into biodiesel, such as straight vegetable oil (SVO), are not biodiesel and should be avoided. Research shows that plant oils, animal fats, and/or greases used in diesel engines, even at concentrations as low as 1%, can cause long-term engine deposits, ring sticking, lube oil gelling and other maintenance problems, and can reduce engine life. These problems are caused mostly by the much higher viscosity, or thickness, of the raw fats and/or oils (around 40 square millimeters per second [mm^2/s]) compared to that of diesel fuel, for which the engines and injectors were designed (1.3 to 4.1 mm^2/s). The significantly higher boiling point of raw fats and oils may also lead to failure of the fuel to fully evaporate, especially during cold start, leading to harmful engine deposits and engine oil sludging. Through the process of converting plant oils or greases to biodiesel by esterification, the viscosity and boiling point of the fuel are reduced to values more similar to conventional diesel fuel (biodiesel viscosity values are typically 4 to 5 mm^2/s).

2. astm.org.

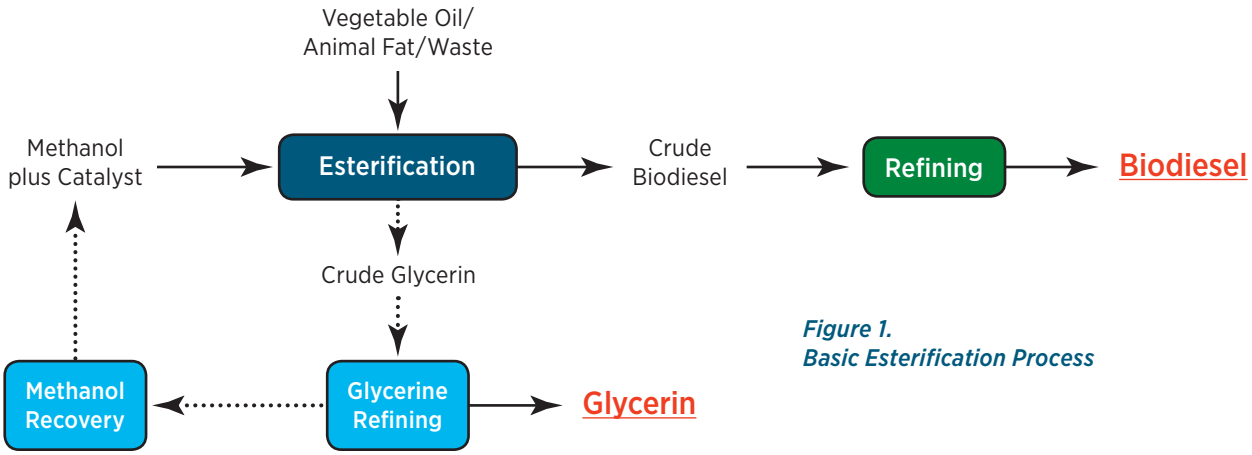

Figure 1.
Basic Esterification Process

Other products, many of which are offered to consumers without the benefit of EPA registration, ASTM specifications, or extensive testing and demonstrations, may be mislabeled as "biofuels," "renewable diesel," or even as "biodiesel." It is up to the consumer to be aware of what they are purchasing. If you purchase methyl esters that do not meet ASTM biodiesel standards, it is not legal biodiesel and should not be used in diesel engines or other equipment designed to operate on diesel fuel. Methyl esters are used as an industrial lubricant and solvent in some applications, so be sure to purchase only ASTM D6751-grade methyl esters (biodiesel) for use in diesel engines.

Specifications and Regulations

Specification D6751 is based on a compilation of efforts from researchers, engine manufacturers, petroleum companies and distributors, and many other fuel-related entities and is intended to ensure the quality of biodiesel used as a blendstock at 20% (B20) and lower blend levels. Any biodiesel used in the United States for blending should meet ASTM D6751 standards. The ASTM standards provide a minimum level of quality for biodiesel regardless of the source of the fuel. Purchasers and sellers can require that biodiesel meet more stringent requirements in purchasing specifications. Both parties must agree to these more stringent requirements, and this is becoming an increasingly common practice.

The ASTM D6751 definition of biodiesel states that biodiesel is composed of "mono-alkyl esters of long-chain fatty acids derived from plant oils or animal fats." The term mono-alkyl esters indicates that biodiesel contains only one ester linkage in each molecule. Raw or refined plant oils, animal fats, and greases contain three ester linkages and are therefore not legally biodiesel. Biodiesel can be made from methyl, ethyl, isopropyl, and other alcohols. Virtually all commercial biodiesel production in the United States today is based on methyl esters. Some research has been conducted on ethyl esters (biodiesel produced with ethanol as the alcohol rather than methanol); however, higher ethanol prices relative to methanol, lower ethyl ester conversions, and the difficulty of recycling excess ethanol from the finished biodiesel have hampered ethyl ester production in the marketplace. Therefore, in this course we will consider only methyl esters.

The definition of biodiesel recognized by both the EPA for fuel registration purposes and the Internal Revenue Service for the blender's tax credit is essentially the same as the definition in ASTM D6751:

> *"A fuel comprised of mono-alkyl esters of long-chain fatty acids derived from vegetable oils or animal fats, designated B100, and meeting the requirements of ASTM D6751."*

EPAct requires that certain federal, state, and alternative fuel provider fleets acquire a fixed percentage (75% or 90%) of AFVs each year based on the total number of light-duty vehicles they acquire. A light-duty vehicle that is approved by the original equipment manufacturer (OEM) to operate on B100 or a biodiesel blend of B20 or higher qualifies as an AFV under EPAct. As of 2015, there are no light-duty vehicles on the market approved to operate on B100, but there are many that are approved to operate on B20. Neat biodiesel may be more expensive than other alternative fuel options, and OEMs have shown little interest in obtaining approval for on-road vehicles to operate on B100.

Congress amended EPAct through the Energy Conservation Reauthorization Act of 1998. Among other things, the Energy Conservation Reauthorization Act added Section 312 to EPAct, thereby enabling covered federal, state, and alternative fuel provider fleets to earn AFV credits for their use of B20 or higher blends in medium- or heavy-duty vehicles (those vehicles with a gross vehicle weight rating of more than 8,500 pounds), with some limitations. This provision has created significant demand for B20 among government and alternative fuel provider fleets (Appendix B).

How is Biodiesel Different than Renewable Diesel?

Renewable diesel is a hydrocarbon diesel fuel produced from renewable feedstocks. Today, all renewable diesel on the market is, like biodiesel, produced from fats and oils. The way these fats and oils are reacted into fuels is the defining difference between biodiesel and renewable diesel. As discussed above, biodiesel is primarily made through esterification. Renewable diesel is produced by hydroprocessing of fats and oils. Hydroprocessing produces alkanes, which are chemically identical to some of the compounds found in conventional diesel fuel. The properties of renewable diesel are also different from biodiesel. Like biodiesel, renewable diesel has near-zero aromatic content and very low sulfur content. It typically has a very high cetane number and a cloud point more like conventional diesel fuels. When used as a neat fuel (RD100), RD100 qualifies as an EPAct alternative fuel, while lower blends, such as RD20, do not.

The only way to determine if diesel fuel has been blended with renewable diesel fuel is through carbon dating using ASTM D6866. In this method, the isotopic ratio of fossil to biological carbon is quantified. Petroleum diesel will be wholly fossil carbon, while the renewable diesel (or biodiesel) content will be identified as biogenic carbon.

Benefits of Biodiesel Use

Biodiesel Reduces Greenhouse Gas Emissions

When biodiesel displaces petroleum, it significantly reduces life-cycle greenhouse gas emissions. Life cycle analysis completed by Argonne National Laboratory found that greenhouse gas emissions for B100 are 74% lower than those from petroleum diesel. More recently, the California Air Resources Board (CARB) reported similar values for its life-cycle analysis of biodiesel from various sources.[3]

When oilseed plants grow, they take carbon dioxide (CO_2) from the air to make the stems, roots, leaves, and seeds. After the oil is extracted from the oilseeds, it is converted into biodiesel. When the biodiesel is burned, CO_2 and other emissions are released and returned to the atmosphere. On balance, most of this emitted CO_2 does not add to the net CO_2 concentration in the air because the next oilseed crop will reuse the CO_2 as it grows. A small fraction of the emitted carbon is fossil derived because of fossil fuel and chemicals used in farming and in the biodiesel production process.

Biodiesel Reduces Tailpipe Emissions

Testing to date shows that biodiesel is fully compatible with the emission control catalysts and filters that dramatically reduce nitrogen oxides (NO_x) and particulate matter (PM) emissions from new diesel engines (sometimes called NTDEs). The effects are feedstock neutral for biodiesel. Research is ongoing to determine whether the current biodiesel specification contains adequate protection for NTDE emission control catalysts and filters.

NO_x emissions have been a concern with older-technology diesel engines and biodiesel. Some of these concerns about emissions have been mitigated by replacing older engines with newer engines. CARB has stated that implementation of NTDEs will eliminate any fuel-related NO_x impacts.[4,5] CARB-certified post-2010 model year vehicles are considered NTDEs.

Table 1. Biodiesel Blend Levels Requiring NO_x-reducing Additives

Type of B100	Time of Year	Blend Level
High-saturation feedstock (cetane ≥ 56)	All year	B10+
Low-saturation feedstock (cetane < 56)	Low ozone season – November 1 to March 31	B10+
Low-saturation feedstock (cetane < 56)	High ozone season – April 1 to October 31	B5+

In late 2015, California set new regulations for the use of biodiesel in California. Blends above the concentration levels shown in Table 1 must include a NO_x-reducing additive.

Exemptions from the requirements in Table 1 are made for the use of B20 for certain fleets that have more than 90% light- and medium-duty vehicles or fleets with heavy-duty vehicles with NO_x-neutral technologies and fleets with NTDEs. In addition, the exemption is in place for retail stations that serve markets where 90% of the fleet is light- and medium-duty vehicles or NTDEs. The requirement for NO_x-reducing additives will sunset when post-2010 model year vehicles comprise 90% of all heavy-duty miles traveled in the state of California, estimated to be in 2023.[6]

Off-road diesel engines have long benefited from emissions reductions using biodiesel blends. With the reduction in the sulfur content of off-road diesel to the

3. California Air Resources Board, *arb.ca.gov/fuels/lcfs/lcfs_meetings/040115_pathway_ci_comparison.pdf* accessed November 2, 2015.
4. California Air Resources Board, *arb.ca.gov/fuels/diesel/altdiesel/021314_PublicMeetingPres.pdf*, February 13, 2014.
5. Lammert, M., R. McCormick, P. Sindler, and A. Williams. 2012. "Effect of B20 and Low Aromatic Diesel on Transit Bus NO_x Emissions Over Driving Cycles with a Range of Kinetic Intensity." *SAE Int. J. Fuels Lubr.* 5(3):1345-1359 doi:10.4271/2012-01-1984. *papers.sae.org/2012-01-1984/.*
6. California Air Resources Board. 2015. *Proposed Regulation on the Commercialization of Alternative Diesel Fuels, Staff Report: Initial Statement of Reasons for Proposed Rulemaking.*

same ultra-low levels as on-road diesel, more and more off-road equipment is using emission control equipment. Similar to on-road engines, biodiesel is fully compatible with these advanced technologies.

When biodiesel is used in boilers or home heating oil applications, NO_x tends to decrease because the combustion process is different (open flame for boilers, enclosed cylinder with high-pressure spray combustion for engines). The NO_x reduction seen with biodiesel blends used in boilers also appears to be independent of the type of biodiesel used. In blends with heating oil up to B20, NO_x is reduced linearly with increasing biodiesel content. For every 1% biodiesel added, NO_x decreases by 1%. A B20 heating oil fuel will reduce NO_x by about 20%.[7,8] The sulfur content of heating oil is steadily being reduced to the same levels found in on- and off-road diesel fuel. Requirements for reductions have already been enacted in New York and Connecticut, with the rest of New England following suit in coming years.[9]

Biodiesel and Human Health

An active research area is the impact of biodiesel and its blends on human health. PM and hydrocarbon emissions from diesel engines may be toxic and/or carcinogenic. There is a wide range of literature available on this subject (see for example[10, 11, 12]). In 2011, the U.S. Department of Labor Mining Safety and Health Administration implemented rules for underground mines that limit worker exposure to diesel PM. The Mining Safety and Health Administration found that switching from petroleum diesel fuels to high blend levels of biodiesel (B50 to B100) significantly reduced PM emissions from underground diesel vehicles and substantially reduced worker exposure. However, even low concentrations of biodiesel reduce PM emissions and provide significant health and compliance benefits wherever humans receive higher levels of exposure to diesel exhaust.

Biodiesel Improves Engine Operation

Biodiesel, even in very low concentrations, improves fuel lubricity and increases the cetane number of the fuel. Diesel engines depend on the lubricity of the fuel to keep moving parts, especially fuel pumps and injectors, from wearing prematurely. To address the reduced natural lubricity of ultra-low sulfur diesel, Specification ASTM D975 for diesel fuel was modified to add a lubricity requirement (a maximum wear scar diameter on the high-frequency reciprocating rig [HFRR] test of 520 microns). Biodiesel can impart adequate lubricity to diesel fuels with poor natural lubricity at blend levels as low as 1%.

Biodiesel Is Easy to Use

Finally, one of the biggest benefits to using biodiesel is that it is easy to use. Blends of B20 or lower require no new equipment or equipment modifications. B20 can be stored in diesel fuel tanks and pumped with the same equipment as diesel fuel. B20 does present a few unique handling and use precautions, but most users can expect a trouble-free B20 experience.

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8. Batey, J.E. 2002. Interim report of test results, Massachusetts Oilheat Council Biodiesel Project.
9. U.S. Energy Information Adminstration. 2013. "Heating Oil Futures Contract Now Uses Ultra-Low Sulfur Diesel Fuel." *eia.gov/todayinenergy/detail.cfm?id=11211*.
10. Steiner, Sandro, Jan Czerwinski, Pierre Comte, Olga Popovicheva, Elena Kireeva, Loretta Müller, Norbert Heeb, Andreas Mayer, Alke Fink, and Barbara Rothen-Rutishauser. 2013. "Comparison of the Toxicity of Diesel Exhaust Produced by Bio- and Fossil Diesel Combustion in Human Lung Cells in Vitro." *Atmospheric Environment 81:380-388*. *dx.doi.org/10.1016/j.atmosenv.2013.08.059*.
11. Bass, Virginia L., Mette C. Schladweiler, Abraham Nyska, Ronald F. Thomas, Desinia B. Miller, Todd Krantz, Charly King, M. Ian Gilmour, Allen D. Ledbetter, Judy E. Richards, and Urmila P. Kodavanti. 2015. "Comparative Cardiopulmonary Toxicity of Exhausts from Soy-Based Biofuels and Diesel in Healthy and Hypertensive Rats." *Inhalation Toxicity* 27(11):545-556. *dx.doi.org/10.3109/08958378.2015.1060279*.
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Other Biodiesel Attributes

Lower Energy Density

Neat biodiesel contains about 8% less energy per gallon than typical No. 2 diesel in the United States, or 12.5% less energy per pound. The difference between these two measurements is due to the higher density of biodiesel compared to diesel fuel. All biodiesel, regardless of its feedstock, provides about the same amount of energy per gallon or per pound. The energy content of petroleum diesel fuel typically varies more widely than that of biodiesel. However, some reference values are:

	Btu/lb.	Btu/gal
Typical Diesel No. 2	18,238	129,488
Typical biodiesel (B100)	16,377	119,550

**Btu = British thermal unit*

The difference in energy content between petroleum diesel fuel and biodiesel can be noticeable with B100. For B20, the differences in power, torque, and fuel economy are 1% to 2%, depending on the base petroleum diesel fuel. Most users report little difference in fuel economy between B20 and No. 2 diesel fuel. Any differences between B20 and No. 2 diesel fuel are about the same as would be expected between summer and winter diesel. As the biodiesel blend level is lowered, differences in energy content become proportionally less significant: blends of B5 or lower cause no noticeable differences in performance compared to No. 2 diesel.

Low-Temperature Operability

In many areas of the country, the cold flow properties of biodiesel are important. Unlike gasoline, petroleum diesel and biodiesel may freeze or gel at common winter temperatures; however, biodiesel's cloud point (the temperature at which crystals begin to form) can be significantly higher than that of petroleum diesel. If the fuel begins to gel, it can clog filters and eventually become so thick that it cannot be pumped from the fuel tank to the engine. However, with proper blending and handling, B20 has been used successfully all year in the coldest U.S. climates.

Soy biodiesel, for example, has a cloud point of 0°C (32°F). In contrast, different petroleum diesels have a wide range of cloud points. Petroleum diesel cloud points can be as low as -45°C (-49°F) or can be higher, such as -7°C (19°F), depending on time of year and region of the country. Blending of biodiesel can raise the cloud point above that of the original diesel fuel, depending on the starting cloud point of the diesel fuel. For example, a recent study[13] showed that when soy biodiesel was blended into a specially formulated cold weather diesel fuel (cloud point of -38°C [-36°F]) to make a B20 blend, the cloud point of that blend was -20°C (-4°F). In very cold climates, this cloud point may not be adequate for wintertime use. To accommodate biodiesel in cold climates, low-cloud point petroleum diesel or low-temperature flow additives, or both, are necessary. Another option is to reduce the percentage of biodiesel in the blend. Generally speaking, with the same biodiesel and diesel fuel, a B10 will have better cold weather operability properties than a B20.

Stability in Extended Storage

Although biodiesel blends have adequate storage stability for normal use, special precautions must be taken if they are to be stored for extended periods. This might occur in seasonal equipment, like a snow plow or farming equipment, or in the fuel tank of a backup generator. If the fuel will be stored for more than a few months, a stability additive is recommended, and oxidation stability should be measured monthly.

Finally, biodiesel is generally more susceptible than petroleum diesel to microbial degradation. In the case of spills in the environment, this is a positive attribute because it biodegrades more rapidly. However, microbial contamination of fuel storage tanks can plug dispensers and vehicle fuel filters and cause vehicles to stall. This is not unheard of for petroleum diesel, but anecdotal evidence suggests it is a greater problem for biodiesel blends. The best way to deal with this issue (for both petroleum diesel and biodiesel) is adequate fuel storage tank housekeeping and monitoring, especially minimizing water in contact with the fuel. Water bottoms must be removed from tanks, and standing tanks should be sampled and tested for microbial contamination.

13. Coordinating Research Council. 2006. Biodiesel Blend Low-Temperature Performance Validation. *crcao.com/reports/recentstudies2008/DP-2a-07/CRC%20650.pdf*.

Biodiesel (B100)

This section describes the basic considerations for handling and blending B100. In the United States, it is equally common to handle B99 and B99.9 blends. The considerations in this section also apply to B99 and B99.9, as these fuel blends often qualify for a tax credit for biodiesel blending. At the time of this writing (2016), a tax credit for blending biodiesel is available through 2016. The storage and handling procedures for B100 are very different than for B20 and lower biodiesel blends and vary significantly from those for diesel fuel. Table 2 lists some of the physical and chemical properties of B100 and petroleum diesel. Using B20 and lower blends significantly reduces or eliminates the effects of these property differences for use as an engine fuel. However, because many distributors store and handle B100 before blending, a good understanding of B100 properties is valuable. Several significant attributes specific to B100 that should be considered when handling, storing, and using it are described below.

