Two North LaSalle Street, Suite 1700, Chicago, IL 60602
Tel: (312) 827-8700 | Fax: (312) 827-8737 | www.enginemanufacturers.org

Technical Statement on the Use of Biodiesel in Compression Ignition Engines

INTRODUCTION

The Engine Manufacturers Association ("EMA") is an international membership organization representing the interests of manufacturers of internal combustion engines.

In 2003, EMA published a "Technical Statement on the Use of Biodiesel Fuel in Compression Ignition Engines." Since that time, increased worldwide interest in reducing reliance on petroleum-based fuels and improving air quality has prompted broadened use of alternative, renewable fuels, including biodiesel. Regulatory agencies around the world have adopted plans requiring the use of renewable fuels, and international standard-setting bodies have approved specifications regarding their use. Understanding the importance of developing new technologies without compromising emission or performance benefits, EMA and its members have actively participated in many of these public and private initiatives.

This Statement, which takes into consideration data collected since the publication of the 2003 Statement, sets forth EMA's position on the use of biodiesel blend stock[1] with current engine technologies. It should be noted, however, that only limited research is available regarding the use of biodiesel with those technologies that have been, or are about to be, introduced to meet the (US) Environmental Protection Agency's ("EPA's") 2010 heavy-duty on-highway or Tier 4 nonroad emission standards.

BIODIESEL

Biodiesel blend stocks are methyl or ethyl esters derived from a broad variety of renewable sources such as vegetable oil, animal fat and recycled cooking oil. These esters are oxygenated organic compounds that can be used in compression ignition engines because some of their key properties are comparable to those of diesel fuel.

"Soy Methyl Ester" diesel ("SME" or "SOME"), derived from soybean oil, is the most common biodiesel available in the United States. "Rapeseed Methyl Ester" diesel ("RME"), derived from rapeseed oil, is the most common biodiesel blend stock available in Europe. Palm Methyl Ester ("PME"), derived from palm oil, is the most common biodiesel blend stock available in Asia. Collectively, these fuels are sometimes referred to as "Fatty Acid Methyl Esters" ("FAME") or "Fatty Acid Ethyl Esters" ("FAEE"). In addition, however, new feedstocks such as Jatropha and genetically engineered algae continue to be investigated in an on-going effort to improve economics and/or greenhouse gas emission benefits of biodiesel blend stocks.

Biodiesel blend stocks are produced by a process called transesterification, in which various oils (triglycerides) are converted into methyl esters through a chemical reaction with methanol (FAME) or ethanol (FAEE) in the presence of a catalyst, such as sodium or potassium

[1] This Statement does not address other renewable fuels such as non-ester renewable diesel fuel.

EMA European Office, Hasenacker Strasse 32, 71397 Leutenbach, Germany | Telephone/Facsimile: +49 7195 957126

hydroxide. By-products of the transesterification process include glycerols and water. These, along with traces of the methanol or ethanol, unreacted triglycerides, and the catalyst are undesirable and need to be removed from the finished product. Biodiesel naturally contains oxygen and must be stabilized to avoid storage problems. Although most biodiesel feedstock does not inherently contain sulfur, this chemical may be present in biodiesel blends that are stored, transported, or blended using equipment or facilities that have been exposed to products containing sulfur.

BIODIESEL SPECIFICATIONS

Biodiesel is produced in a pure form (100% biodiesel blend stock referred to as "B100" or "neat biodiesel") and is typically blended with petroleum-based diesel fuel. Such biodiesel blends are designated as BXX, where XX represents the percentage by volume of pure biodiesel contained in the blend (e.g., "B5," "B20").

Several international organizations have adopted and continue to revise biodiesel specifications and guidelines. Specifically, ASTM International recently approved revisions to its specification for B100 biodiesel blend stock referenced as D6751. Europe's Committee for Standardization ("CEN") has adopted a technical standard for biofuels referred to as EN 14214. The European specification includes more stringent limits for water and sediment, limits for mono-, di-, and tri- glycerides, and an Iodine value, none of which are included in the current ASTM specification. Oxidation stability requirements also vary between the two standards, in part because ASTM D6751 is specifically intended for use in B20 and lower blends. Several engine manufacturers have issued individual specifications or recommendations regarding biodiesel blends for their engines. In March 2009, the Worldwide Fuel Charter Committee (WWFC), of which EMA is a member, published Biodiesel Guidelines for B100 biodiesel used in blends up to 5% (B5).

To the extent feasible, standards for neat biodiesel and biodiesel blends should be performance-based and therefore feedstock neutral. Regardless of the biomass feedstock and the process used to produce the fuel, B100 blend stock should meet the requirements of ASTM D6751, EN 14214, or individual engine manufacturer recommendations.

