

XI. BIODIESEL

A. Product Overview and Description

Biodiesel is a renewable distillate fuel derived from a number of vegetable oils, animal fats, or used frying oils. These oils are converted into methyl esters before they are used as diesel fuel. ASTM International defines biodiesel as the “mono alkyl esters of long chain fatty acids derived from renewable lipid feedstocks, such as vegetable oils and animal fats, for use in compression ignition engines.” In the 1980s and 1990s significant R&D was conducted to evaluate a variety of biodiesel blending stocks, develop emissions data, assess engine/vehicle performance, and develop cost-effective manufacturing processes. Pure biodiesel is referred to as B100, while biodiesel blends with petroleum-based diesel fuel are referred to as BXX, where “XX” is the volume percent of biodiesel fuel blended with the petroleum-based diesel fuel.

In comparison with petroleum-based diesel fuel, biodiesel is characterized by:

- Lower heating value (by about 10-12%).
- Higher cetane value (typically 45-60).
- About 11% oxygen content (petroleum-based diesel contains no oxygen).
- No aromatics contents (and no PAHs).
- No sulfur or extremely low sulfur content.
- Better lubricity.
- Higher viscosity.
- Higher freezing temperature (higher cloud point and pour point).
- Higher flash point.
- No toxicity or low toxicity.
- Biodegradability.
- Different corrosive properties.

Some of the above properties, such as the high cetane value or good lubricity, are obvious advantages of biodiesel while others, including the lower heating value, high freezing point (and inferior flow properties at low temperature), or corrosion properties are its drawbacks. Biodiesel changes the character and can increase the intensity of the odor of diesel exhaust (see www.dieseln.net).

B. Emission Reduction

Biodiesel fuel can reduce PM, HC, and CO emissions, but typically increases NO_x emissions (largely because of the chemically bound oxygen found in biodiesel). The percentage of emission reductions and increase in NO_x is a function of the percentage of the fuel blend that is comprised of biodiesel.

Since the biodiesel base stock can come from a variety of sources (several different vegetable oils, animal fats, waste cooking oils, etc.), the specific fuel properties vary somewhat, depending on the biodiesel source and degree of processing refinement. Thus, the specific emissions effects vary according to biodiesel fuel composition. Several studies and assessments of emissions from biodiesel have been completed, including extensive work by the U.S. EPA. The general emission trends for a “generic” B20 blend with today’s conventional highway low sulfur diesel fuel compared with 100% conventional highway diesel fuel typically shows for total PM emissions, B20 provides about a 10-15 % reduction; for CO and HC (including the air toxics components of HC emissions), 0 to 10% reduction; for sulfate emissions (formed from SO₂ emissions), up to a 20% reduction; and for NO_x, up to a 10% increase. PM_{2.5} reductions comprise about 3% or less, of the 10% reduction for total PM.

The NO_x increase is a function of engine fuel/emission control systems design, and several biodiesel properties, including cetane value, oxygen content, density, and physical properties, all of which vary with the specific biodiesel base stock. Some newer diesel engines (produced in 2002 and later) have shown less of a propensity for a NO_x increase with B20. Research has shown that for older engines, injection timing changes can reduce or eliminate the NO_x increase, but performing these changes is not recommended. Certain types of additives mixed with B20 were found to reduce or eliminate the NO_x increase.

Compared to petroleum-based diesel fuel, biodiesel has been shown to reduce vapor-phase hydrocarbons in the C1 to C12 range, aldehydes and ketones, PAH and NPAH emissions, and has generated no new emission species compared to those currently present in diesel or biodiesel exhaust.

C. Status & Availability

According to the National Biodiesel Board, current and proposed biodiesel production plants are located in 20 states in the U.S. More than 1000 distributors are making biodiesel available in all 50 states (see www.biodiesel.org).

Researchers from South Dakota State University and the University of Missouri-Columbia undertook a survey of U.S. state transportation agencies to collect performance, storage and economic information related to the use of biodiesel fuels, and found that B20 was the most common biodiesel blend used across the country. This survey found five states that have mandated the use of biodiesel in state government vehicles, and that nearly 65% of the states in the U.S. reported either considering or enacting biodiesel blended fuel mandates, or using biodiesel blended fuel. Table 11-1 illustrates the states that currently require the use of biodiesel in some form, and those that offer incentives for biodiesel production or use, or both. Nearly 40% of the states indicated some level of experience using biodiesel blend, either in tests

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or as policy. In addition, there are a multitude of non-state DOT government agencies and private sector fleets that have either tested or are currently using biodiesel blends. B20 is an allowable fuel for satisfying the state government and fuel provider requirements for alternative fuel vehicle acquisition/usage under the Energy Policy Act of 1992 (EPACT).