- **B100 is a good solvent.** It may loosen or dissolve varnish and sediments in fuel tanks and fueling systems left by conventional diesel over time. If a system contains sediments, the tanks and fuel system should be cleaned before B100 is handled or used. A good indication that B100 is cleaning the tank is an initial increase in filter plugging. Over time, filter change intervals should return to normal. This should not be an issue for B20 or lower blends.
- **B100 gels at higher temperatures than most diesel fuel.** This must be taken into account if handling or using B100, especially in aboveground storage tanks (ASTs). The temperature where B100 starts to gel will vary with the feedstock and can range from 0°C to 15°C (32°F to 60°F) or higher, so heated fuel lines and tanks may be needed during winter, even in moderate climates. As B100 begins to gel, the viscosity rises to much higher levels than most diesel fuel, which can increase the stress on

Table 2. Select Properties of Typical No. 2 Diesel and Biodiesel Fuels

Fuel Property	Diesel	Biodiesel, No. 1-B grade
Fuel standard	ASTM D975	ASTM D6751
Higher heating value, Btu/gal Lower heating value, Btu/gal	~138,490 ~129,488	~127,960 ~119,550
Kinematic viscosity, @ 40°C (104°F)	1.3 – 4.1	4.0 – 6.0
Specific gravity @ 15.5°C (60°F)	0.85	0.88
Density, lb/gal @ 15.5°C (60°F)	7.1	7.3
Carbon, wt %	87	77
Hydrogen, wt %	13	12
Oxygen, by dif. wt %	0	11
Sulfur, wt % (parts per million [ppm])	0.0015 max. (15 ppm max.)	0.0 – 0.0015 (0 – 15 ppm)
Boiling point, °C (°F)	180 – 340 (356 – 644)	315 – 350 (599 – 662)
Flash point, °C (°F)	60 – 80 (140 – 176)	100 – 170 (212 – 338)
Cloud point, °C (°F)	-35 – 5 (-31 – 41)	-3 – 15 (26 – 59)
Pour point, °C (°F)	-35 – -15 (-31 to 5)	-5 – 10 (23 – 50)
Cetane number	40 – 55	47 – 65

pumps. The high cloud point of B100 makes its use challenging in colder climates.

- **B100 is not compatible with some hoses and gaskets.** B100 may soften and degrade certain types of rubber compounds used for hoses and gaskets (buna-N, nitrile, natural rubber) and may cause them to leak and degrade to the point where they crumble and become useless. For bulk handling of B100, seals, gaskets, and hoses must be compatible with B100. (See Appendix C for information about material compatibility.) Using B100 in an engine constructed with incompatible materials can cause a fuel spill on a hot engine, ruin a fuel pump, or clog a filter as the hose material gradually erodes. Use extreme care to ensure that any part of the fuel system that touches the fuel is compatible with B100. Some systems may employ certain grades of Viton, which are biodiesel-resistant materials, but many do not, because these materials are usually slightly more expensive.
- **B100 is not compatible with some metals and plastics.** Biodiesel will degrade and form high sediment levels if contacted for long periods by copper or copper-containing metals (brass, bronze) or with lead, tin, or zinc (galvanized surfaces). These high sediment levels may clog filters. B100 may also permeate some common plastics (polyethylene, polypropylene) over time, so these should not be used for storing B100.

B100 Quality Specification

The specification for biodiesel (B100) is frequently updated, and as of this writing the most current version is D6751-15cε1, summarized in Table 3. For the most up-to-date version of the specification, check the ASTM website (*astm.org*).

In 2012, a new grade of B100 was added to the D6751 specification. This new grade is referred to as the No. 1-B grade and is a special-purpose grade of biodiesel meeting more stringent purity requirements intended to provide better low-temperature performance. Most biodiesel produced at the time of publication is No. 1-B grade. This grade may be required in certain applications, but it is up to the customer to select the proper grade of biodiesel for their application.

Specification D6751 is intended to ensure the quality of biodiesel to be used as a blend stock in middle distillates, like diesel fuel and heating oil, at 20% and lower levels. Any biodiesel used in the United States should meet ASTM D6751 before blending. ASTM D6751 is based on the physical and chemical properties needed for safe and satisfactory diesel engine and boiler operations. It is not based on the specific raw materials or the manufacturing process used to produce the biodiesel. The finished blend stock must meet the properties specified in Table 3 as well as the following definition from D6751:

Table 3. Requirements for Biodiesel (B100) Blend Stock as Listed in ASTM D6751-15cε1

Property	Test Method	Grade No. 1-B, S15	Grade No. 1-B, S500	Grade No. 2-B, S15	Grade No. 2-B, S500
Sulfur, % mass (ppm), max	D5453	0.0015 (15)	0.05 (500)	0.0015 (15)	0.050 (500)
Cold soak filterability, s, max	D7501	200	200	360	360
Monoglycerides, % mass, max	D6584	0.40	0.40	–	–
		Requirements for All Grades			
Calcium and magnesium, combined, ppm, max	EN14538	5			
Flash point (closed cup), °C, min	D93	93			
Alcohol Control One of the following shall be met: 1. Methanol Content, mass %, max 2. Flash Point, °C, min	 EN14110 D93	 0.2 130			

Table 3 continued on next page

Table 3 *(cont.)*. Requirements for Biodiesel (B100) Blend Stock as Listed in ASTM D6751-15cε1

Property	Test Method	Grade No. 1-B, S15	Grade No. 1-B, S500	Grade No. 2-B, S15	Grade No. 2-B, S500
		Requirements for All Grades			
Water and sediment, % volume, max	D2709	0.050			
Kinematic viscosity, mm^2/s, 40°C	D445	1.9 – 6.0			
Sulfated ash, % mass, max	D874	0.020			
Copper strip corrosion, max	D130	No. 3			
Cetane number, min	D613	47			
Cloud point, °C	D2500	Report			
Carbon residue, % mass, max	D4530	0.050			
Acid number, mg KOH/g, max	D664	0.50			
Free glycerin, % mass, max	D6584	0.020			
Total glycerin, %mass, max	D6584	0.240			
Phosphorus content, % mass, max	D4951	0.001			
Distillation temperature, 90% recovered, °C, max	D1160	360			
Sodium and potassium, combined, ppm, max	EN14538	5			
Oxidation stability, hr, min	EN15751	3			

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"Biodiesel, noun, a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100."

This specification was never intended to be applied to B100 to be used as a neat fuel. However, buyers and sellers are encouraged to use ASTM D6751 for the commercial trading of biodiesel (B100) for blending. Other arrangements or specifications can be legally used if the buyer and seller agree as long as they meet pertinent local, state, and federal regulations (EPA sulfur limits, Occupational Safety and Health Administration [OSHA] safety limits on flash point, etc.). However, B100 must meet the requirements of D6751 for blends to be legal fuels under the Clean Air Act fuel registration requirements and to be a legal blending component under many state regulations.

The intent of each quality requirement in Table 3 is described here:

- **High levels of Group I and II metals.** Sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg) can cause deposits to form, catalyze undesired side reactions, and poison emission control equipment. The Group I and II metals are limited as the combination of metals in each category, Na+K and Ca+Mg. The specification upper limit is 5 parts per million (ppm), combined, for each pair of metals. Research is ongoing to determine whether these metals limits are adequate for protection of NTDE emission control catalysts and filters.
- **Flash point.** A minimum flash point for diesel fuel is required for fire safety. B100's flash point is required to be at least 93°C (200°F) to ensure all the

alcohol from production is removed; it is classified as nonhazardous under the National Fire Protection Association code.

- **Alcohol.** It is critical to ensure that the manufacturer has removed excess alcohol (typically methanol) used in the manufacturing process. Residual methanol in the fuel is a safety issue, because even very small amounts dramatically reduce the flash point, can affect fuel pumps, seals, and elastomers, and can result in poor engine combustion properties. The intent of the alcohol control requirement is to limit volatile alcohols to less than 0.2 percent by weight (wt %). This can be accomplished by meeting a higher flash point requirement of 130°C (266°F) or by measuring methanol content by gas chromatography.
- **Water and sediment.** This refers to free water droplets and sediment particles suspended in the B100. The allowable level for B100 is set at the same level as for conventional diesel fuel. Poor drying techniques during manufacturing or contact with excessive water during transport or storage can cause B100 to be out of specification for water content. Excess water can lead to corrosion and provides an environment for microorganisms. Fuel oxidation can also raise sediment levels, so this test can be used in conjunction with acid number, oxidation stability, and viscosity to determine if fuels have oxidized too much during storage.
- **Viscosity.** A minimum viscosity is required for some engines because of the potential for power loss caused by injection pump and injector leakage. This is not an issue for B100, and the minimum is set at the same level as for petroleum diesel. The maximum viscosity is limited by the design of engine fuel injection systems. Higher viscosity fuels can cause poor fuel combustion that leads to deposit formation as well as higher in-cylinder penetration of the fuel spray, which can result in elevated engine oil dilution with fuel. The maximum allowable viscosity in ASTM D975 for No. 2 diesel is 4.1 mm^2/s at 40°C (104°F). ASTM D6751 allows for slightly higher viscosity than D975, primarily because the normal viscosity of B100 is slightly higher than that of diesel fuel. Biodiesel blends of 20 vol% or lower should have viscosities between 1.9 and 4.1 mm^2/s, within the range allowed by D975.
- **Sulfated ash.** This test measures the amount of residual alkali catalyst in the biodiesel as well as any other ash-forming compounds that could contribute to injector deposits or fuel system fouling.
- **Sulfur.** This is limited to 15 ppm to reduce sulfate and sulfuric acid pollutant emissions and to protect exhaust catalyst systems on NTDEs. Biodiesel generally contains less than 15 ppm sulfur. The test for sulfur in fuel (ASTM D5453) should be used for accurate results instead of D2622, which will provide falsely high results caused by test interference with the oxygen in the biodiesel.
- **Copper strip corrosion.** This test is used to indicate potential difficulties with copper and bronze fuel system components. The requirements for B100 and conventional diesel are identical, and biodiesel meeting other D6751 specifications always passes this test. Copper and bronze may not corrode in the presence of biodiesel, but prolonged contact with these catalysts can degrade the fuel and cause sediment to form.
- **Cetane number.** An adequate cetane number is required for good engine performance. Conventional diesel must have a cetane number of at least 40 in the United States. Higher cetane numbers help ensure good cold start properties and minimize the formation of white smoke. The ASTM minimum limit for B100 cetane number is set at 47 because this is the level identified for "Premium Diesel Fuel" by the National Conference of Weights and Measures. Also, a 47 cetane number has been the lowest cetane number found in U.S. biodiesel, from a wide array of diverse feedstocks. The cetane index (ASTM D976) is not an accurate predictor of cetane number for biodiesel or biodiesel blends because it is based on a calculation that uses specific gravity and distillation curve, both of which are different for biodiesel than for petroleum diesel.
- **Cloud point** is the most commonly used measure of low-temperature operability. Fuels are generally expected to operate at temperatures as low as their cloud point. The cloud point of B100 is typically higher than the cloud point of conventional diesel fuel. Cloud point must be reported for biodiesel. Low-temperature properties and strategies for ensuring good low-temperature performance of biodiesel blends are discussed in more detail in later sections.
- **Carbon residue** measures the carbon-depositing tendency of a fuel and is an approximation of the tendency for carbon deposits to form in an engine. For conventional diesel fuel, the carbon residue is measured on the 10% distillation residue. Because B100 boils entirely at the high end of the diesel fuel range and in a very narrow temperature range, it is

difficult to leave only a 10% residue when distilling biodiesel. So biodiesel carbon residue specifies that the entire biodiesel sample be used rather than the 10% distilled residue.

- **Acid number** for biodiesel is primarily an indicator of free fatty acids (natural degradation products of fats and oils or a component of some biodiesel feedstocks) and can be elevated if a fuel is not properly manufactured or has undergone oxidative degradation. Acid numbers higher than 0.50 milligram potassium hydroxide per gram (mg KOH/g) have been associated with fuel system deposits and reduced life of fuel pumps and filters.
- **Free and total glycerin numbers** measures the amount of unconverted or partially converted fats/oils and by-product glycerin in the B100. Incomplete conversion of the fats and oils into biodiesel can lead to high total glycerin from elevated mono-, di-, and tri-glycerides. Incomplete removal of glycerin can lead to high free and total glycerin. If the glycerides are too high, the storage tank, fuel system, and engine can be contaminated. Fuels that exceed these limits are highly likely to plug dispenser and/or vehicle filters and cause other problems. One of the major shortcomings of the D6584 gas chromatograph method is its sensitivity to diesel fuel. Diesel fuel components overwhelm the column used in the gas chromatograph, making accurate determination of glycerin and glycerides difficult or impossible, and may damage the column. Thus, many laboratories are unable to determine free and total glycerin by this method in samples with even small amounts of diesel fuel.
- **Phosphorus content** is limited to 10 ppm maximum in biodiesel because it can damage emission control systems. Phosphorus above 10 ppm can be present in some plant oils and recycled greases. At this time, biodiesel produced in the United States generally has phosphorus levels of about 1 ppm.
- **The T90 distillation** is the temperature where 90% of the fuel has distilled. The specification was incorporated to ensure that fuels have not been contaminated with high boiling materials such as used motor oil or triglycerides. B100 exhibits a boiling point rather than a distillation curve. The fatty acids from which biodiesel are produced are mainly straight chains with 16 to 18 carbons that have similar boiling point temperatures. The atmospheric boiling point range of biodiesel is generally 330°C to 357°C (626°F to 675°F).
- **Oxidation stability.** Biodiesel can oxidize during storage and handling, leading to the formation of peroxides, acids, gums, and deposits. The minimum oxidation stability requirement is intended to ensure the storage stability of B100 and biodiesel blends in clean tanks.
- **Cold soak filterability** was added in 2008 in response to data indicating that some B100 could, in blends with petroleum diesel of up to 20%, form precipitates above the cloud point. B100 meeting the cold soak filterability requirements does not form these precipitates. This, along with cloud point, is needed to predict low-temperature operability.
- **No. 1-B grade.** The No. 1-B grade has year-round limits on cold soak filterability and monoglycerides. These limits ensure that trace components in biodiesel are minimized, while not requiring the measurement of many different compounds that may or may not be present in biodiesel. In particular, the limit on monoglycerides limits the saturated monoglyceride (SMG) content of the biodiesel. The percent of SMG in a B100 will be determined by the percent of saturated FAME. For example, if a B100 is 30% saturated FAME, the monoglyceride in the B100 will contain approximately 30% SMG.

Specification D6751 also includes the following workmanship statement:

> *"The biodiesel fuel shall be visually free of undissolved water, sediment, and suspended matter."*

Variation in Biodiesel Properties

As with petroleum-based fuels, the ASTM specification for biodiesel allows for a variety of feedstocks and processes to be used in its production. In today's market, biodiesel is most commonly a blend of B100 from two or more feedstocks. Many producers use feedstocks from a variety of sources to obtain B100 with desired properties and to improve production economics.

The specification prescribes a largely feedstock-neutral, performance-based set of requirements that ensure the B100 is fit to be used in diesel engines. Biodiesel can be produced commercially from a variety of oils and fats:

- **Animal fats.** Tallows, lard, choice white grease, yellow grease, poultry fats, and fish oils

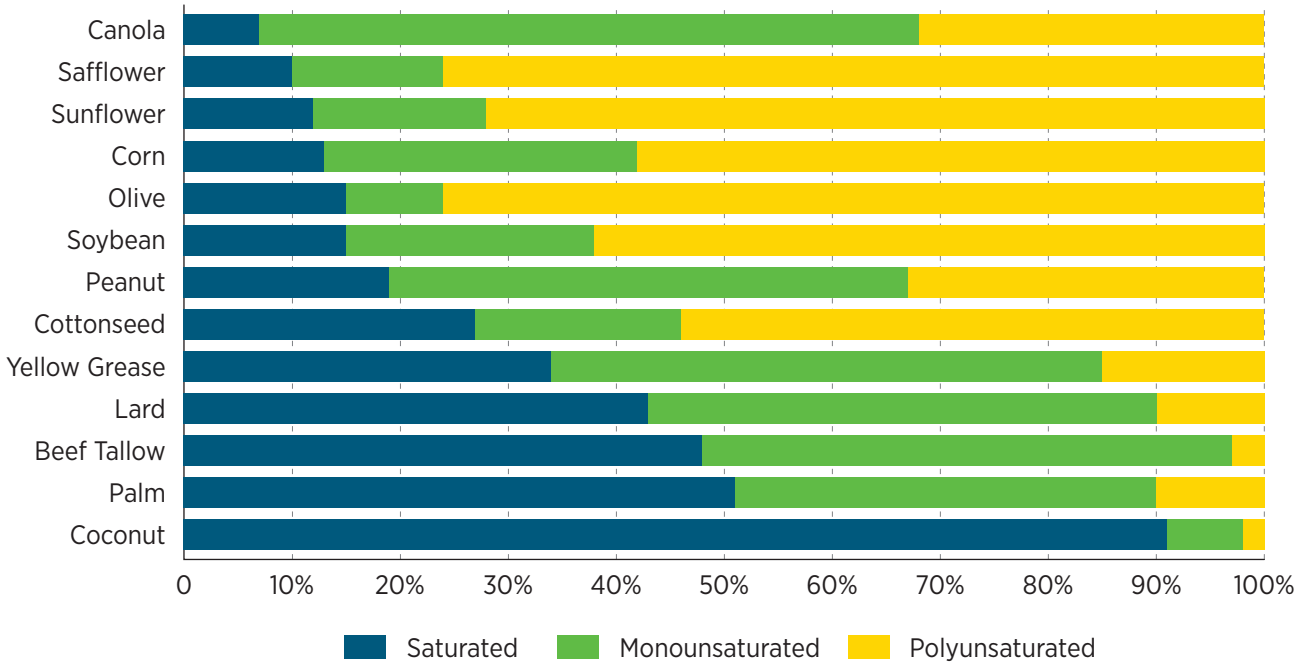


Figure 2. Composition of various biodiesel feedstocks in order of increasing saturated fatty acid content

- **Plant oils**. Soy, corn, canola, sunflower, rapeseed, cottonseed, corn
- **Recycled greases.** Used cooking oils and restaurant frying oils.

Biodiesel can also be made from other oils, fats, and recycled oils such as mustard, palm, coconut, peanut, olive, sesame, and safflower oils, trap greases, and even oils produced from algae, fungi, bacteria, molds, and yeast. Some properties of finished biodiesel such as cetane number, cloud point, and stability depend heavily on the feedstock.