It should be noted that the National Biodiesel Board has created a National Biodiesel Accreditation Commission whose purpose is to develop and implement a voluntary certification program for the producers and marketers of biodiesel in North America. The Commission has developed a standard entitled, "BQ-9000, Quality Management System Requirements for the Biodiesel Industry," for use in the certification process. In addition, it has provided its program materials to organizations outside North America that are interested in creating comparable quality assurance programs in their regions.

BIODIESEL BLENDS

In the United States, lawmakers and government agencies each have pursued efforts to promote and regulate the use of biodiesel blend stock. For example, the (United States) Energy Policy Act of 1992 ("EPAct") was amended in 1998 to allow covered fleets to use biodiesel to fulfill up to fifty percent (50%) of their annual alternative fuel vehicle (AFV) acquisition requirements. Under EPAct's Biodiesel Use Credits provisions, covered fleets are allocated one biodiesel use credit (the equivalent of a full vehicle credit) for each 450 gallons of B100 purchased and consumed. Such credits are awarded only if the blended fuel contains at least twenty percent biodiesel (B20) and is used in new or existing vehicles weighing at least 8500 pounds. No credits are awarded for biodiesel used in a vehicle already counted as an AFV. EPA has issued a renewable fuel standard (RFS) that includes requirements for renewable fuel production and recently proposed a second round of standards with higher annual production requirements (RFS-2). The (United States) Energy Independence and Security Act of 2007 establishes minimum alternative fuel production requirements, including those for biodiesel, beginning in 2009. The Act requires 500 million gallons per year of alternative fuel to be produced in 2009, with increases each year up to 1 billion gallons by 2012. Several other national standards which would require the increased use of renewable fuels, including biodiesel, are either in place or under review. At the same time, the U.S. Federal Trade Commission has established pump labeling requirements for all publicly available pumps dispensing biodiesel blends greater than B5. Pumps dispensing blends greater than B20 are required to identify the specific percentage blend being dispensed.

In addition, industry standard-setting organizations have modified existing fuel specifications and created new specifications to account for the use of biodiesel blends. For example, diesel fuel specifications ASTM D975 and EN 590 have been modified to allow for the use of biodiesel blends up to B5 and B7 respectively. In addition, ASTM International has adopted ASTM D7467 as a fuel specification to cover finished fuel blends containing six (6) to twenty (20) percent by volume biodiesel meeting ASTM D6751 in combination with a light-middle or middle distillate petroleum diesel fuel meeting ASTM D975.

A consortium of diesel fuel injection equipment manufacturers ("FIE Manufacturers") have also weighed in on the issue. Specifically, they issued a position statement concluding that blends up to B7 meeting the requirements of EN590 are acceptable provided that the biodiesel utilized meets EN14214. The FIE Manufacturers also accept the use of B5 blends meeting ASTM D975 but express concerns that the D975 specification does not include a stability requirement and the stability specification included in D6751 is inadequate. The FIE Manufacturers also stipulate, however, that additional standard revisions to EN590, EN14214, ASTM D7467, and ASTM D6751 will be required to facilitate higher blend levels.[2]

Based on their current understanding of biodiesel and blending with petroleum-based diesel fuel, EMA members expect that blends up to a maximum of B5 should not cause engine or fuel system problems, provided the B100 used in the blend meets the requirements of ASTM D6751 or EN 14214. Although blends in the B6-B20 range should be acceptable for use, provided that the finished fuel meets the requirements of ASTM D7467, engine and vehicle owners and operators should nonetheless consult their engine manufacturer regarding the acceptability of those blends in specific engine models. Biodiesel blends greater than B20 are not included in existing finished fuel specifications and are not generally recommended.

ENGINE OPERATION, PERFORMANCE AND DURABILITY

The energy content of neat biodiesel (B100) blend stock is about eleven percent (11%) lower than that of petroleum-based diesel fuel (on a per gallon basis). The actual power loss will vary depending on the percentage of biodiesel blended in the fuel, but is generally not

[2] See, "Fuel Requirements for Diesel Fuel Injection Systems _ Diesel Fuel Injection Equipment Manufacturers Common Position Statement 2009" (September 2009).

identifiable for B20 and lower blends. Any adjustment to the engine in service to compensate for such power loss may result in a violation of EPA's anti-tampering provisions. To avoid such illegal tampering, as well as potential engine problems that may occur if the engine is later operated with petroleum-based diesel fuel, EMA recommends that users not make such adjustments.