Table 11-1, States Requiring Use of Biodiesel or Providing Incentives

State	Legislation Requiring Biodiesel Use	Legislation Providing Incentives for Biodiesel Production or Use
Arkansas		X
Iowa		X
Idaho		X
Illinois	X	X
Indiana		X
Kansas	X	
Kentucky	X	X
Maryland		X
Michigan	X ¹	X
Minnesota	X	
Missouri	X	X
Mississippi		X
Montana		X
North Carolina		X
North Dakota		X
Nebraska		X
New Jersey		X
Rhode Island		X
South Dakota		X
Texas		X
Washington	X	X

¹ Approved by the Michigan House Agriculture Committee. Pending approval in the Michigan House

There are several U.S. projects that have documented the use of biodiesel in diesel engine fleet applications as a retrofit strategy. The reasons most often cited are the effectiveness of emission reductions, ease of transition to use, and minimal impacts on current operating equipment and vehicles. According to the National Biodiesel Board, nearly 1.2 million gallons of biodiesel fuel were used in 2004, and as of January 2005, there were more than 400 major

fleets using biodiesel, including all branches of the U.S. military, Yellowstone National Park, NASA, several state departments of transportation, major public utility fleets, various city agencies, and over 50 school districts (see www.biodiesel.org).

D. Selection & Use Criteria

Available information from U.S. retrofit programs suggests that biodiesel blends do not appear to be incompatible with the use of DPFs and DOCs. Retrofit product manufacturers should be consulted before using any retrofit product with any biodiesel fuel.

Limited engine and vehicle testing suggest that compared to diesel fuel, the use of biodiesel with DPFs, can extend the time to regenerate by up to 4 times. A DPF technology provider has verified the use of a DPF on B20 fuel (www.arb.ca.gov/verdev/verdev.htm).

In general, no engine modifications need to be performed or special fuel additives be incorporated when using biodiesel up to a blend level of B20 that has been produced to the latest ASTM International specifications. Aside from the lack of need for engine modifications, modifying an engine may potentially create a violation of EPA's engine/vehicle anti-tampering provisions of the Clean Air Act. The EMA, Stanadyne Automotive (a major supplier of diesel engine fuel system components), and most diesel engine manufacturers (including General Motors, Ford Motor Company, Detroit Diesel Corporation, Deere and Company, Caterpillar, Inc., Cummins Engine Company, and International Engine Company) limit engine warranty coverage to use of biodiesel blends of 5% or less. Choice of a biodiesel blend level (particularly if the biodiesel component is greater than 20%) should be made with care, particularly if the engines using it are likely to be operating in sub-freezing conditions that may contribute to fuel gelling of the biodiesel blending component.

E. Costs

The cost of biodiesel can vary as a function of several factors, including the cost and type of the biodiesel feedstock, specifics of the manufacturing process, production plant size, distance from production plant to blending and distribution points, the value of Federal and state production incentives and/or tax credits, and price supports to users. As such, a range of costs has been reported and can be found across the U.S. Data collected and developed by EPA show that in 2002, B100 could be purchased for \$1.95 to \$3.00 per gallon (or about twice the price of conventional diesel fuel), and that B20 was priced at \$0.30 to \$0.40 more per gallon than conventional diesel fuel, exclusive of any production or use incentives or price supports. A recent report prepared by the DOE-EIA analyzed the factors that comprise the cost of biodiesel production, and concluded that over the next few years, the cost of producing biodiesel was not likely to be competitive with that of petroleum diesel. Various production incentives, tax credits and price supports are likely to continue to create a pricing structure that can be favorable to biodiesel fuel users.

F. Product Quality, Delivery, Storage and Fueling

The diesel Fuel Injection Equipment (FIE) manufacturers and EMA have developed positions on the use of biodiesel fuels in the products of their respective member manufacturers. In 2000, the U.S. Army developed a Department of Defense Purchase Description (DOD PD) for the use of B20 in diesel-powered non-tactical ground vehicles.