Compared to the chemistry of diesel fuel, which contains hundreds of compounds, the chemistries of different fats and oils typically used for biodiesel are very similar. Each fat or oil molecule is made up of a glycerin backbone of three carbons, and on each carbon is attached a long-chain fatty acid that reacts with methanol to make the methyl ester, or biodiesel. The glycerin backbone is turned into glycerin and sold as a co-product of biodiesel manufacturing. Currently, the fats and oils used to make commercial biodiesel contain 10 common types of fatty acids that have 12 to 22 carbons, more than 90% of which are 16 to 18 carbons. Some of these chains are saturated, some are monounsaturated, and others are polyunsaturated. Within the limits of the specifications, the differing levels of saturation can affect some biodiesel fuel properties.

Each feedstock is set apart from the others because it is made of different proportions of saturated, monounsaturated, and polyunsaturated fatty acids (Figure 2).

In general, saturated FAME have high cetane numbers and cloud points and are more stable. As unsaturation increases (i.e., the number of double bonds increases), the cetane number and cloud point decrease, as does the natural stability of the FAME. The cetane number and stability are easily treated with conventional additives, while the cloud point is more difficult to treat. The length of the fatty acids also has an impact on the biodiesel properties. For example, coconut methyl esters are highly saturated, and the shorter chain length results in a cloud point of -5°C. While it is useful to understand the relationship between saturation and biodiesel properties, users are encouraged to base purchase decisions on measured fuel properties.

As with conventional diesel fuel, the best type of biodiesel for your applications will be based on several factors. A No. 2 petroleum diesel fuel with a cetane number of 50 and a cloud point of -3°C (26°F) may be suitable for December in Texas, but a No. 1 petroleum diesel with a cetane number of 42 and a cloud point of -29°C (-20°F) may be best for December in Minnesota. The considerations and tradeoffs for biodiesel use are like those made for petroleum diesel fuel. The following data provide more detail about B100 properties and considerations.

Energy Content

With conventional diesel fuels, the inherent energy content of the fuel is the largest factor affecting the fuel economy, torque, and horsepower delivered by the fuel. The energy content of conventional diesel can vary up to 15% from supplier to supplier and from summer to winter. This variability is due to changes in its composition that are determined by the petroleum feedstock, as well as refining and blending practices to produce finished diesel fuels. No. 2 diesel fuel usually has higher energy content than No. 1 diesel fuel, with blend values somewhere in between.

With B100, the refining (esterification or transesterification) process and blending of B100 from different feedstocks has no significant effect on energy content. The energy content of B100 varies little because the energy content of the fats and oils used in biodiesel production is highly similar. Therefore, B100 made from most of the common feedstocks will have the same fuel economy, power, and torque when burned in an engine. Compared to most No. 2 diesel fuel in the United States, B100 has a slightly lower energy content (12.5% per pound or 8% per gallon). Typical No. 2 diesel fuel has an energy content of around 18,200 Btu/lb. Losses in power, torque, and fuel economy would be expected to be proportional to the difference in energy content, although any differences may be too small to notice. The energy content of biodiesel blends and diesel fuel is proportional to the amount of biodiesel in the blend and the heating value of the biodiesel and diesel fuel used to make the blend. For example, B20 users experience a nearly 1% loss in fuel economy on average, which may not be noticeable to the driver, and rarely report changes in torque or power.

Low-Temperature Properties

The low-temperature properties of biodiesel and conventional petroleum diesel are extremely important. Unlike gasoline, petroleum diesel and biodiesel can freeze or gel as the temperature drops. Different diesel fuel formulations are sold during the winter in many climates. If the fuel begins to gel, it can clog filters on dispensing equipment and may eventually become too thick to pump. B100 is commonly stored in heated aboveground tanks for blending in winter. Important low-temperature performance metrics for handling and blending of B100 are:

- **Cloud point.** The temperature at which small solid crystals are first visually observed as the fuel is systematically cooled. The crystals formed in B100 are not like the crystals formed in diesel fuel and may behave differently in the fuel. Below the fuel's cloud point, these crystals might plug filters or could drop to the bottom of a storage tank. However, fuels can usually be pumped at temperatures below the cloud point.
- **Pour point.** The temperature at which the fuel contains so many agglomerated crystals it is essentially a gel and will no longer flow. Distributors and blenders use pour point as an indicator of whether the fuel can be pumped, even if it would not be suitable for use without heating or taking other steps.

These guidelines should be followed for storing biodiesel (B100) in winter:

- B100 should be stored at temperatures at least 2.5°C to 5°C (5°F to 10°F) higher than the cloud point. Because the cloud point of the B100 varies, the storage temperature will not be the same for all biodiesels.
- B100 from all but the highest cloud point feedstocks such as tallow or palm oil can be stored underground in most cold climates without additional considerations because underground storage temperatures are normally above 7°C (45°F). Aboveground storage and handling systems should be protected with insulation, agitation, heating systems, or other measures if temperatures regularly fall below the cloud point. This precaution includes piping, tanks, and pumping equipment.

The cloud point of B100 starts around -1°C to 0°C (30°F to 32°F) and can go as high as 20°C (68°F) or higher for biodiesel from highly saturated feedstocks (see Table 4 on next page). The pour point of B100 is usually only a few degrees lower than the cloud point, so once biodiesel begins to freeze, gelling can occur rapidly if the temperature drops only a few degrees further.

B100 tanks and fuel lines should be designed for the cold flow properties of the biodiesel being used and the local climate. Fuel pumps, lines, and dispensers must be protected from cold and wind chill with properly approved heating and insulating equipment. Fuel in aboveground tanks should be heated to 2.5°C to 5°C (5°F to 10°F) above the fuel cloud point.

Table 4.
Cold Flow Data for Various B100s[14]

Degree of saturation	B100 Cloud Point ASTM D2500		B100 Pour Point ASTM D97	
	°F	°C	°F	°C
Low	26	-3	25	-4
	32	0	25	-4
Mid	46	8	43	6
	56	13	55	13
	61	16	59	15
High	66	19	60	16

In some rare cases, as B100 gets colder, impurities like SMGs may precipitate out of solution. SMGs exhibit an interesting behavior known as polymorphism,[15] where the crystal form changes after precipitation. When SMGs first precipitate out of solution, they are in a less stable and more soluble form. Over time, the SMG crystals can transform into a more stable and less soluble form. These highly stable SMG crystals are difficult to bring back into solution, and the B100 must be heated well with adequate mixing.

Most of the time, once crystals form, they will generally go back into solution as the fuel warms. However, that process can be slow if the fuel is heated only slightly above the cloud point. Crystals formed in biodiesel or diesel fuel can drift to the bottom of the tank and begin to build up. Slow agitation can prevent crystals from building up on the tank bottom or, once present in the fuel, can help to bring the crystals back into liquid form. If B100 has gelled completely, the B100 should be heated to 38°C to 43°C (100°F to 110°F) to dissolve the most highly saturated biodiesel components if the fuel needs to be used immediately. Lower temperatures can be used if there is more time to allow the biodiesel to liquefy.

The low-temperature performance of B100 cannot be effectively managed with current cold flow additives, as can petroleum diesel and biodiesel blends. The level of saturated compounds in B100 is too high for most additives to be effective. Cold flow additives have been used much more successfully with biodiesel blends. You should work directly with the additive manufacturers on this issue.

Cetane Number

Cetane number is a measure of the ignition delay (the time from fuel injection into the combustion chamber to ignition); higher cetane numbers are believed to provide easier starting and quieter operation. ASTM D6751 for biodiesel requires a minimum cetane number of 47; the cetane number required of petroleum diesel fuel is 40. B100 produced from highly saturated feedstocks can have a cetane number of 60 or higher. Figure 3 shows the cetane numbers of various biodiesel samples and compares them to diesel cetane numbers. While it is interesting to know the cetane numbers of biodiesels from different feedstock oils, biodiesel is most commonly a blend from two or more feedstocks. Thus, buyers should focus on measured fuel properties rather than trying to determine the feedstock source.

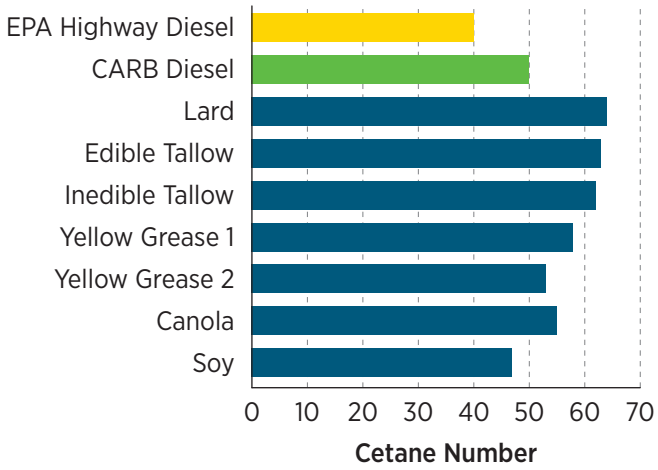


Figure 3. Cetane numbers of two petroleum diesels and several biodiesels

14. Kinast, J.A. 2003. *Production of Biodiesels from Multiple Feedstocks and Properties of Biodiesels and Biodiesel/Diesel Blends: Final Report;* Report 1 in a Series of 6, p. 13. National Renewable Energy Laboratory, Golden, CO. NREL/SR-510-31460. *nrel.gov/docs/fy03osti/31460.pdf.*

15. Chupka, G.M., Yanowitz, J., Chiu, G., Alleman, T.L., and McCormick, R.L., "Effect of Saturated Monoglyceride Polymorphism on Low-Temperature Performance of Biodiesel." *Energy and Fuels*, 2011 25(1), 398=405, doi: 10.1021/ef1013743.

Transport and Storage

Stability

Stability can refer to two issues for fuels: long-term storage stability or aging and stability at elevated temperatures and/or pressures as the fuel is recirculated through an engine's fuel system. For petroleum diesel, long-term storage stability is commonly referred to as oxidative stability. Thermal stability is the common term for the stability of fuels at elevated fuel system temperatures. For B100, storage stability is the paramount concern; thus, D6751 includes an oxidation stability requirement.

The oxidation stability test, EN15751 (also referred to as the Oil Stability Index or the Rancimat test), involves heating a specified quantity of B100 to 110°C (230°F) while air is bubbled through the sample at a controlled flow rate. After bubbling through the B100, the air bubbles through a water bath that collects volatile acids formed by oxidation of the biodiesel. A conductivity meter is used to monitor the water. A stable B100 can go for many hours under these conditions without forming volatile oxidation products. This period of time, before oxidation products form, is called the induction time or induction period. The stability requirement in D6751 is that the B100 have a minimum three-hour induction time. Because this requirement applies at the time of blending, many biodiesel producers make B100 with higher induction times.

In biodiesel, fuel aging and oxidation can lead to high acid numbers, high viscosity, and the formation of gums and sediments that clog filters. If the oxidation stability, acid number, or viscosity measurements exceed the limits in ASTM D6751, the B100 is degraded to the point where it is out of specification and should not be used. Biodiesel with high oxidation stability (longer induction time) will generally take longer than biodiesel with low oxidation stability to reach an out-of-specification condition. Monitoring the induction time and acid number of B100 over time can provide an indication of oxidation. B100 should be tested at receipt to ensure it is within specification. If the biodiesel will be stored prior to blending, the induction time and acid number should be monitored at regular intervals to ensure the biodiesel is not oxidizing.

In some cases, deposits from the cleaning or solvent effect of B100 have been confused with gums and sediments that could form in storage as the B100 ages. Although sediment can clog a filter in either case, care should be taken to make sure the reason for the clogging is properly identified. For example, if oxidation stability and acid number are within specification, sediments are most likely due to the cleaning effect and not to aging or oxidation.

Guidelines to help identify biodiesel and storage conditions that will provide the highest levels of stability follow:

- The higher the level of unsaturation, the more likely that the B100 will oxidize. Saturated fatty acid esters are fairly stable, and each time the level of unsaturation increases (for example, from monounsaturated to polyunsaturated), the stability of the fuel decreases exponentially. The points of unsaturation on the biodiesel molecules can react with oxygen, forming peroxides that break down into acids, sediments, and gums.
- Heat and sunlight will accelerate this process.
- Certain metals such as iron, rust, copper, brass, bronze, lead, tin, and zinc will accelerate the degradation process and form even higher levels of sediment. B100 should not be stored in systems that contain these metals.
- Some types of feedstock processing and biodiesel processing can remove natural antioxidants, potentially lessening inherent stability. Plant oils and fats are produced with natural antioxidants—nature's way of protecting the oil from degradation. Bleaching, deodorizing, or distilling oils and fats, either before or as part of the biodiesel process, can remove these natural antioxidants.
- Antioxidants, whether natural or incorporated as additives, can significantly increase the storage life or stability of B100.
- Keeping oxygen from the biodiesel reduces or eliminates fuel oxidation and increases storage life. Commercially, this is done by using a nitrogen blanket on storage tanks or storing biodiesel in sealed drums or totes with minimal headspace.

The ASTM D4625 test is used to simulate storage at ambient temperature, roughly 21°C (70°F). The test is accelerated by a factor of 4 for petroleum fuels, that is, one week of storage at D4625 conditions (43°C or 110°F, open to air) simulates one month of storage at 21°C (70°F). This acceleration factor has not been validated

for B100, but it is still a useful guide. ASTM D4625 data (see Figure 4)[16] indicate that B100 will lose oxidation stability over time under these storage conditions. Higher initial induction period values can provide longer storage time before biodiesel goes out of specification. Figure 4 also shows that, as the oxidation stability is reduced to near zero, the material will oxidize due to a loss of "oxidation reserve." This is evident in the increase in peroxide values. Acid numbers remain relatively constant until peroxide values become very high. Once sufficient peroxides have formed, the acid number increases rapidly due to peroxide degradation. Measurement of insoluble material in these B100s was not statistically significant during D4625 storage for 13 weeks (simulating 1 year of storage); however, highly oxidized biodiesels—having acid numbers well above the D6751 limit of 0.5 mg KOH/g—have historically been shown to form insoluble materials.[17]

B100 should not be stored longer than four months unless it has been treated with synthetic antioxidants and has an oxidation stability of 6 hours or longer. Non-oxidizing storage conditions in containers with little head space or under a nitrogen blanket will also be helpful. In fact, when B100 is being stored longer than about two months, it should be tested for oxidation stability every two weeks. One of the best ways to stabilize biodiesel is to blend it with petroleum diesel.

Microbial Contamination

Biocides are recommended for fuels wherever biological growth in the fuel has been a problem. If biological contamination occurs, water contamination should be suspected and will need to be controlled because the aerobic fungus, bacteria, and yeast hydrocarbon-utilizing microorganisms usually grow at the fuel-water interface. Anaerobic colonies, which usually reduce sulfur, can be active in sediments on tank surfaces and cause corrosion. Because the biocides work in the water phase, products that are used with diesel fuels work equally well with biodiesel.

16. Christensen, E., and R.L. McCormick. 2014. "Long-Term Storage Stability of Biodiesel and Biodiesel Blends," *Fuel Processing Technology* 128:339–348.

17. McCormick, R.L., and S.R. Westbrook 2010. "Storage Stability of Biodiesel and Biodiesel Blends." *Energy & Fuels* 24(1):690–698.

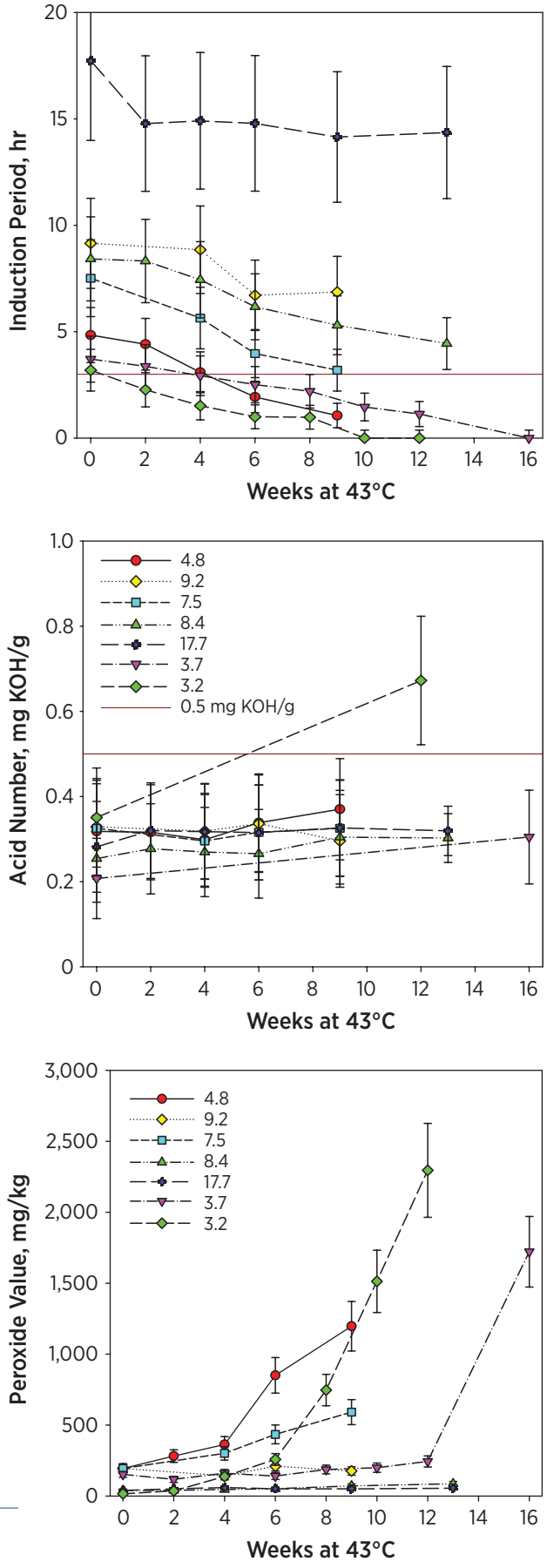


Figure 4. ASTM D4625 long-term storage stability for B100 samples having a range of initial induction periods

Cleaning Effect

Methyl esters have been used as low volatile organic compound cleaners and solvents for decades. Methyl esters make excellent parts cleaners, and several companies offer methyl esters as a low volatile organic compound, nontoxic replacement for the volatile solvents used in parts washers. B100 will dissolve the accumulated sediments in diesel storage and engine fuel tanks. These dissolved sediments can plug filters. If this happens, it can cause injector deposits and even fuel injector failure. If you plan to use or store B100 for the first time, clean the tanks and any parts in the fuel system where sediments or deposits may occur before filling with B100.

The level of cleaning depends on the amount of sediment in the system (if the system is free of sediment, there should be no effect) as well as the biodiesel blend level—the higher the blend level, the greater the cleaning potential. The cleaning effect is much greater with B100 and blends with 35% or more biodiesel, compared to B20 and lower blends.

Biodiesel spills should be immediately cleaned up because biodiesel can damage some types of body and engine paint. Biodiesel can also remove decals from tanks or vehicles near the fueling areas. All materials that are used to absorb biodiesel spills should be considered combustible and stored in a safety can.