Neat biodiesel and higher percentage biodiesel blends can cause a variety of engine performance problems, including fuel filter plugging, injector coking, piston ring sticking and breaking, elastomer seal swelling and hardening/cracking, and severe engine lubricant degradation and dilution. At low ambient temperatures, biodiesel is more viscous than conventional diesel fuel, which can limit its use in certain geographic areas. Biodiesel blends generally have a higher temperature cloud point than petroleum diesel fuels, but the specific numbers vary significantly depending on feedstock. Fuel blenders and distributors monitor both petroleum diesel and biodiesel blends for cold flow properties, but users traveling from warmer to colder climates should refuel frequently to avoid use of warm area fuel in cold climates. In addition, elastomer compatibility with biodiesel remains unclear; therefore, when biodiesel blends are used, the condition of seals, hoses, gaskets, and wire coatings should be monitored regularly. When converting from petroleum-based diesel to a biodiesel blend, residual fuel system deposits may accumulate in fuel filters due to the high solvency of the fuel; thus, more frequent filter service may be required until the fuel system deposits are stabilized.

As a result of their generally poor storage stability (described under "Storage and Handling" below), biodiesel blends are not recommended for use in equipment that is used infrequently (e.g., standby electrical power generators) or seasonally (e.g. snow removal equipment) that rely on extended fuel storage times.

There is limited information available on the effect of neat biodiesel and biodiesel blends on engine durability during various engine duty cycles and environmental conditions. For example, biodiesel blends have been shown to dilute engine lubricating oil, and, in some cases, significantly reduce lubricant performance under certain duty cycles or in cold ambient conditions. When using biodiesel blends, engine lubricant should be monitored to determine if service intervals need to be reduced. More information is needed, however, to assess the viability of these fuels over the mileage and operating periods typical of the wide variety of products that utilize heavy-duty engines.

EMISSION CHARACTERISTICS

Multiple agencies have published reports on the emission effects of biodiesel. In October 2002, EPA released a draft report entitled, "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions." The draft technical report can be found on the EPA Web site at: http://www.epa.gov/otaq/models/biodsl.htm. In October 2006, the National Renewable Energy Laboratory (NREL) published a report entitled, "Effects of Biodiesel Blends on Vehicle Emissions." That report can be found on the NREL Web site at: http://www.nrel.gov/vehiclesandfuels/npbf/pdfs/40554.pdf. In addition, the California Air Resources Board is in the process of analyzing the effects of biodiesel blends on exhaust emissions from newer engine technologies. A report is expected by December 2009.

Use of biodiesel blends in place of petroleum-based diesel fuel may reduce visible smoke and particulate matter emissions, which are of particular concern in older diesel engines in nonattainment areas. In addition, biodiesel blends may achieve some reductions in reactive hydrocarbon ("HC") and carbon monoxide ("CO") emissions when used in an unmodified diesel engine. Those reductions are attributed to the presence of oxygen in the fuel. Depending on the engine and duty cycle, biodiesel blends may produce higher NOx emissions than petroleum-based diesel fuel. The improvements or increases in emissions are reduced as the blend level is reduced and may be eliminated for newer engines that utilize advanced emission control technologies.

STORAGE AND HANDLING

Untreated biodiesel blend stocks generally exhibit poor oxidation stability, which can result in long-term storage problems. Anti-oxidation additives may be needed to improve storage stability. To demonstrate their stability under normal storage and use conditions, neat biodiesel blend stocks, tested using EN 14112, should meet ASTM D6751 or EN 14214 limits for oxidation stability. The test is intended to predict the resistance of fuel to degradation during storage and to provide an indication of overall fuel stability. In addition, all biodiesel should comply with the cold soak filterability test requirement included in ASTM D6751, including the 200 second limit for blend stock anticipated to be utilized for blends exposed to cold ambient temperatures.

Biodiesel blend stock and higher biodiesel blends act as solvents, removing historical deposits accumulated from the use of petroleum diesel fuel. The materials removed accumulate in fuel filters, resulting in more frequent than typical service intervals until the deposits have stabilized. Therefore, when converting from petroleum diesel fuel to a biodiesel blend, fuel storage and vehicle/equipment tanks should be cleaned and rid of any residual water.

When biodiesel blends are used at low ambient temperatures, filters may plug, and the fuel in the tank may become more viscous to the point where it will not flow sufficiently for proper engine operation. Therefore, it may be prudent to store biodiesel blend stock in a heated building or storage tank, as well as heat the fuel systems' fuel lines, filters, and tanks. Additives also may be needed to allow for the use of biodiesel blends in a wider range of ambient temperatures. (Some common petroleum diesel fuel cold flow improvers may be less effective when used with biodiesel.)

Poor blending practices can result in significant discrepancies between the intended blend and the uniformity of the blend delivered. For example, recent industry survey results indicate that a blend intended to be B20 ranged from less then B5 to greater than B50. Thus, care should be taken to ensure that biodiesel blend stock and petroleum diesel fuel are uniformly blended. Splash blending should be conducted only with careful monitoring of the consistency of the blend. Injection blending systems typically provide acceptable uniformity but should be verified on initial installation and periodically confirmed.