The FIE manufacturers have documented a number of operating problems with biodiesel fuels (particularly those used before the ASTM specifications were created). The key concern of these manufacturers is related to resistance to oxidation. Aged or poor quality biodiesel fuel may contain organic acids, free water, peroxides and products of fuel processing that may attack engine and fuel system components leading to reduced service life. The DOE National Renewable Energy Laboratory (NREL) has conducted a nationwide survey of biodiesel quality, and found several B100 specification failures (four samples out of 27) for acid number, total glycerin or phosphorous. Further, of 50 samples of B20 taken nationwide, only 32 samples were actually found to contain about 20% biodiesel. Additives of the types used commercially in diesel fuel have been shown to provide improvements to the quality of biodiesel blends in areas such as detergency, water separation, cold flow characteristics, fuel system corrosion and foaming. Such additives should not be applied by fleet fuel users unfamiliar with fuels manufacturing and distribution.

In December 1998, the ASTM International Subcommittee D02.E0 approved the first provisional standard for the manufacture of biodiesel. Prior to that time, no common standard, or specification of characteristics important for reliable engine operation was available. The most recent specification for biodiesel was established in 2003 as “ASTM D6751-03a Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels” and is to be used for blending with ASTM Specification D975 Grades 1-D, 2-D and low sulfur 1-D or 2-D diesel fuels. This current ASTM International specification includes test methods for establishing and measuring 35 individual biodiesel fuel characteristics or properties that are important to diesel engine/vehicle operation, including energy content, cetane number, cloud point, absorbed water, lubricity, viscosity, density, storage stability and flash point.

A specification for B20 is currently under development by ASTM International’s Subcommittee D02.E0 as Work Item (WK) 6286. Specifications are under development for three grades of B20, with the biodiesel component of the blend conforming to the requirements of ASTM D6751, and the remainder of the fuel being a middle distillate grade diesel fuel conforming to ASTM D975:

- B20 (S15) with a diesel fuel component maximum sulfur level of 15 ppm.
- B20 (S500) with a diesel fuel component maximum sulfur level of 500 ppm.
- B20 (S5000) with a diesel fuel component maximum sulfur level of 5000 ppm.

Given the variability in properties of biodiesel feedstocks, biodiesel should be purchased in accordance with the latest ASTM International specifications. Biodiesel fuels should be

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purchased from known, established suppliers that can attest to the quality of the biodiesel fuel product as being manufactured according to the latest ASTM International specification. The best place to have fuel quality verified (via testing) is as close to its final destination as possible, which is usually at the point of delivery to the user. Testing for conformance to key specifications at the point of delivery provides a minimal level of assurance that a quality product is being off-loaded into the user's fuel storage equipment. Another means of assuring fuel quality is for buyers of biodiesel fuels to require that the supplier be BQ-9000 accredited by the National Biodiesel Accreditation Program (www.bq-9000.org). This program is a unique combination of the ASTM International specification for biodiesel (ASTM D 6751) and a quality systems program that includes storage, sampling, testing, blending, shipping, distribution, and fuel management practices. The accreditation process is comprehensive and includes a detailed review of the supplier's quality system documentation, followed by a formal audit of its system. As of the writing of this report, there were two BQ-9000 accredited suppliers in the U.S., with additional suppliers involved in the accreditation process.

Clean, well-maintained and monitored equipment (preferably dedicated to exclusive use of biodiesel fuels) should be used to store and dispense biodiesel fuels, to minimize the effects of water contamination, sediment pick-up, extended storage, temperature extremes and their subsequent problems. To minimize cold weather-related problems and gelling, biodiesel blends with diesel fuel should be stored in tanks that can ensure the fuel temperature will remain at least 5°F to 10°F above the cloud point of the blend.

The solvency action of biodiesel can loosen and carry fuel tank sediment that will collect in fuel filters and clog them. Accordingly, fuel filters used on dispensers and engines should be inspected and replaced periodically. Such filters should be identified as being compatible for use with biodiesel fuels. Some fuel filter-related field problems with biodiesel blends were reported by a number of state DOT agencies. These filter problems declined or were completely resolved once the filters were replaced. Several state agencies avoided potential weather-related problems by discontinuing the use of biodiesel during cold weather periods.

Biodiesel, particularly at blend levels with diesel fuel of greater than B20, can be contaminated by growth of biological microorganisms. These microorganisms typically grow at the fuel-water interface and may not always be captured in fuel system filters. Should this occur, biocides are available to control growth. An excellent reference on this subject, Manual 47, Fuel and Fuel System Microbiology, is available from ASTM International, and provides a good understanding of fuel and fuel system biodeterioration, sampling requirements, test methods, and remediation practices.