Materials Compatibility

B100 will degrade, soften, or seep through some hoses, gaskets, seals, elastomers, glues, and plastics with prolonged exposure. Nitrile rubber compounds, polypropylene, polyvinyl, and Tygon materials are particularly vulnerable to B100. Before handling or using B100, ask the equipment vendor or OEM if the equipment is suitable for B100 or biodiesel. In some cases, the vendor may need the chemical family name for biodiesel (the methyl esters of fats and oils) to look up the information or even the exact chemical name of some of the biodiesel components such as methyl oleate, methyl linoleate, methyl palmitate, or methyl stearate. Oxidized biodiesel and biodiesel blends can contain organic acids and other compounds that can significantly accelerate elastomer degradation. (Published data on B100 material compatibility are summarized in Appendix C.) There have not been significant material compatibility issues with B20 unless the B20 has been oxidized.

Corrosion can also be the result of impurities like water, free glycerin, free fatty acids, or the sodium or potassium used in biodiesel processing. Oxidized biodiesel and biodiesel blends can contain organic acids and other compounds that can significantly accelerate elastomer degradation. Ensuring that all biodiesel meets the specifications when brought on site and in storage can minimize corrosion risks.

If your equipment is not compatible with B100, the materials should be replaced with materials such as Teflon, Viton, fluorinated plastics, or nylon. You should consult B100 suppliers and equipment vendors to determine material compatibility, and ask B100 vendors in other regions what problems they may have experienced and what kind of replacement materials they are using. It is advisable to set up a monitoring program to visually inspect the equipment once a month for leaks, seeps, and seal decomposition.

Transport

As with petroleum diesel, B100 must be transported in a way that does not lead to contamination. The following procedures are recommended for trucks and railcars and are used by distributors and transporters of diesel fuel.

- Ensure that trucks and railcars are constructed of aluminum, carbon steel, or stainless steel.
- Ensure proper inspection or washout (washout certificate) before loading.
- Check for previous load carried and residual material. Generally, only diesel fuel or biodiesel is acceptable as a residual. If the vessel has not gone through a washout, some residuals, including food products or raw plant oils, gasoline or lubricants, may not be acceptable.
- Ensure there is no residual water in the tank.
- Check that hoses and seals are clean and made from materials that are compatible with B100.
- Determine the need for insulation or a method to heat truck or rail car contents if shipping during cold weather. B100 is challenging to ship in cold weather. In the winter, most B100 is shipped in one of the following ways:
  - Hot (or at least warm) in trucks for immediate delivery at 27°C to 54°C (80°F to 130°F).

- Frozen after several days in cold weather in railcars equipped with external steam coils (the fuel in the tank cars is melted at the final destination with steam).
- In a blend with winter diesel, kerosene, or other low cloud point fuel in either railcars or trucks.

Regardless of how the biodiesel arrives, procedures that prevent the temperature of B100 from dropping below its cloud point must be in place. The cloud point of the biodiesel, the biodiesel and ambient temperatures, and the time the fuel is in transport should all be considered when transporting B100 to ensure the fuel does not freeze or can be reliquified.

Use of B100 and High Blend Levels

Most biodiesel currently in use involves blends of B20 or lower in a variety of applications. The price and lack of regulatory incentives have limited the experience with blend levels of B50 and higher, although some niche markets are using higher blends. High-level biodiesel blends are successfully used in underground mining equipment. The ability of biodiesel to reduce PM emissions and reduce human exposure to this criteria pollutant has driven the industry to adopt higher blends of biodiesel. Thus, most of the information in this section is intended for biodiesel use as a blending component. In particular, Specification D6751 is for the use of biodiesel as a blendstock, not as a neat fuel. If you want to use B100 as a fuel, these recommendations should help:

- Contact other users of higher-level blends and B100. The National Biodiesel Board (NBB) has names of individuals and businesses as well as reference materials about storage, handling, and use of higher-level blends and B100. If you manage a fleet, contact your Fleet Management Association or Clean Cities Coalition to find out if anyone near you has experience with B100 or blends above B20. Ask your B100 supplier for recommendations.
- Ask other users what they did, how they did it, how long it took, how much it cost, what problems they encountered, how long they have been using higher-level blends or B100, and what kinds of engines and equipment use higher-level blends and B100 at their sites.
- Discuss your needs with your vehicle manufacturer and ask for advice, including any recommendations from other U.S. fleet customers.
- Replace materials you know will be problematic and institute a monitoring program based on the information presented in section 3.6.4, Materials Compatibility.
- Plan and budget for the time and expense of increased fuel filter changes or cleaning your fuel system when first starting to use higher-level blends and B100.

Biodiesel Blends

This section focuses on blending B100 with petroleum diesel to make B6 to B20 blends, but the approach is similar for other blend levels such as B2 or B5. As discussed in the previous sections, the performance properties of B100 can be significantly different from those of conventional diesel. Blending biodiesel into petroleum diesel can minimize these property differences and retain some of the benefits of B100. B20 is popular because it represents a good balance of cost, emissions, cold weather performance, materials compatibility, and ability to act as a solvent. B20 is also the minimum blend level that can be used for EPAct compliance for covered fleets.

Specifications

B5 and Lower Blends

The specification for conventional diesel fuel, ASTM D975, allows for up to 5 vol% biodiesel to be blended into compliant diesel fuels. The biodiesel used in the blend must meet D6751. Blends up to B5 must meet all the numeric requirements for diesel fuel properties specified in D975; none were changed or relaxed to accommodate biodiesel. ASTM Method D7371, Standard Test Method for Determination of Biodiesel (Fatty Acid Methyl Esters) Content in Diesel Fuel Oil Using Mid Infrared Spectroscopy (FTIR-ATR-PLS Method), may be used to determine the biodiesel blend percentage. There is no requirement that D975-compliant fuels list the percent of biodiesel in the blend. Users may not know if the fuel they are using or purchasing is B0, B2, or B5 unless they measure the biodiesel content using ASTM D7371 or an alternate method.

B6 to B20 Blends

The specification for B6 to B20 blends requires that the biodiesel meet the D6751 specification prior to blending with diesel fuel. The general requirements of the B6-B20 specification, D7467-15cε1, are shown in Table 5. Beyond the properties in Table 5, there are many other requirements within the specification that are important for users. Consult the full specification for additional details (available at *astm.org*). The requirements are based on those in D975 with some additional requirements to ensure the fuel is fit-for-purpose. The 90% distillation temperature is allowed to be 5°C higher than for D975 diesel fuel. The specification is designed such that if a D6751-compliant B100 and a D975-compliant diesel fuel are blended, the resultant blend will meet the specification. However, diesel fuel that does not fully meet D975 can also be used (for example by having inadequate lubricity, high sulfur, or high aromatics), and biodiesel can be used to blend these properties into compliance.

Pump Labeling

As part of the Energy Independence Security Act, the Federal Trade Commission was required to publish biodiesel pump labeling requirements. Pumps are required to be labeled to inform consumers about the percentage biodiesel being offered for sale. The rules also cover renewable diesel (also called biomass-based diesel.[18] Pumps selling up to B5 blends require no separate labeling. Figure 5 shows the label for blends between B6 and B20. Although the label indicates the blend is "B-20," the regulations allow this label to be used for any blend inclusively between B6 and B20. Blends higher than B20 are required to be labeled with the exact blend percentage; for example, a B30 blend will have a pump label stating the blend is B30.

It should be noted that these federal requirements are the minimum necessary at pumps to inform consumers about the blends they are purchasing. Individual states may have requirements that exceed the federal requirements.

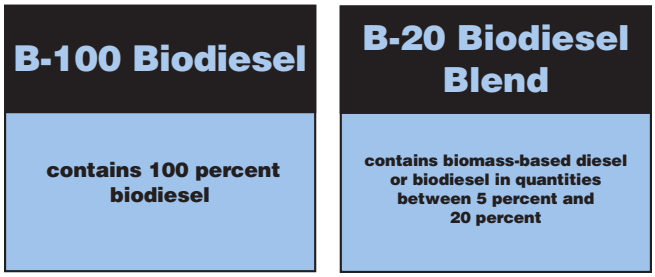


Figure 5. FTC-compliant B20 and B100 pump labels

18. Federal Register / Vol. 73, No. 48 / Tuesday, March 11, 2008 / Proposed Rules. "Federal Trade Commission, 16 CFR Part 306 RIN #3084–AA45, Automotive Fuel Ratings, Certification and Posting." *ftc.gov/sites/default/files/documents/federal_register_notices/automotive-fuel-rating-certification-and-posting-16-cfr-part-306/080311automotivefuelratings.pdf.*

Table 5. ASTM D7467-15cε1 Specification for Diesel Blends B6 to B20				
Property	**Test Method**	**Grade**		
		B6 to B20 S15	**B6 to B20 S500**	**B6 to B20 S5000**
Acid Number, mg KOH/g, max.	D664	0.3	0.3	0.3
Viscosity, mm^2/s at 40°C	D445	1.9 – 4.1[a]	1.9 – 4.1[a]	1.9 – 4.1[a]
Flash Point, °C, min	D93	52[b]	52[b]	52[b]
Cloud Point, °C, max or LTFT/CFPP, °C, max	D2500	c	c	c
Sulfur Content, (µg/g or ppm) mass %, max. mass %, max.	D5453 D2622 D129	15 – –	– 0.05 –	– – 0.50
Distillation Temperature, °C, 90% evaporated, max.	D86	343	343	343
Ramsbottom carbon residue on 10% bottoms, mass %, max.	D524	0.35	0.35	0.35
Cetane Number, min.	D613	40	40	40
One of the following must be met: (1) Cetane index, min. (2) Aromaticity, vol%, max.	D976-80 D1319-03	40 35	40 35	40 –
Ash Content, mass %, max.	D482	0.01	0.01	0.01
Water and Sediment, vol%, max.	D2709	0.05	0.05	0.05
Copper Corrosion, 3 h @ 50°C, max.	D130	No. 3	No. 3	No. 3
Biodiesel Content, % (V/V)	D7371	6.– 20.	6.– 20.	6.– 20.
Oxidation Stability, hours, min.	EN15751	6	6	6
Lubricity, HFRR @ 60°C, (micron), max.	D6079	520	520	520

Note: Reprinted with permission of ASTM.

CFPP: cold filter plug point

LTFT: low-temperature flow test

a. If Grade No. 1-D or blends of Grade No. 1-D and Grade No. 2-D diesel fuel are used, the minimum viscosity shall be 1.3 mm^2/s.

b. If Grade No. 1-D or blends of Grade No. 1-D and Grade No. 2-D diesel fuel are used or a cloud point of less than -12°C is specified, the minimum flash point shall be 38°C.

c. It is unrealistic to specify low-temperature properties that will ensure satisfactory operation at all ambient conditions. However, satisfactory operation below the cloud point (or wax appearance point) may be achieved depending on equipment design, operating conditions, and the use of flow-improver additives as described in Appendix X3.1.2 to the test method. Appropriate low-temperature operability properties should be agreed upon between the fuel supplier and purchaser for the intended use and expected ambient temperatures. Test Methods D4539 and D6371 may be useful to estimate vehicle low-temperature operability limits when flow improvers are used, but their use with Bxx blends from a full range of biodiesel feedstock sources has not been validated. Due to fuel delivery system, engine design, and test method differences, low-temperature operability tests may not provide the same degree of protection in various vehicle operating classes. Tenth percentile minimum air temperatures for U.S. locations are provided in Appendix X3 as a means of estimating expected regional temperatures. The tenth percentile minimum air temperatures may be used to estimate expected regional target temperatures for use with Test Methods D2500, D4539, and D6371. Refer to Appendix X3.1.3 for further general guidance on test application.

Low-Temperature Properties

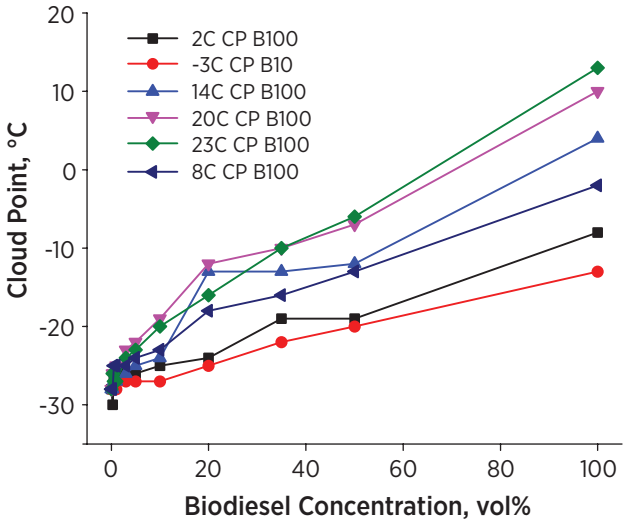
Blending biodiesel with petroleum diesel moderates low-temperature operability problems of B100 by dilution, although the effects are not necessarily linear. Conventional low-temperature operability additives can be used with blends as these are believed to be effective in the petroleum portion of the blend. When biodiesel is blended with diesel fuel, the key variables are the cold flow properties of the diesel fuel, the properties of the biodiesel, the blend level, and the effectiveness of cold flow additives.

There are some critical metrics for low-temperature operability. Note that cold filter plugging point (CFPP) and low-temperature flow test (LTFT) are particularly useful for revealing the presence of additives. For blends, these include:

- **Cloud point.** The temperature at which small solid crystals are first visually observed as the fuel is cooled (ASTM D2500, D5771, D5772, or D5773). Below the cloud point of the blend, these crystals might plug filters and/or drop to the bottom of a vehicle or storage tank. Cloud point is the most widely used and most conservative estimate of the low-temperature operability limit. However, fuels can usually be pumped at temperatures below the cloud point.
- **Pour point.** The temperature at which the fuel contains so many agglomerated crystals it is essentially a gel and will no longer flow (ASTM D97, D5949, or D5950). Distributors and blenders use pour point as an indicator of whether the fuel can be pumped, even if it would not be suitable for use without heating or taking other steps.
- **Cold filter plugging point.** This is the temperature under a standard set of test conditions, as defined in ASTM D6371, where a fuel filter plugs. The CFPP test employs rapid cooling conditions. CFPP results more than 10°C (18°F) below the cloud point should be viewed cautiously as they may not reflect the true low-temperature operability limit. The test simulates the performance of an average or typical vehicle and is not protective of the most severe fuel system designs, which make up roughly one-third of heavy-duty vehicles or one-fifth of light-duty vehicles.
- **Low-temperature flow test.** This test also reports a temperature under a standard set of conditions, defined in ASTM D4539, where a fuel filter plugs. LTFT employs slow cooling at 1°C per hour and simulates the most severe (and common) fuel system designs in North American heavy-duty trucks from the standpoint of low-temperature operability.

It is strongly recommended that you consult Appendix X.5 to ASTM D975 or Appendix X.3 to ASTM D7467 to understand the history and relative utility of tests for cloud point, CFPP, and LTFT.

B100 cold flow properties depend on FAME composition, which affects the cold flow properties of blends (Figure 6 and Figure 7). Measurements of cloud point and pour point are not exact, but have ±2°C (±3.5°F) repeatability. The same is true of diesel fuel. In addition, different No. 2 diesel fuels may have cloud points of -35°C to -5°C (-31°F to 23°F). Some fuels can have



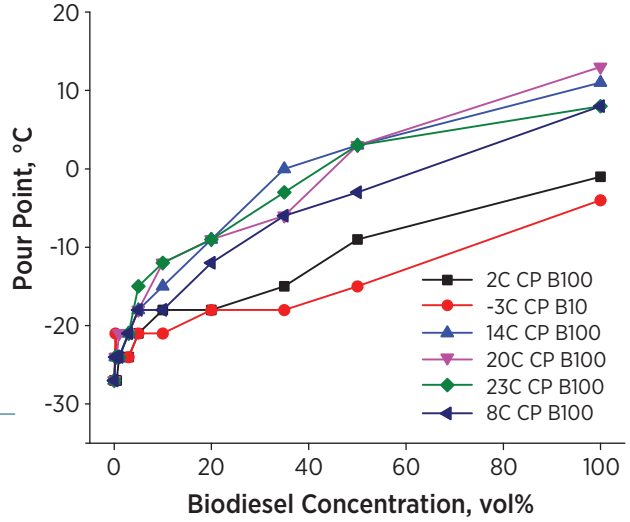


Figure 6 (top). Biodiesel/diesel blend cloud point test results

Figure 7 (bottom). Biodiesel/diesel blend pour point test results

cloud points higher or lower than these figures. No. 1 diesel, jet A, or kerosene may have cloud points of -40°C to -51°C (-40°F to -60°F). A recent Coordinating Research Council study showed that biodiesel blends (B5 and B20), made from B100 meeting D6751-08a, would provide operability down to cloud point. Additives may allow operation at even lower temperatures.[19]

From this same study, it was found that for biodiesel blends prepared from B100 meeting D6751-08a, the cloud point and LTFT will be nearly the same, and CFPP will be 2°C to 3°C (3.5°F to 5°F) lower, if no low-temperature flow improver additives are used. Additives do not usually alter cloud point, but can lower CFPP and LTFT. Thus, for additized fuels, CFPP or LTFT may be a better predictor of low-temperature operability.

Blends of No. 1 and No. 2 diesel fuel are frequently used to meet customer cold flow requirements (see Figure 8). Adjusting the blend of kerosene (or No. 1 diesel) in the diesel fuel alone or with additives can modify the cloud and pour point temperatures of B20. An accurate estimate of how B20 will perform in the winter months will require mixing the biodiesel with the winter diesel typically delivered in your area and testing the mixture.

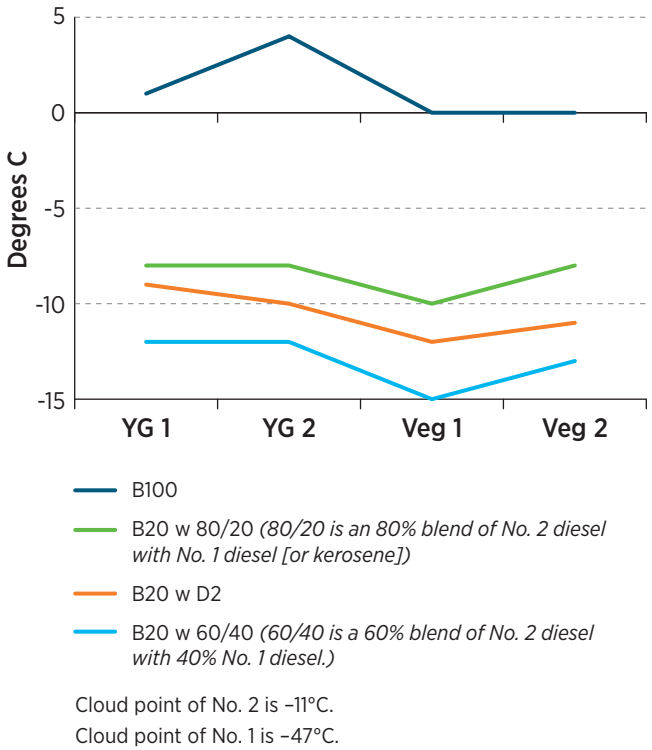


Figure 8. Adjusting cloud points of B20 fuels with blends of No. 1 and No. 2 diesel

Neither ASTM D975 nor ASTM D7467 has a specific requirement for the maximum or minimum cloud point, but the cloud point should be provided to the customer as part of the certificate of analysis. Appendix D shows a sample certificate of analysis. Cold flow properties needed for the fuel depend on where it is being used (for example, Michigan or Texas) and what time of year the fuel is being used (for example, January or July). A petroleum diesel or biodiesel fuel with a cloud point of -7°C (20°F) may be fine for a Texas summer, but not for a Michigan winter.