Biodiesel blend stock and biodiesel blends are an excellent medium for microbial growth. Inasmuch as water accelerates microbial growth and is naturally more prevalent in biodiesel than in petroleum-based diesel fuels, care must be taken to remove water from fuel tanks. The effectiveness of conventional anti-microbial additives in biodiesel has generally been positive but depends on the fuel and additive combination actually in use. The presence of microbes may cause operational problems as a result of fuel system corrosion, premature filter plugging, and sediment build-up in fuel systems.

In the U.S., Underwriters Laboratory (UL) provides approval for fuel handling and dispensing equipment such as service station pumps. UL has verified that biodiesel blends of B5 and lower are acceptable in traditional service station pumps. UL is in process of evaluating B6-B20 blends.

Additional information regarding biodiesel storage, handling, and use may be found in the National Renewable Energy Laboratory (NREL) publication, entitled “Biodiesel Handling and Use Guide.”[3]

HEALTH & SAFETY

Neat biodiesel has been tested and found to be nontoxic in animal studies. Emissions from engines using biodiesel blends have undergone successful health effects testing in accordance with EPA Tier 2 requirements for fuel and fuel additive registration.

Biodiesel blend stocks are biodegradable, which may render them useful in applications where biodegradability is desired (e.g., marine or farm applications).

Biodiesel is believed to be as safe in handling and storage as petroleum-based diesel fuel. Biodiesel has a higher flash point than petroleum-based diesel fuel, which, depending on local regulations, may allow for transportation and storage without the restrictions associated with flammable materials.

WARRANTIES

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

ECONOMICS

The cost of biodiesel blend stock varies depending on the basestock, geographic area, variability in crop production from season to season, government tax incentives, and other factors. Although the cost may be reduced if relatively inexpensive feedstock, such as waste oils or rendered animal fat, is used instead of soybean, rapeseed, palm or other plant oil, the average cost of biodiesel blend stock nevertheless exceeds that of petroleum-based diesel fuel.

That said, users considering conversion to an alternative fuel should recognize that the relative cost of converting an existing fleet to biodiesel blends may be lower than the conversion cost associated with the use of any other alternative fuels because no major engine, vehicle, or dispensing system changes are required.

[3] NREL/TP-540-43672, January 2009: http://www.nrel.gov/vehiclesandfuels/pdfs/43672.pdf

CONCLUSIONS

- Regardless of the biomass feedstock and the process used to produce the fuel, B100 blend stock should meet the requirements of ASTM D6751, EN 14214, or individual engine manufacturer specifications/recommendations.
- Biodiesel blends up to a maximum of B5 should not cause engine or fuel system problems, provided the B100 used in the blend meets the requirements of ASTM D6751 or EN 14214.
- Biodiesel blends ranging from B6 up to B20 should meet the requirements of ASTM D7467. Engine manufacturers should be consulted prior to using B6-B20 blends because acceptability varies by engine model. Biodiesel blends greater than twenty percent (B20) are not typically recommended and should be used only after consulting the engine manufacturer.
- Biodiesel blends may require additives to improve storage stability and allow use in a wider range of temperatures. In addition, the conditions of seals, hoses, gaskets, and wire coatings should be monitored regularly when biodiesel blends are used. When converting from a petroleum-based diesel to a biodiesel blend, fuel tanks should be cleaned and more frequent filter service may be required until fuel system deposits are stabilized.
- Although the actual power loss will vary depending on the percentage of biodiesel blended in the fuel, B100 fuel's energy content is approximately 5-7% lower than that of petroleum diesel fuel. Biodiesel blends of B20 and lower typically do not result in observable power loss or reduction in fuel economy.
- Biodiesel blends reduce particulate, HC and CO emissions. Depending on the engine type and duty cycle, they may produce increased NOx emissions compared with those of petroleum-based diesel fuel used in an unmodified diesel engine. Engines designed to meet stringent emission regulations have not demonstrated additional reductions in particulate, HC, and CO emissions or increases in NOx emissions when using biodiesel blends but more testing is required to confirm the interaction between the emission reduction strategies and biodiesel blends.
- Biodiesel blend stocks have generally been found to be nontoxic and biodegradable, which may promote their use in applications where biodegradability is desired.
- Individual engine manufacturers determine what implications, if any, the use of biodiesel blends have on the manufacturer's commercial warranties.
- Although several factors affect the cost of biodiesel blend stock, its average cost exceeds that of petroleum-based diesel fuel. The relative cost of converting an existing fleet to biodiesel blends, however, is likely lower than the cost of converting to other alternative fuels.

Dated: October 2009

EMADOCS: 27902.14