The appendices to ASTM Specifications D975 and D7467 contain maps of the 10th percentile minimum temperature for all states for October through March. At the 10th percentile temperature, only 10% of the days were colder during that month on average, based on data from several decades. Some users and distributors use the 10th percentile as the target for their low-temperature operability requirement. Many diesel fuel users will specify a cloud point in their purchase contract, for example, that the fuel cloud point be no higher than the 10th percentile minimum temperature. Some users do not monitor cold flow properties at all and rely on their distributors to make sure low-temperature operability is managed for their location.

The University of Minnesota Center for Diesel Research tested soy B20 made with various diesel fuels available in the region.[20] Their database of biodiesel blends (0%, 2%, 5%, 10%, 20%, and 100%) shows how different diesel fuels and soy biodiesel blends alter cold flow properties (cloud point, pour point, and CFPP). CFPP is another measure of low-temperature operability that tends to predict an operability limit lower than cloud and may not protect in the most severe duty-operation vehicles. Some of the data are shown in Figure 9 (next page).

No. 1 diesel fuel typically costs more than No. 2, so blenders may prefer to use additives. Many cold flow additives are available for diesel fuel. Most reduce the size of crystals or inhibit crystal formation in some way. Most have limited effectiveness on B100, but work with varying degrees of effectiveness with B20.

19. Coordinating Research Council. 2008. *Biodiesel Blend Low-Temperature Performance Validation*. crcao.com/reports/recentstudies2008/DP-2a-07/CRC%20650.pdf.

20. Minnesota Department of Agriculture. 2009. *Report to the Legislature: Petroleum Diesel Fuel and Biodiesel Technical Cold Weather Issues*. mda.state.mn.us/news/publications/renewable/biodiesel/biodieselcoldissues.pdf.

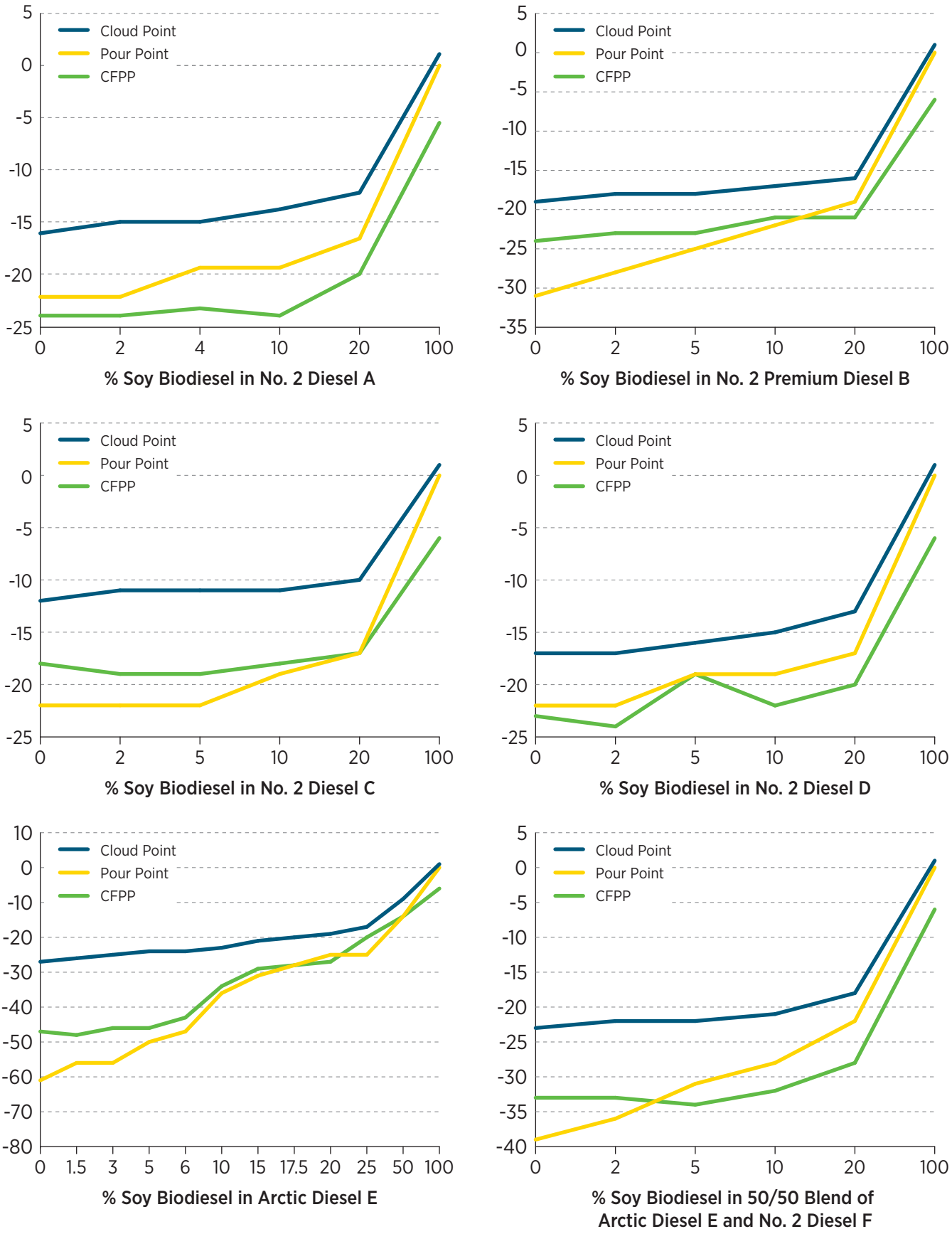


Figure 9. Cold flow properties of some soy biodiesel blends, °C

Lubricity

Blending biodiesel into petroleum diesel even at low levels can improve the lubricity of diesel fuel (i.e., reduce wear scar diameter). As little as 0.25% biodiesel can significantly improve lubricity.[21] Figure 10 shows results of lubricity testing using the HFRR, the test used to determine if diesel fuels meet the ASTM lubricity requirement of a maximum 520-micron wear scar diameter. The exact blending level required to achieve adequate lubricity depends on the properties of the conventional diesel. Preliminary evidence suggests that 2% biodiesel almost always imparts adequate lubricity.

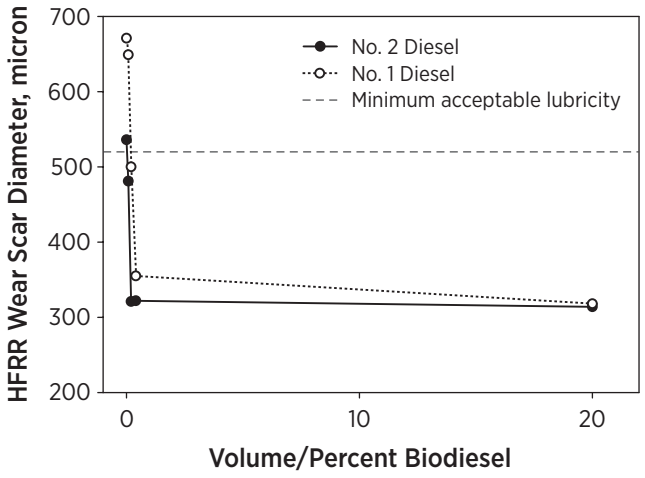


Figure 10. HFRR lubricity as a function of biodiesel content for a No. 1 and a No. 2 diesel fuel

Blending, Storage, and Transport

Blending

Most biodiesel users purchase finished B20 or lower blends from their petroleum distributors or biodiesel marketers. In this case, the distributor is responsible for ensuring that the biodiesel has been properly blended and that the cold flow properties of the finished blend will provide satisfactory performance for the area and time of year. You may also want to specify in your purchase contract or agreement that the fuel meet certain low-temperature operability requirements.

21. Kinast, J.A. 2003. *Production of Biodiesels from Multiple Feedstocks and Properties of Biodiesels and Biodiesel/Diesel Blends: Final Report;* Report 1 in a Series of 6, p. 13. National Renewable Energy Laboratory, Golden, CO. NREL/SR-510-31460. *nrel.gov/docs/fy03osti/31460.pdf.*

Biodiesel blending procedures depend on a variety of factors, including the volume of B100 required to make the blend, the finished blend level, the volume of blended products being sold, tank and space availability, equipment and operational costs, and customer requirements for blends, both now and in the future. **Biodiesel is a fuel for diesel applications only and is not to be blended with gasoline.**

Generally, biodiesel is blended into diesel fuel via several methods:

- B100 may be splash blended with diesel fuel by the end user in a storage tank or transport truck.
- B100 is blended at a petroleum terminal or rack by a pipeline or terminal operator (usually through injection blending) and offered as a finished blend. This product is sold directly to customers or to a petroleum jobber or distribution company for further sale to customers. This is the preferred method because it ensures complete blending.

The chemical nature of biodiesel allows it to be blended with any kind of distillate or diesel fuel. This includes light distillate fuels such as jet fuel, kerosene, No.1 diesel, and military fuels (JP8, JP5), as well as diesel fuel such as No. 2 diesel for diesel engines and gas turbines and heating oil for boilers and home heating. Once biodiesel is blended thoroughly with diesel fuel, they stay blended together and do not separate over time, if the blend is maintained at temperatures above its cloud point.

B100 should be blended with diesel fuel as soon as reasonable after purchasing, regardless of the time of year. B100 is less oxidatively stable than petroleum diesel and biodiesel blends. Cloud point considerations are less of a concern for biodiesel blends than for B100 during cold weather. If you have only a few B100 customers, you might consider holding a tote of B100 indoors or storing some underground or in heated tanks, depending on your climate, and blending the rest as soon as possible.

Always retain one-quart samples of the diesel and B100 before blending. If any problems arise, these samples may help you determine whether they were caused by the fuel or by something else. Once the customers have run through the current batch of blended fuel with no problems, you can mix the retained samples into the new batch of blended fuel.

Petroleum terminals and pipeline racks responded to increasing demand by installing biodiesel blending capability so jobbers and distributors can receive a

biodiesel blend directly at the rack and store and distribute only the blended biodiesel. This finished blend can then be sold to fleet or other applications that have some type of onsite storage. An increasing number of public pumps and key card pumps carry biodiesel blends for individual users or fleets that do not have their own onsite storage capability.

Many blending options are available, depending on your area. As the market continues to mature and volumes increase, the point of blending will likely occur farther and farther upstream in the distribution system where it is most efficient and economical. This is especially true with lower blends of biodiesel such as B2 and B5. Most users find blending their own fuel to be time consuming and costly, so they increasingly request that their petroleum supplier make finished blends available.

The blending process is usually done by splash blending or in-line blending.

- **Splash Blending.** Splash blending is appropriate for locations where the biodiesel and diesel fuel are loaded separately, or, in some cases, at the same time through different incoming sources, but at a high enough fill rate that the fuels are sufficiently mixed (several hundred gallons per minute for the diesel fuel). In some cases, the tank may need to be recirculated or further mixed to thoroughly blend the two fuels. If mixing is not complete, the slightly denser biodiesel will settle to the bottom. If the entire load is then pumped in to a customer tank, this action will usually be enough to cause complete mixing. But for loads split between customers, the load must be well mixed at the time of blending.

  This pumping is generally enough mixing for biodiesel blends, except in cold weather where the ambient temperature is significantly below the B100 cloud point. Putting B100 into a cold, empty tank truck can cause the fuel to gel, resulting in the two fuels mixing poorly or not at all. In cold weather, it is better to load half the diesel, then the biodiesel, followed by the rest of the diesel fuel.

- **In-Line Blending.** In-line blending occurs when the biodiesel is added to a stream of diesel fuel as it travels through a pipe or hose in such a way that the biodiesel and diesel fuel become thoroughly mixed by the turbulent movement through the pipe. The biodiesel is added slowly and continuously into the moving stream of diesel fuel via a smaller line inserted in a larger pipe, or it can be added in small slug or pulsed quantities spread evenly throughout the time the petroleum diesel is being loaded. This is similar to the way most additives are blended into diesel fuel today and is most commonly used at pipeline terminals and racks. In some cases, distributors who carry B100 and petroleum diesel in separate compartments and blend the two as they are loading into a customer's tank also use this method.

  In-line blending uses two metered pumps and a dual-fuel injection system, so requires an investment in equipment. This approach is the most accurate and reliable for guaranteeing a specific fuel blend. A variety of equipment is available for in-line blending. Systems have to be sized for a specific blend level (B2, B20) and generally cannot handle both types of blends.

In general, blending biodiesel is not difficult if you remember that biodiesel is slightly heavier and more viscous than diesel fuel and the more it is mixed, the better.

Biodiesel has a specific gravity of 0.88 compared to No. 2 diesel at 0.85 and No. 1 diesel at 0.80. If you put the biodiesel into an empty tank and then pour diesel fuel slowly on top, the fuels may not blend properly. If you fill the tank with diesel and then slowly add biodiesel, the biodiesel may go directly to the bottom of the tank. Biodiesel is heavier, so it may stay unmixed at the bottom of the tank. Most pumps draw from the bottom of a fuel tank; if not properly mixed, this bottom layer can contain higher concentrations of biodiesel than the intended blend level. The problems generally manifest themselves in cold months as the high-concentration biodiesel has a much higher cloud point than the well-blended fuel, leading to filter plugging and forming a gel layer at the bottoms of aboveground tanks. Because the low-temperature operability problems may not manifest themselves in the summer and any adverse effects on hoses and gaskets associated with higher blends may take some time to develop, users may go for many months without a problem. Another issue is that a concentrated layer of biodiesel could also start to dissolve tank sediments, which can cause filter clogging in warm months.

Two simple tests can be performed to determine if a tank has been thoroughly mixed:

- Top, middle, and bottom samples of the tank can be taken (see ASTM D4057 or D4177 for the proper way to take a representative sample of a tank) and analyzed for the percent biodiesel or by

measuring the specific gravity or density. This can be done with any available means of measuring density or specific gravity (digital density meter, hydrometer). If the values vary by no more than 0.003 specific gravity units from top to bottom, the mix is probably adequate.[22] The test procedure for determining the percent biodiesel by infrared spectroscopy is ASTM D7371-14. Several instrument companies currently offer relatively inexpensive equipment to measure the percent biodiesel in the field, similar to equipment used for ethanol in gasoline.

- Put the samples from the three layers in a freezer with a thermometer and check every five minutes until the fuel in one sample begins to crystallize. Record that temperature. Then, continue to check every few minutes until all three samples show crystallization. Compare the crystallization temperatures on all three samples; they should be within 3°C (6°F) of each other. Otherwise, the fuel will require agitation to mix thoroughly. Alternatively, the cloud point of the three samples could be measured, and values should be within 3°C (6°F) of each other. See sidebar at right for an example.

Cold weather blending is a concern in situations where the diesel fuel temperature falls below the cloud point of the B100 you are blending. If the diesel fuel temperature is above the cloud point of the final blend, any crystals that form during blending should go back into solution. This process can be assisted by blending equipment that agitates the two fuels during blending. That agitation helps disperse the fuels and crystals more uniformly and can provide some energy to help the crystals dissolve.

Blends should be stored in tanks that can ensure the fuel temperature will remain above the cloud point of the blend. Blended fuels can be stored below ground in most climates. B20 may be stored in aboveground tanks, depending on the cloud and pour points of the blended fuel, the heating capacities for the fuel, and the local ambient weather conditions.

Stability

Long-term storage stability of B5 and B20 blends has recently been examined using the D4625 test that simulates storage at normal ambient temperature, roughly 21°C (70°F). The test is accelerated by a factor of 4, such that one week of test time simulates one month of actual storage. This test was carried out for 39 weeks (simulating 3 years of biodiesel blend storage) with four biodiesels of varying stability blended with two diesel fuels.[23] Results for B5 blends are shown in Figure 11 on page 28. For B100 with a three-hour or higher induction time, the D4625 test shows no indication that oxidation is occurring in B5 blends under these test conditions. Based on these results, B5 blends made from in-specification B100 can be stored for one year or longer. However, as storage conditions can influence stability, we recommend that you consider adding a synthetic antioxidant and monitoring the condition of the fuel periodically if you store fuel for longer than 6 months.

Consider an example: Small-scale or hand blending shows that the cloud point of the B20 blend will be -18°C (0°F), the cloud point of the diesel is -23°C (-10°F), and the biodiesel has a cloud point of 1°C (34°F) and is stored at a temperature above cloud point. The diesel fuel temperature is -6°C (21°F) on the day you decide to blend. The diesel fuel temperature is lower than the cloud point of your B100. This is an acceptable situation because the B20 cloud point is below the temperature of your diesel fuel and the gap between the temperature of the diesel fuel and the target B20 cloud point is pretty generous, about 12°C (23°F). Any crystals that form during blending (because the diesel temperature is below the cloud point of the B100) will return into solution. If the gap was smaller, for example, 3°C (5°F), crystals may be slow to return to solution and have a chance to settle out.

Figure 12 (page 29) shows the results for B20 blends. All of the B20 blends, with one exception, remained within specification by the end of 39 weeks and showed no signs of oxidation beyond a decrease in induction period. The results for the lowest stability blend were notably different between the two base diesels. In the case of Diesel A, this blend went out of specification for induction period by 23 weeks and remained at a constant value for the remaining storage time. This blend showed no signs of oxidation by the end of test. The blend prepared with Diesel B went out of specification by 17 weeks and showed a steady drop in induction period from 31 to 39 weeks, eventually reaching zero. At the end of the test, the peroxide value of this blend had increased significantly and the acid number was out of

22. NBB quality program, BQ-9000, *bq-9000.org/*

23. Christensen, E., and R.L. McCormick. 2014. "Long-Term Storage Stability of Biodiesel and Biodiesel Blends," *Fuel Processing Technology* 128:339–348

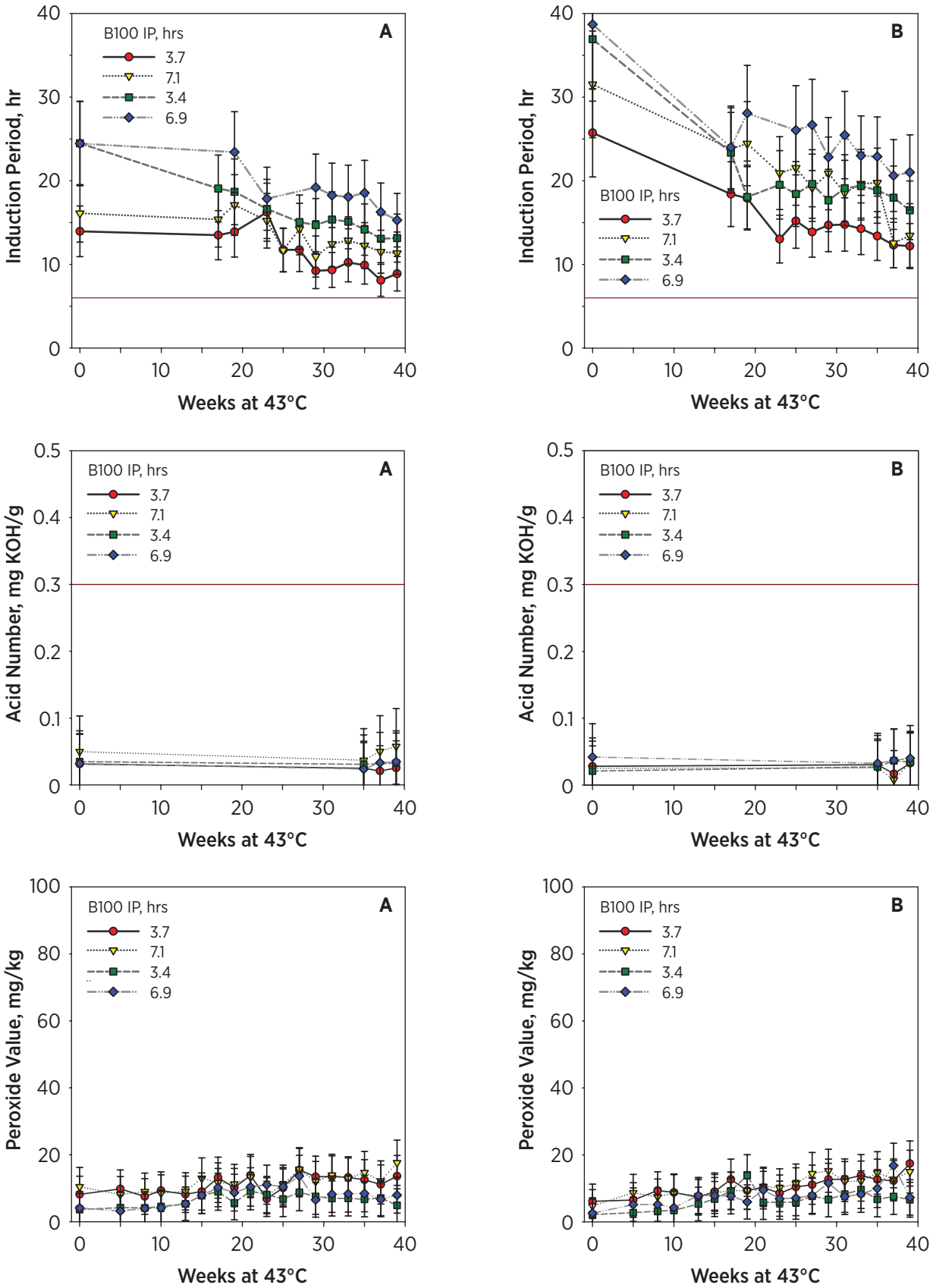


Figure 11. D4625 storage results for B5 blends made from B100 with varying levels of oxidation stability and two diesel fuels as measured by EN15751

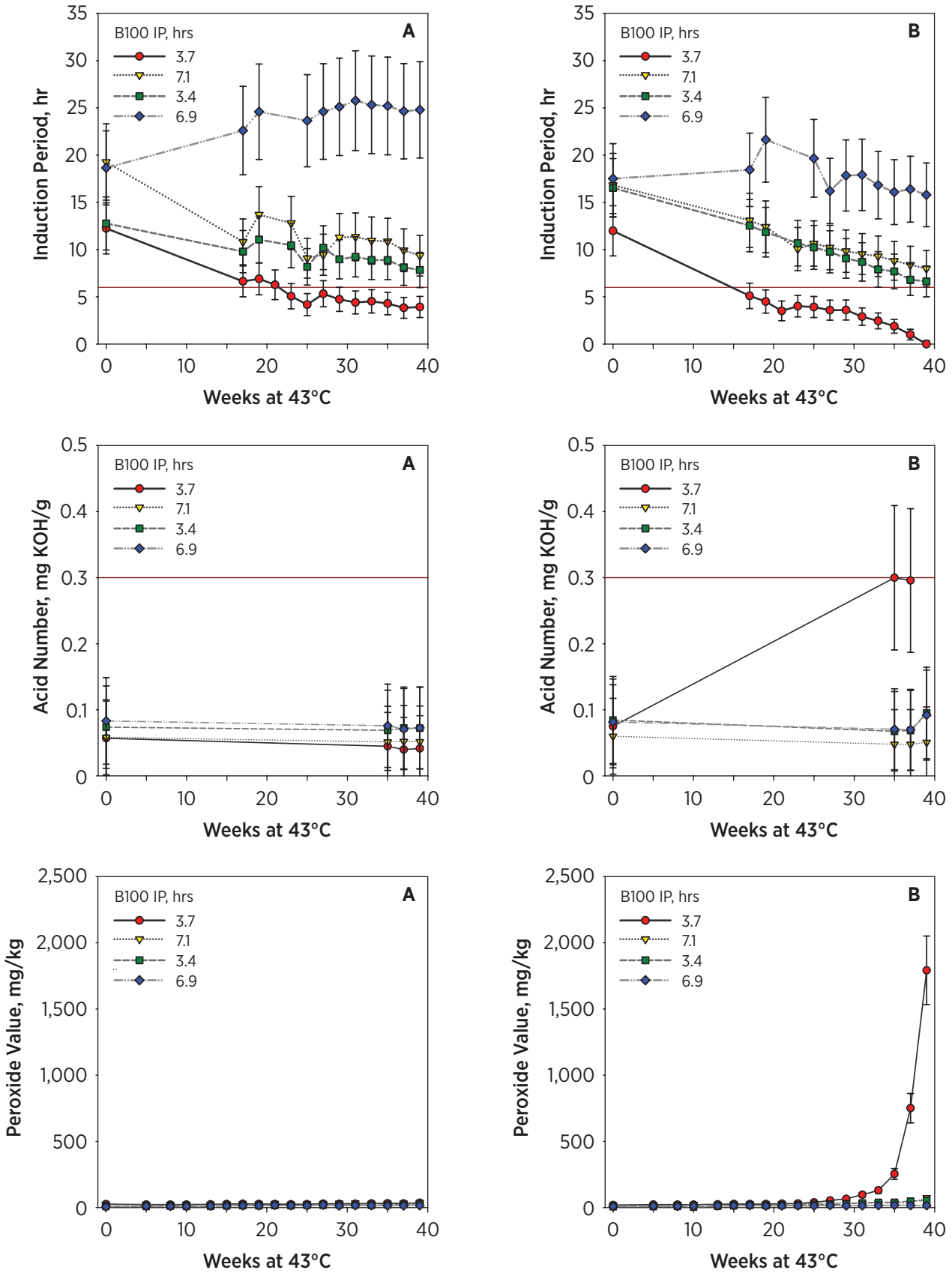


Figure 12. D4625 storage results for B20 blends made from B100 with varying levels of oxidation stability as measured by EN15751

specification. Based on these results, B20 blends made from in-specification B100 can be stored for one year and possibly longer. The base diesel used to prepare a blend also influences the storage stability of the blended fuel. Again, we recommend the use of a synthetic antioxidant and monitoring of the fuel periodically if you store fuel for longer than 6 months.

As biodiesel ages in storage, the induction period decreases, the peroxide value increases, the acid number eventually increases and goes out of specification, gums and varnish can form, and the viscosity can increase. Induction period, acid number, viscosity, and water and sediment tests can be used to ensure your biodiesel blend meets ASTM specifications for either B6 to B20 (D7467) or diesel fuel (D975). The results of the study presented here did not detect any statistically significant insoluble material formation in the B20s during storage. Previous studies have shown that when the acid number of a biodiesel blend increases to above the specification limit, a considerable amount of insoluble material can form.[24] Some data suggest that when oxidized or aged biodiesel is blended with diesel to make B20, some of the sediments and gums soluble in the B100 become insoluble and come out of solution, forming sediments. This information is presented as a warning only. You should never blend out-of-specification B100 into diesel to make B20. Make sure the induction period, water and sediment, acid number, and viscosity values are all in specification before blending. Fuel should be monitored for changes in induction period and acid number during storage. Blends that have gone above the maximum acid number of 0.3 mg KOH/g should not be used.

Thermal stability is generally meant to indicate that the fuel is degrading when it is subjected to high temperatures for a short period, similar to what would be experienced in the fuel injector or fuel system of a modern diesel engine. If the fuel degrades in a hot engine, the primary concern is the potential for fuel pump and injector fouling or corrosion. The data suggest thermal stability should not be a concern with biodiesel.

Cleaning Effect

Blends of 20% biodiesel or lower minimize any cleaning or solvent effect issues with accumulated sediments in tanks although minor filter plugging may be observed during the initial weeks of B20 use. Blends higher than 20% should always be stored in clean, dry tanks as recommended for conventional diesel fuel. Using B20 for a year or more will probably not clean your tanks and is not a substitute for a thorough tank cleaning when preparing for higher level blends or B100 storage.

Most people do not clean their tanks before B20 use, although it is still wise to keep some extra filters on hand and monitor potential filter clogging a little closer than normal when first starting to use B20. The cleaning effect of the biodiesel in B20 is sufficiently diluted that most problems are insignificant, but a fuel filter may plug when the fuel is first used. Drivers should be aware that sediments in the vehicle system might plug fuel filters during the first few weeks of using B20. Any filter clogging with B20, if it occurs at all, typically goes away after the first few times the tank is filled.

Some consumers who did not encounter problems with B20 assume they can switch to higher blends because the B20 has already cleaned their tanks. B20 is too dilute to clean tanks, so caution is still warranted with higher blends. The cleaning effect should not be an issue with B5 and lower blends.

Materials Compatibility

B20 or lower blends minimize most issues associated with materials compatibility. Experience over the last 10 years indicates B20 compatibility with all elastomers in diesel fuel systems, even those such as nitrile rubber, that are sensitive to higher blends. Customers should thus continue to check for and fix leaks.

Improper or lengthy storage of biodiesel or biodiesel blends can result in oxidation and the formation of corrosive organic acids and water that can adversely affect vulnerable materials. Although only limited research has been done on this issue, tests indicate that the degree of oxidation may be more important than the concentration of biodiesel. Unless used within a few months, biodiesel and biodiesel blends should be stabilized with antioxidants to reduce susceptibility to oxidation and degradation.

B20 may degrade faster than petroleum diesel if oxidizing metals such as iron, rust, copper, bronze, brass, or zinc are in fueling systems. If filters clog more frequently with B20 than with petroleum diesel, the fueling system should be checked for these materials and they should be replaced with biodiesel-compatible parts. Typically, these metals are found in lead solders, zinc linings, copper pipes, and brass and copper fittings. Stainless steel, carbon steel, and aluminum are good replacements. Data on the materials compatibility of biodiesel blends are summarized in Appendix C.

24. McCormick, R.L., and S.R. Westbrook 2010. "Storage Stability of Biodiesel and Biodiesel Blends." *Energy & Fuels* 24(1):690–698.

Viscosity of Various Biodiesel Blends as a Function of Temperature

Others have found good correlation with measured viscosity when predicting the viscosity of biodiesel blends using the standard method for calculating kinematic viscosities of mixtures:

$$\log \eta_B = m_1 \log \eta_1 + m_2 \log \eta_2$$

η_B = viscosity of the blend
η_1 and η_2 = viscosity of the compnents
m_1 and m_2 = mass fraction of the components

The results of this equation for various blends of a commercial biodiesel are shown in Figure 16.

These results suggest that this equation could be used to estimate viscosities of other intermediate blends.

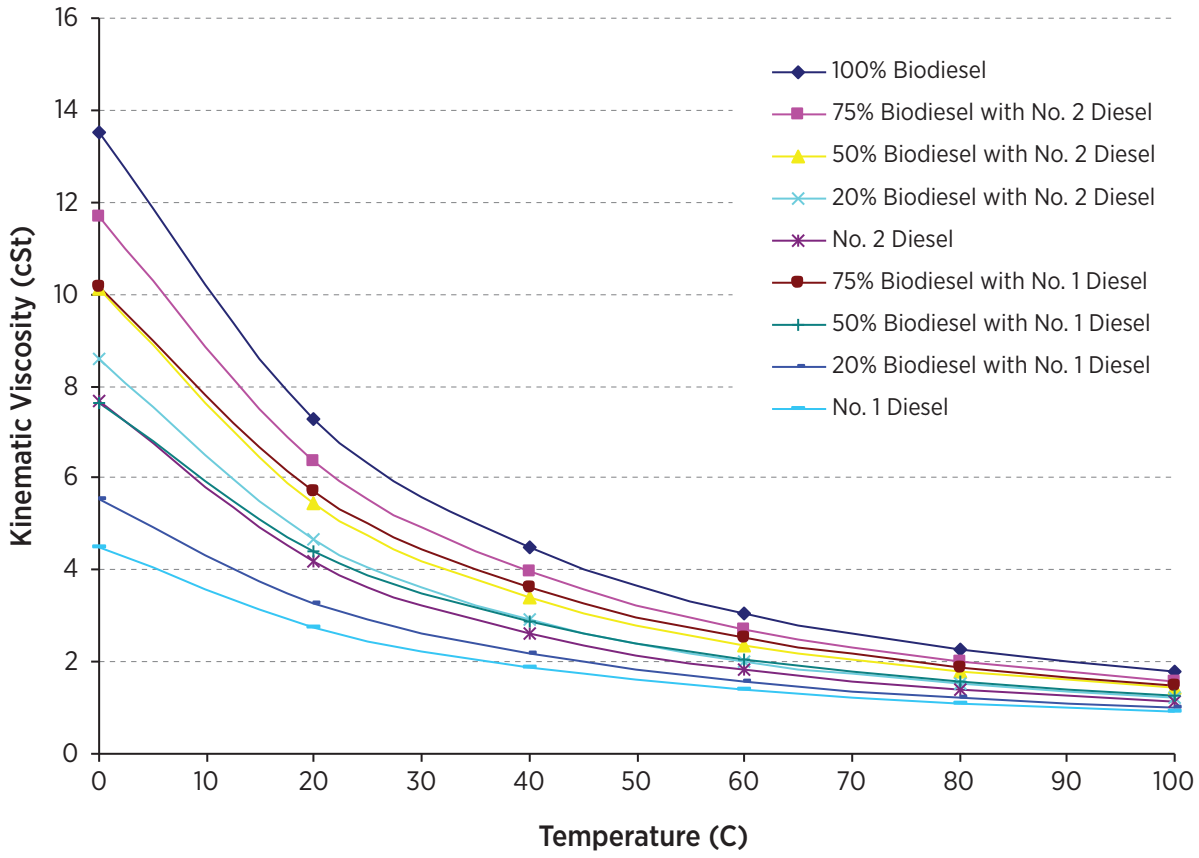


Figure 16. Kinematic viscosity for a commercial biodiesel in various blends[30]

30. Tat, M.E., and J. van Gerpen, 1999. "The Kinematic Viscosity of Biodiesel and Its Blends with Diesel Fuel." *JAOCS, 76,* 12, 1511-1513.

Safety, Health, and Environmental Issues

Neat biodiesel contains no hazardous materials and is generally regarded as safe. A number of studies have found that biodiesel biodegrades much more rapidly than conventional diesel. Users in environmentally sensitive areas such as wetlands, marine environments, and national parks have taken advantage of this property by replacing toxic petroleum diesel with biodiesel.

Like any fuel, biodiesel will burn; thus, certain fire safety precautions must be taken as described in this section. Of much greater concern are biodiesel blends that may contain kerosene or petroleum diesel. Kerosene is highly flammable with a flash point of 38°C to 72°C (100°F to 162°F). Diesel fuel is generally considered flammable—its flash point is 52°C to 96°C (126°F to 204°F). The flash point of biodiesel is required to be greater than 93°C (200°F), so is considerably less dangerous. However, biodiesel blends will have flash points in between diesel and biodiesel. The U.S. Department of Transportation considers a blend flammable and the Resource Conservation & Recovery Act of 1976 considers it to be ignitable if the flash point is lower than 60°C (140°F) or combustible if the flash point is 60°C to 93°C (140° to 200°F).

Signs, Labels, and Stickers

No placards or warning signs are required for the transport of neat biodiesel. However, biodiesel blends with diesel and kerosene are required to be transported in placarded trucks if the flash point of the blend is lower than 93°C (200°F), according to federal Department of Transportation regulations. If the flash point is lower than 60°C (140°F), the liquid is considered flammable and the Hazard Class 3 flammable placard is required (see Figure 17). Between 60° to 93°C (140°F and 200°F), the liquid is generally considered Hazard Class 3 combustible, and the combustible placard shown in Figure 16 is required for transport.

Local fire regulations determine the requirements for signage on storage containers, but typically tanks containing fuels (including B100) must be labeled with National Fire Protection Association diamonds. The National Fire Protection Association diamonds will indicate whether the fuel is flammable or combustible.

Fire Safety Considerations

Neat biodiesel can be extinguished with dry chemical, foam, Halon, CO_2, or water spray, although the water stream may splash the burning liquid and spread the fire. Oil-soaked rags can cause spontaneous combustion if not handled properly. Before disposal, wash rags with soap and water and dry in a well-ventilated area. Because biodiesel will burn if ignited, keep it away from oxidizing agents, excessive heat, and ignition sources.

Figure 17. Placards for transport of combustible and flammable liquids

Glossary

Additive: Material added in small amounts to finished fuel products to improve certain properties or characteristics.

Antioxidant: Substance that inhibits reactions promoted by oxygen.

Biodiesel: Methyl esters of fatty acids meeting the requirements of ASTM Specification D6751.

Biodegradable: Capable of being broken down by the action of microorganisms.

Boiling range: The spread of temperature over which a fuel or other mixture of compounds distills.

Cetane index: An approximation that correlates with a diesel fuels aromatic content based on an empirical relationship with density and volatility parameters such as the mid-boiling point; widely mistaken as an approximation of cetane number. This approximation is not valid for biodiesel or biodiesel blends.

Cetane number: A measure of the ignition quality of diesel fuel based on ignition delay in an engine. The higher the cetane number, the shorter the ignition delay and the better the ignition quality.

Cloud point: The temperature at which a sample of a fuel just shows a cloud or haze due to crystals when it is cooled under standard test conditions, as defined in ASTM D2500.

Energy Conservation Reauthorization Act: The Energy Conservation and Reauthorization Act of 1998 amended EPAct to allow qualified fleets to use B20 in existing vehicles to generate AFV purchase credits, with some limitations.

Elastomer: A rubber-type material frequently used in vehicle fuel systems (but not necessarily natural or synthetic rubber; may also apply to other polymers).

Energy content: The heat produced on combustion of a specified volume or mass of fuel; also known as heating value or heat of combustion.

EPAct: Energy Policy Act of 1992. Title III provides incentives to promote the use of alternative fuel vehicles in transportation.

FAME: Fatty acid methyl esters. A mono alkyl ester of long-chain fatty acids from naturally occurring plant oils, animal fats, and recycled greases.

Fatty acid: Any of the saturated or unsaturated monocarboxylic acids that occur naturally in the form of triglycerides (or mono- or diglycerides) or as free fatty acids in fats and fatty oils.

Flash point: The lowest temperature at which vapors from a fuel will ignite when a small flame is applied under standard test conditions.

Free fatty acids: Any saturated or unsaturated monocarboxylic acids that occur naturally fats, oils, or greases but are not attached to glycerol backbones. These can lead to high acid fuels and require special processes technology to convert into biodiesel.

Hydrocarbon: A compound composed of hydrogen and carbon. Hydrocarbons can refer to fuel components and to unburned or poorly combusted components in vehicle exhaust.

Induction period: The period of time before oxidation products form as biodiesel begins to age and degrade.

Kerosene: A refined petroleum distillate of which different grades are used as heating oil, blended into diesel fuel, and as fuel for aviation turbine engines.

Lubricity: The ability of a fuel to mitigate wear on metal-metal contact surfaces.

Microbial contamination: Containing deposits or suspended matter formed by microbial degradation of the fuel.

NTDE: A new technology diesel engine manufactured after 2010, with advanced emission control systems for reduction of PM, NO_x, hydrocarbons, and carbon monoxide emissions.

Oxidation: Loosely, the chemical addition of oxygen to a molecule.

Oxidative stability: The ability of a fuel to resist oxidation during storage or use.

Oxygenate: A fuel component that contains oxygen, e.g., biodiesel or ethanol.

PM: Particulate matter. The solid or semi-solid compounds of unburned fuel that are emitted from engines.

Polyunsaturated fatty acids: Fatty acids with more than one double bond.

Pour point: The lowest temperature at which a fuel will just flow when tested under standard conditions as defined in ASTM D97.

Renewable diesel fuel: A diesel fuel most closely associated with production from the hydrotreating of renewable feedstocks, such as fats and oils.

Saturation or saturated compound: A paraffinic hydrocarbon or fatty acid, i.e., with only single bonds and no double or triple bonds.

Solvent: A liquid capable of dissolving another substance to form a solution. A solution is a homogeneous mixture composed of two or more substances.

Specific gravity: The ratio of the density of a substance to the density of water.

Splash blending: The fuels to be blended are delivered separately into a tank truck.

Stratification: Separation into layers.

Storage stability: The ability of a fuel to resist deterioration in storage due to oxidation.

Torque: A force that produces rotation.

Viscosity: A measure of the resistance to flow of a liquid.

Appendix A: Sample Biodiesel Safety Data Sheet

[redacted]

Safety Data Sheet (SDS)

[redacted]

Section 1 – Chemical Product and Company Identification

Product identifier: Methyl Esters

Other means of identification

Synonyms: Biodiesel, B100, methyl soyate, soy methyl esters (SME), rapeseed methyl esters (RME), canola methyl esters (CME), corn oil methyl esters, methyl tallowate, fatty acid methyl esters, fatty acid alkyl esters.

Recommended use: Fuel, solvent, cleaning agent, heating oil, blend stock

Restrictions on use: Not intended for direct human consumption

Supplier information: [redacted]

Emergency phone number: Chemtrec: (800) 424-9300

Section 2 – Hazard(s) Identification

Classification (in accordance with 29 CFR 1910.1200)

Hazard Class	Hazard Category	Route of Exposure
Skin Irritation	Category 2 (irritation)	Absorption
Eye Irritation	Category 2B (mildly irritating)	Absorption

Signal word: **WARNING**

Pictograms:

Hazard Statements: Causes skin and eye irritation

Hazards not otherwise specified: None identified

Precautionary statements

Prevention: Wear appropriate protective gloves, protective garments, and eye protection. Avoid breathing mists and sprays.

Response: If on skin, wash thoroughly with soap and water. Take off contaminated clothing and wash it before reuse. If skin irritation or rash occurs, get medical advice.
If in eyes: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. If irritation persists: Get medical attention.

Storage: Store in cool tightly closed container

Disposal: Dispose of contents/container in accordance with local, state, and federal regulations.

[redacted]

Safety Data Sheet (SDS)

[redacted]

Section 3 – Composition / Information on Ingredients

Chemical Name	Common Name & Synonyms	CAS number	% of product
Unsaturated methyl esters	Methyl Esters, biodiesel	67762-26-9	100%

Section 4 – First Aid Measures

First aid measures for exposure

Inhalation:	Move to fresh air
Eyes:	Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. If eye irritation persists: Get medical attention.
Skin:	Wash affected skin with soap and water. Take off contaminated clothing and wash it before reuse.
Ingestion:	Rinse mouth out with water. If feeling unwell, seek medical attention.

Most important symptoms / effects

Acute:	May cause eye and skin irritation.
Delayed / Chronic:	No information available

Indication of immediate medical attention and special treatment needed, if necessary:	No special treatment identified. Treat symptomatically and supportively.

Section 5 – Fire Fighting Measures

Suitable extinguishing media:	Water mist, firefighting foam, dry chemical, carbon dioxide, or clean extinguishing agents (such as Halon or Halotron)
Unsuitable extinguishing media:	Do not use a solid water stream, as it may scatter and spread the fire
Specific hazards arising from the chemical:	May burn if heated, but does not readily ignite. Materials saturated with this product, such as oily rags, used oil dri, soaked insulation pads, etc., may spontaneously combust due to product decomposition in the presence of oxygen. Place all such materials into appropriate oily waste containers (such as metal cans with metal lids or oily waste dumpsters with lids), and dispose of according to local, state, and federal regulations.
Hazardous combustion products include:	Carbon monoxide, carbon dioxide, nitrogen oxides, and hydrocarbons
Protective equipment and precautions for firefighters:	Incipient stage fires may be controlled with a portable fire extinguisher. For fires beyond the incipient stage, evacuate all unnecessary personnel. Emergency responders in the immediate area should wear

[redacted]

Safety Data Sheet (SDS)

[redacted]

standard firefighting protective equipment, including self-contained breathing apparatus (SCBA) and full bunker gear. In case of external fires in proximity to storage containers, use water spray to keep containers cool, if it can be done safely. Prevent runoff from entering streams, sewers, storm drains, or drinking water supply.

Section 6 – Accidental Release Measures

Personal precautions, protective equipment, and emergency procedures:	Keep all sources of ignition away from spill. Wear protective garments, impervious oil resistant boots, protective chemical-resistant gloves, and safety glasses. If product has been heated, wear appropriate thermal and chemical protective equipment. If splash is a risk, wear splash resistant goggles and face shield. Shut off source of spill, if safe to do so. Contain spill to the smallest area possible. Isolate immediate hazard area and remove all nonessential personnel. Prevent spilled product from entering streams, sewers, storm drains, unauthorized treatment drainage systems, and natural waterways. Place dikes far ahead of the spill for later recovery and disposal. Immediate cleanup of any spill is recommended. **If material spills into or upon any navigable waters and causes a film or sheen on the surface of the water, immediately notify the National Response Center at 1-800-424-8802.**
Methods for containment and clean-up	
Small spill / incidental release:	Small spills can be cleaned up with a properly rated vacuum system, absorbent inert media (oil dri, sand, or earth), or absorbent pads. Use soapy water or degreaser to remove oily residue from the affected area, then rinse area with water. Place saturated materials in an appropriate oily waste container (metal can with a metal lid or an enclosed oily waste dumpster), and dispose of according to local, state, and federal regulations.
Large spill / release:	A spill remediation contractor with oil booms and skimmers may be needed for larger spills or spills that come into contact with a waterway or sensitive wetland. Recover as much product as possible by pumping it into totes or similar intermediate containers. Remove any remaining product with a properly rated vacuum system, absorbent inert media (oil dri, sand, or earth), or absorbent pads. Use soapy water or degreaser to remove oily residue from the affected area, then rinse area with water. Place saturated materials in an appropriate oily waste container (metal can with a metal lid or an enclosed oily waste dumpster), and dispose of according to local, state, and federal regulations.
Other information:	Materials saturated with this product, such as oily rags, used oil dri, soaked insulation pads, etc., may spontaneously combust due to product decomposition in the presence of oxygen. Place all such materials into appropriate oily waste containers (such as metal cans with metal lids or oily waste dumpsters with lids), and dispose of according to local, state, and federal regulations.

Section 7 – Handling and Storage

Precautions for safe handling:	When transferring product, use pipes, hoses, and tanks that are electrically bonded and grounded to prevent the accumulation of static electricity.
Conditions for safe storage, including incompatibilities:	Keep away from strong oxidizing agents, strong reducing agents, strong acids, and strong bases. Store the product in a cool dry place, in a tightly closed container. Storage tanks should have an appropriate ventilation and pressure relief system.

[redacted]

Safety Data Sheet (SDS)

[redacted]

Section 8 – Exposure Controls / Personal Protection

Precautions for safe handling:	When transferring product, use pipes, hoses, and tanks that are electrically bonded and grounded to prevent the accumulation of static electricity.
Component exposure limits:	There were no OSHA PELs or ACGIH TLVs for this product.
Appropriate engineering controls:	Keep product enclosed in primary containment (hoses, pipes, tanks, etc.) to avoid contact with skin. Handle in accordance with good industrial hygiene and safety practices.
Personal protective equipment	
Eyes / face:	Wear safety glasses. If splash potential exists, use splash resistant goggles and a face shield.
Skin:	Wear disposable nitrile or other similar chemical-resistant gloves for incidental contact. For more substantial contact, wear thicker nitrile or other similar chemical-resistant gloves. Wear protective garments, such as a chemical apron, chemical resistant coveralls, or chemical resistant coat and pants, along with impervious oil-resistant boots. Remove soaked protective equipment, decontaminate with soapy water, and rinse thoroughly before reuse. **Note**: product will cause natural rubbers to degrade at a very rapid rate. Such protective equipment will need to be carefully inspected after decontamination to see if it is still in serviceable condition. Any defective or worn out equipment should be immediately discarded.
Respiratory:	No exposure limits are available, but appropriate organic vapor or supplied air respiratory protection may be worn if irritation or discomfort is experienced. Respiratory protection must be provided and used in accordance with all local, state, and federal regulations.

Section 9 – Physical and Chemical Properties

Physical State:	Liquid	Color:	Water white to pale yellow to brown if undyed
Odor:	Mild oily or animal fat odor	Odor Threshold:	*No available information*
pH:	Not applicable	Melting/Freezing Point:	-1°C to 20°C / 30°F to 68°F
Boiling Point/Range:	>280°C / 536°F (at 1 atm)	Flash Point:	>110°C / >230°F (ASTM D93)
Evaporation Rate:	*No available information*	Flammability (solid/liq):	*No available information*
LFL:	*No available information*	UFL:	*No available information*
Vapor Pressure:	*No available information*	Vapor Density:	*No available information*
Relative Density:	0.87-0.89 @ 25°C	VOC:	*No available information*
Solubility (H20):	Negligible	Solubility *(other)*:	*No available information*
Auto Ignition Temp.:	*No available information*	Decomposition Temp.:	*No available information*
Viscosity:	3.8-5.0 cSt @ 40°C	Partition coefficient (n-octanol/water) :	*No available information*

Section 10 – Chemical Stability and Reactivity Information

Reactivity:	When handled and stored appropriately, no dangerous reactions are known
Chemical stability:	Stable in closed containers at room temperature under normal storage and handling conditions

[redacted]

Safety Data Sheet (SDS)

[redacted]

Possibility of hazardous reactions:	When handled and stored appropriately, no dangerous reactions are known
	See Sections 5 and 6 regarding spontaneous combustion of product-saturated absorbent materials.
Conditions to avoid:	Ignition sources, accumulation of static electricity, heating product to its flash point, or allowing the product to cool below its melting point (otherwise it may solidify and not be transferable until it is reheated).
Incompatible materials:	Keep away from strong oxidizing agents, strong reducing agents, strong acids, and strong bases.
Hazardous decomposition products:	Carbon oxides, hydrogen sulfide, nitrogen oxides, and hydrocarbons

Section 11 – Toxicological Information

Likely routes of exposure:	Absorption, ingestion, and inhalation
Symptoms	
Inhalation:	Coughing or irritation
Eye contact:	Redness or irritation and tearing
Skin contact:	Redness or irritation
Ingestion:	Nausea, vomiting, or feeling unwell
Acute toxicity	
Oral:	LD50 >17,500mg/kg (rat) estimated
Dermal:	LC50 >2000mg/kg (rat)
Inhalation:	No available information
Skin corrosion / irritation:	(rat) after 24 hr exposure, some irritation which subsided within 12 – 14 days (human) after 24 hr exposure, some minor irritation (less than that of a 4% soap & water solution)
Serious eye damage / eye irritation:	Industrial experience has shown that product in the eyes can cause redness and irritation which subsides within 7 days.
Sensitization *(Respiratory or Skin)*:	*No available information*
Germ cell mutagenicity:	*No available information*
Carcinogenicity:	Not listed as a carcinogen by IARC, NTP, or OSHA
Component carcinogenicity:	*No available information*
Reproductive / developmental toxicity:	*No available information*
Specific target organ toxicity	
Single exposure:	*No available information*

[redacted]

Safety Data Sheet (SDS)

[redacted]

Repeated exposure:	*No available information*
Aspiration hazard:	*No available information*

Section 12 – Ecological Information

Acute ecotoxicity - short-term exposure

Fish:	48hr LC50 (rainbow trout) 2.8-4.6 ug/L 96hr LC50 (bluegill) >1000mg/L
Invertebrates:	LC-50 (Daphnia Manga) 23 ppm
Long Term Exposure (Fish & algae):	NOEL >100mg/L (fish, invertebrate, and algae)
Persistence and degradability:	Product is biodegradable in aerobic conditions (90% biodegraded within 23 days)
Bioaccumulative potential:	There is a potential for bioaccumulation of this product
Mobility in soil:	*No available information*
Other adverse effects:	See section 5 & 6 regarding spontaneous combustion of materials that are soaked in this product

Section 13 – Disposal Considerations

Disposal *(waste / unwanted product)*:	This material, as supplied, is not a hazardous waste according to Federal regulations (40 CFR 261). This material could become a hazardous waste if chemical additions are made to this material, or if the material is processed or otherwise altered. Consult 40 CFR 261 to determine whether the altered material is a hazardous waste. Consult the appropriate local, state, regional, or federal regulations for additional requirements.
Disposal *(containers with residue)*:	Dispose of all containers with residue according to local, state, regional, and federal regulations.

Section 14 – Transport Information

UN number:	Not Regulated as a hazardous material
UN proper shipping name:	Not Regulated as a hazardous material
Transport hazard class:	Not Regulated as a hazardous material
Packing group:	Not Regulated as a hazardous material
Marine pollutant:	☐Yes ☒ No
Transport in bulk requirements:	Not Regulated as a hazardous material
Special transportation precautions:	Not Regulated as a hazardous material

[redacted]

Safety Data Sheet (SDS)

[redacted]

Section 15 – Regulatory Information

Inventory Listings

TSCA	☒ Listed ☐ Exempt
DSL	☒ Listed ☐ Exempt

U.S. Federal Regulations

SARA 313: Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). This product contains the following chemical(s) subject to the reporting requirements of the Act and Title 40 of the Code of Federal Regulations, Part 372:

None

SARA 311/312 Hazard Categories:

Acute Health Hazard	☐Yes	☒No
Chronic Health Hazard	☐Yes	☒No
Fire Hazard	☐Yes	☒No
Sudden Release of Pressure Hazard	☐Yes	☒No
Reactive Hazard	☐Yes	☒No

Clean Water Act: This product contains the following chemical(s) regulated as pollutants pursuant to the Clean Water Act (40 CFR 122.21 and 40 CFR 122.42):

None

CERCLA: This material, as supplied, contains the following chemical(s) regulated as hazardous substances under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) (40 CFR 302) or the Superfund Amendments and Reauthorization Act (SARA) (40 CFR 355). There may be specific reporting requirements at the local, regional, or state level pertaining to releases of this material.

None

U.S. State Regulations

California Proposition 65:

☒ This product does not contain any Proposition 65 chemicals.

U.S. State Right-to-Know Regulations:

No State Listed

[redacted]

Safety Data Sheet (SDS)

[redacted]

Section 16 – Other Information

Issuing Date: [redacted]

Revision Date: [redacted]

Version #: [redacted]

NFPA 704 Ratings	
Health Hazard:	1
Flammability:	1
Instability:	0
Other:	-

Revision Note: Updated format and information to meet the requirements of the Global Harmonization Standard

WARNING: POTENTIALLY HAZARDOUS MATERIAL. IMPROPER USE OR MISHANDLING CAN RESULT IN SERIOUS INJURY OR DEATH. THIS PRODUCT CONTAINS SUBSTANCES WHICH, IF MODIFIED, MAY BE FLAMABLE AND MAY BURN OR EXPLODE IF HEATED OR EXPOSED TO FLAME OR OTHER IGNITION SOURCE OR WATER, OXIDIZING AGENTS, ACIDS OR OTHER CHEMICALS. AVOID INGESTION, INHALATION AND CONTACT WITH SKIN AND EYES.

Disclaimer:
The information provided on this SDS is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as a guide for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered as a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other material or in any process, unless specified in the text.

End of SDS

Appendix B: Biodiesel Materials Compatibility Summary Tables

Neat biodiesel is not compatible with certain elastomers, metals, and plastics that are commonly used with petroleum diesel. Generally (but not always), biodiesel blends of 20% or lower have a much smaller effect on these materials; the very small concentrations of biodiesel in B5 or B2 have no noticeable effect on materials compatibility. If in doubt, contact the manufacturer for more information about the compatibility of specific materials with biodiesel fuels or fatty methyl esters (see Table C-1).

Elastomers

Table B-1. Elastomer Compatibility with Biodiesel

Material	Compatibility with Fresh, Unoxidized Methyl Oleate Unless Noted	Reference
Buna-N	Not recommended	3,4
Butadiene	Not recommended	2
Butyl	Mild effect	2,4
Chemraz	Satisfactory	4
Ethylene propylene (EPDM)	Moderate effect	2,4
Fluorocarbon	Satisfactory	2,4,5
Fluorosilicon	Mild effect; increase swelling	1
Fluorosilicone	Mild effect	2,4
Hifluor	Satisfactory	2
Hypalon	Not recommended	2,4
Natural Rubber	Not recommended	2,4
Neoprene	Not recommended	3,4
Neoprene/Chloroprene	Not recommended	2
Nitrile	Not recommended	1,2
Nitrile, high aceto-nitrile	Mild effect with B20, swelling and break strength affected	5
Nitrile, hydrogenated	Not recommended	2,4
Nitrile, peroxide-cured	Mild effect with B20, swelling and break strength affected	5
Nordel	Moderate to severe effect	3
Nylon	Satisfactory	1
Perfluoroelastomer	Satisfactory	2
Polypropylene	Moderate effect; increased swelling, hardness reduced	1
Polyurethane	Mild effect; increased swelling	1
Styrene-butadiene	Not recommended	2,4
Teflon	Satisfactory	1,3,4

Table C-1 continued on next page

Table B-1 *(cont.)*. **Elastomer Compatibility with Biodiesel**

Material	Compatibility with Fresh, Unoxidized Methyl Oleate Unless Noted	Reference
Viton	Satisfactory; type of cure affects compatibility with oxidized biodiesel see specific types of Viton below	1,3
Viton A-401C	Satisfactory with fresh RME; not recommended for oxidized blends B20 and above	6
Viton F-605C	Satisfactory with fresh RME; not recommended for oxidized blends B20 and above	6
Viton GBL-S	Satisfactory with RME and with all oxidized blends	6
Viton GF-S	Satisfactory with RME and with all oxidized blends	6
Wil-Flex	Moderate to severe effect	3

RME = rapeseed methyl ester

1. Bessee, G.B. and J.P. Fey. Compatibility of Elastomers and Metals in Biodiesel Fuel Blends. SAE 971690. 1997.
2. Parker O-Ring Handbook, Parker Hannifin Corporation, O-Ring Division, Lexington, KY, 2007.
3. Chemical Resistance Guide, Wilden Pump & Engineering Co., Grand Terrace, CA, 2005.
4. O-Ring Chemical Compatibility Guide, Custom Rubber O-Ring Mfg., Accessed November 2, 2015. *efunda.com/designstandards/oring/oring_chemical.cfm*
5. Terry, B., R.L. McCormick, M. Natarajan. "Impact of Biodiesel Blends on Fuel System Component Durability." SAE 2006-01-3279, 2006.
6. Thomas, E., R.E. Fuller, K. Terauchi. "Fluoroelastomer Compatibility with Biodiesel Fuels," SAE 2007-01-4061, 2007.

Metals

Certain metals may affect the biodiesel by accelerating its oxidation process and creating fuel insolubles. Lead, tin, brass, bronze, and zinc significantly increase sediment formation in both B100 and B20. Galvanized metal and terne-coated sheet metal are not compatible with biodiesel at any blend level.

UL Standards

Table B-2. UL Biodiesel Testing Standards for Refueling Equipment

UL Testing Standard	Equipment Covered	Biodiesel Test Fuel Blends in UL Standard
UL 58	Underground Steel Tanks	No test fuels
UL 1316	Underground Fiberglass Tanks	No biodiesel test fuels
UL 80	Aboveground Combustible Liquid Fuel Tanks - Heating Oils	No test fuels in UL 80, but UL 2258 for nonmetallic tanks requires B25a & B100a
UL 971 & UL 971A	Underground Pipes and Pipe Fittings	No biodiesel test fuels
UL 2447	*Sumps:* tank, dispenser, transition, fill/vent (spill buckets) types *Sump fittings:* penetration, termination, internal, test and monitoring types *Sump accessories:* covers/lids, frames, brackets, chase pipes	Requires B25a test fluid.
UL 2583	*Part I Vapor Control Products:* emergency vents, pressure vacuum vents, fill and vapor adaptors, and monitor well caps *Part II Liquid Control Products:* overfill prevention devices (for fill pipes) with drop tube extractor tee, jack screw, & seal adapter options; flow restriction devices (for vent pipes), and overfill containment devices	Requires B25a test fluid.
UL 2039	Flexible connector pipes with underground, sump & aboveground rating options	B25a test fuel required with B100a test fuel option
UL 87B	Diesel, biodiesel & diesel/biodiesel blend dispensers	B25a test fuel required with B100a test fuel option
UL 25B	Diesel, biodiesel & diesel/biodiesel blend meters	B25a test fuel required with B100a test fuel option
UL 79B	Diesel, biodiesel & diesel/biodiesel blend pumps	B25a test fuel required with B100a test fuel option
UL 330B	Diesel, biodiesel & diesel/biodiesel blend hoses and hose assemblies	B25a test fuel required with B100a test fuel option
UL 331B	Diesel, biodiesel & diesel/biodiesel blend filters and strainers	B25a test fuel required with B100a test fuel option
UL 428B	Diesel, biodiesel & diesel/biodiesel blend submersible turbine pumps	B25a test fuel required with B100a test fuel option
UL 567B	Diesel, biodiesel & diesel/biodiesel blend break-aways, swivels, pipe connection fittings	B25a test fuel required with B100a test fuel option
UL 842B	Diesel, biodiesel & diesel/biodiesel blend shear valve (emergency shut-off valve)	B25a test fuel required with B100a test fuel option
UL 2586B	Diesel, biodiesel & diesel/biodiesel blend nozzles	B25a test fuel required with B100a test fuel option

Tank Manufacturer Compatibility

Table B-3. Tank Manufacturer Compatibility with Biodiesel Blends	
Manufacturer	**B100**
Fiberglass[a]	
Containment Solutions	✓
Owens Corning	✗
Xerxes	✓
Steel[b]	
Acterra Group Inc.	✓
Caribbean Tank Technologies Inc.	✓
Eaton Sales & Service LLC	✓
General Industries	✓
Greer Steel, Inc.	✓
Hall Tank Co.	✓
Hamilton Tanks	✓
Highland Tank	✓
J.L. Houston Co.	✓
Kennedy Tank and Manufacturing Co., Inc.	✓
Lancaster Tanks and Steel Products	✓
Lannon Tank Corporation	✓
Mass Tank Sales Corp.	✓
Metal Products Company	✓
Mid-South Steel Products, Inc.	✓
Modern Welding Company	✓
Newberry Tanks & Equipment, LLC	✓
Plasteela	✓
Service Welding & Machine Company	✓
Southern Tank & Manufacturing Co., Inc.	✓
Stanwade Metal Products	✓
Talleres Industriales Potosinos, S.A. de C.V.	✓
Tanques Antillanos C. x A.	✓
Watco Tanks, Inc.	✓
We-Mac Manufacturing Company	✓

Letters stating compatibility:

a. PEI *pei.org/ust-component-compatibility-library*

b. STI *steeltank.com/Publications/E85BioDieselandAlternativeFuels/ManufacturerStatementsofCompatibility/tabid/468/Default.aspx*

Underground Equipment

Table B-4. Underground Equipment			
Company	**Product**	**Model**	**Biodiesel Compatibility**
Manufacturers introduce and discontinue models over time. If you do not see your equipment on this list please contact the manufacturer. Note, "X" in these lists can be substituted for any value.			
Federal code requires compatibility of this equipment with specific fuels. This is achieved through either third-party listing or a letter from the manufacturer stating compatibility. If a specific manufacturer or model is not in the list, please contact the manufacturer directly to determine compatibility. Compatibility letters are available at: *pei.org/ust-component-compatibility-library*.			
Bravo Systems	Fiberglass fittings	Series F, FF, FPE, FR, Retrofit-S, D-BLR-S, D-INR-S, FLX, FLX-INR, FPS, TBF	B100
Bravo Systems	Spill buckets	B3XX	B100
Bravo Systems	Tank Sumps & covers	B4XX	B100
Bravo Systems	Transition sumps	B5XX, B6XX, B7XX, B8XX	B100
Bravo Systems	Under dispenser containment sumps	B1XXX, 7XXX, B8XXX, B9XXX	B100
Brugg	Piping	FLEXWELL-HL, SECON-X, NITROFLEX, LPG	B100
Cimtek	Filter	200, 250, 260-10, 260-30, 260AHS, 260HS, 300-02, 300-10, 300-30, 300HS, 400-02, 400-10, 400-30, 400HS, 800-02, 800-10, 800-30, 800HS	B20
Cimtek	Filter	260BHG, 260BMG, 300BHA, 300BMG, 300MB, 400BHA, 400BMG, 400MB, 450-10, 450-30, 475XL-10, 475XL-30, 450HS-10, 450HS-30, 475XLHS-10, 475XLHS-30, 800BHA, 800BHG, 800BMG	B100
Franklin Fueling	Other UST equipment	Franklin has third-party certified equipment compatible with biodiesel blends. Contact manufacturer for specific part numbers.	
Franklin Fueling	Piping	Franklin has third-party certified equipment compatible with biodiesel blends. Contact manufacturer for specific part numbers.	
Husky	Pressure vacuum vents	4620, 4885, 5885, 11730, 11735, 11740, 450MG-10, 475XLMB-10	B20
Morrison Bros.	Overfill prevention valve	9095S	B20
Morrison Bros.	Anti-syphon valve	912	B100
Morrison Bros.	AST adaptor	927	B100
Morrison Bros.	Ball valves	691BSS	B100
Morrison Bros.	Clock gauges	818	B100

Table C4 continued on next 3 pages

Table B-4 *(cont.)*. Underground Equipment			
Company	**Product**	**Model**	**Biodiesel Compatibility**
Morrison Bros.	Clock gauge with alarm	918	B100
Morrison Bros.	Combination vent/overfill alarm	922	B100
Morrison Bros.	Drop tubes	419A, 539TO, 539TC	B100
Morrison Bros.	Emergency vents	244	B100
Morrison Bros.	Expansion relief valve	076DI, 078DI	B100
Morrison Bros.	External emergency valves	346DI, 346FDI, 346SS, 346FSS	B100
Morrison Bros.	Flame arrestor	351S	B100
Morrison Bros.	Frost proof drain valve	128DIS	B100
Morrison Bros.	In-line check valve	958	B100
Morrison Bros.	Internal emergency valves	272DI, 72HDI	B100
Morrison Bros.	Overfill alarm	918TCP	B100
Morrison Bros.	Overfill prevention valve	9095A-AV, 9095SS	B100
Morrison Bros.	Series cap	305C	B100
Morrison Bros.	Solenoid valves (3", must be all-Teflon version)	710SS	B100
Morrison Bros.	Spill containers	515/516/517/518	B100
Morrison Bros.	Swing check valves	246ADI, 246DRF	B100
Morrison Bros.	Vapor recovery adaptor	323	B100
Morrison Bros.	Vapor recovery caps	323C	B100
Morrison Bros.	Vent-pressure vacuum	548, 748, 749	B100
Morrison Bros.	Vent-updraft	354	B100
National Environmental Fiberglass	Sumps and accessories	all	B100
NOV Fiberglass	Piping	RedThread IIA, Ameron Dualoy	B100
NUPI	Piping	Smartflex	B100
OMEGAFLEX	Piping	DoubleTrac (stainless steel fittings)	B100
OPW	AST anti-siphon valve	199ASV	B20
OPW	AST check valve	175, 1175	B20
OPW	AST emergency shut off valve	178S	B20
OPW	AST emergency vent	201, 301	B20
OPW	AST mechanical gauge	200TG	B20

Table C4 continued on next 2 pages

Table B-4 *(cont.)*. Underground Equipment			
Company	**Product**	**Model**	**Biodiesel Compatibility**
OPW	AST spill container	211-RMOT, 331, 332	B20
OPW	AST swing check valve	all	B20
OPW	AST tank alarm	444TA	B20
OPW	AST vapor adaptor	1611AVB-1625	B20
OPW	AST vapor cap	1711T-7085-EVR, 1711LPC-0300	B20
OPW	Ball float vent valve	53VML, 30MV	B20
OPW	Check valve	70, 70S	B20
OPW	Dispenser sumps & accessories	FlexWorks	B20
OPW	Drop tube	61FT	B20
OPW	Extractor fittings and plug	233, 233VP	B20
OPW	Face seal adaptor (threaded riser adaptor)	FSA	B20
OPW	Fill adaptor-side	61AS	B20
OPW	Fill adaptor-top	633T, 633TC	B20
OPW	Fill Cap	634TT-7085-EVR, 634LPC, 634TT-4000	B20
OPW	Fill cap-side	62TT	B20
OPW	Fill-swivel adaptor	61SALP-MA, 61SALP-1020-EVR	B20
OPW	Flexible connectors	FCxx	B20
OPW	Jack screw	61JSK, 71JSK	B20
OPW	Manhole	Conquistador, Fiberlite, 104A, 104FG, 104C, 6110,6120	B20
OPW	Monitoring well cap kit	634TTM	B20
OPW	Monitoring well probe cap	62M, 116M, 62M-MA	B20
OPW	Multi-port spill containment	6511, 6421, 6511, 6521, 6561, 6571, Fiberlite	B20
OPW	Piping	FlexWorks	B20
OPW	Piping	FlexWorks, KPS, Pisces (discontinued)	B20
OPW	Pressure vacuum vent	523V, 623V	B20
OPW	Spill container (bucket)	1-2100, 1SC-2100, 1C-2100,1C-2200, EDGE (1-3100), '1-2105, 101-BG2100	B20
OPW	Tank sumps & accessories	Fiberlite, FlexWorks	B20
OPW	Transition sumps & accessories	FlexWorks	B20

Table C4 continued on next page

Table B-4 *(cont.)*. Underground Equipment			
Company	**Product**	**Model**	**Biodiesel Compatibility**
OPW	Vapor adaptor	1611AV, 1611AVB	B20
OPW	Vapor cap	1711T-7085-EVR, 1711LPC	B20
OPW	Vapor-swivel adaptor	61VSA-MA, 61VSA-1020-EVR	B20
Veeder-Root	Ground water monitoring	P/N 794380-621, 794380-622, 794380-624	B20
Veeder-Root	Interstitial and secondary containment monitoring	P/N 794380-XXX, 794390-XXX, 847990-00X, 857080-XXX, P/N 794380-321, 794380-323, 794380-333, 794380-344, 794380- 345, 794380-351, 794380-430	B20
Veeder-Root	Continuous interstitial tank system	P/N 857280-100, 857280-200, 857280-30X	B100
Veeder-Root	Electronic line leak detector	Series 8484, 8590	B100
Veeder-Root	Interstitial and secondary containment monitoring	794380-344, 794380-345, 794380- 321, 794380-351	B100
Veeder-Root	Magnetostrictive Probe	Mag Plus Series 8463XX, Mag Series 8473XX	B100
Veeder-Root	Red Jacket Maxxum Pump	410763-XXX (MXP300JX-XXX or MXP500JX-XXX)	B100
Veeder-Root	Tall tank probe	Mag-FLEX 889560-XXX, MAGXL-XXX	B100
Veeder-Root	Vapor monitoring	P/N 394390-700	B20
Western Fiberglass	Co-flex piping	all	B100
Western Fiberglass	Co-flow hydrostatic monitoring systems	all	B100
Western Fiberglass	Cuff fittings	all	B100
Western Fiberglass	Sumps (dispenser, tank, transition, vapor, vent)	all	B100

Aboveground Equipment (Dispensers, Hanging Hardware, etc.)

Table B-5. Dispensers, Hanging Hardware, Shear Valves, Submersible Turbine Pumps			
Company	**Product**	**Model**	**Biodiesel Compatibility**
UL B20 Listed Equipment			
Manufacturers introduce and discontinue models over time. If you do not see your equipment on this list, please contact the manufacturer. Note, X in these lists can be substituted for any value.			
Franklin Fueling	Shear valve	Franklin has third-party certified equipment compatible with biodiesel blends. Contact manufacturer for specific part numbers.	
Franklin Fueling	Submersible turbine pump	Franklin has third-party certified equipment compatible with biodiesel blends. Contact manufacturer for specific part numbers.	
Gilbarco	Dispenser	All Encore models since 1/1/2014	B20
Husky	Breakaway	5812 Safe-T-Brake	B20
Husky	Nozzle	VIII	B20
Husky	Swivel	4860	B20
OPW	Breakaway	66V-030RF, 66V-130RF, 66V-135RF, 66RB-20RF	B20
OPW	Nozzle	7H models ending in -B20; 11A models ending in -B20; 11B models ending in -B20	B20
OPW	Swivel	241TPS-75RF, 241TPS-10RF	B20
OPW	Shear valve	10P-0152	B20
Veyance	Hose	Flexsteel Futura	B20
Wayne	Dispenser	Option on Ovation and Helix models. Contact Wayne for Specific model information.	B20

1. **Which are the most commonly used biodiesel blends in the United States?**
   - ○ B5 to B20
   - ○ B20 to B40
   - ○ B75 to B100
   - ○ B40 to B75

2. **Biodiesel by definition is a fuel comprised of _____ of long chain fatty acids derived from vegetable oils or animal fats, designated B100.**
   - ○ mono-alkyl esters
   - ○ dialkyl esters
   - ○ mono-alkyl amides
   - ○ All of the above

3. **100 lbs. of oil or fat reacted with 10 lbs. of methanol in the presence of a catalyst will produce approximately how much biodiesel?**
   - ○ 10 lbs.
   - ○ 50 lbs.
   - ○ 100 lbs.
   - ○ 110 lbs.

4. **Which of the following standard/specification is for biodiesel?**
   - ○ ASTM D6751
   - ○ Energy Policy Act of 1992
   - ○ ECRA
   - ○ ASTM D975

5. **True or False? Biodiesel reduces tailpipe emissions and greenhouse gas emissions.**
   - ○ True
   - ○ False

6. **6. Biodiesel contains _____ energy per gallon than typical No.2 Diesel.**
   - ○ 8% more
   - ○ 8% less
   - ○ 12.5% more
   - ○ 12.5% less

7. **What is the minimum cetane number of biodiesel?**
   - ○ 40
   - ○ 47
   - ○ 87
   - ○ 100

8. **What is called the temperature at which the fuel contains so many agglomerated crystals that it is essentially a gel and will no longer flow.**
   - ○ Cloud point
   - ○ Pour point
   - ○ Cold filter plug point
   - ○ Freeze point

9. **True or False? Since B100 is comprised of methyl esters, a known cleaner and solvent, B100 will dissolve the accumulated sediments in diesel storage and engine fuel tanks.**
   - ○ True
   - ○ False

10. **What low-temperature critical metric is the indicator for whether a fuel can be pumped or not?**
    - ○ Cloud point
    - ○ Pour point
    - ○ Cold filter plugging point (CFPP)
    - ○ Low-temperature flow test (LTFT)

11. **In general, blending biodiesel is not difficult if you remember that biodiesel is slightly _____ and _____ viscous than diesel fuel, and the more it is mixed, the better.**
    - ○ Lighter, less
    - ○ Heavier, more
    - ○ Heavier, less
    - ○ Lighter, more

12. **True or False? Blending as little as 0.25% biodiesel into petroleum diesel can significantly improve lubricity**
    - ○ True
    - ○ False

13. **In regard to storage stability, which of the following will have the shortest life without additives?**
    - ○ B100
    - ○ B20
    - ○ B5
    - ○ All have same storage stability

14. True or False? Biodiesel contains no hazardous materials and is generally regarded as safe. A number of studies have found that biodiesel biodegrades much more rapidly than conventional diesel.

- True
- False

15. A measure of the resistance to flow of a liquid is called what?

- Lubricity
- Specific gravity
- Viscosity
- Stratification

16. Which extinguishing media should be used to safety control a biodiesel fire?

- Dry chemical
- Halon
- Water mist
- All of the above

17. In reference to the Safety Data Sheet, what is the appearance and odor of biodiesel?

- Pale yellow liquid, mild odor
- Clear liquid, strong odor
- Luminescent liquid, no odor
- Light grey color, Pungent odor

18. True or False? Biodiesel has a lower viscosity when compared to No. 1 Diesel.

- True
- False

19. What following elastomer should not be used with pure biodiesel?

- Nylon
- Teflon
- Fluorocarbon
- Neoprene

20. Which of the following metals affect biodiesel by accelerating its oxidation process?

- Lead
- Brass
- Tin
- All of the above