Truck & Engine Manufacturers Association®
Bringing Clean Power to the World™

333 West Wacker Drive, Suite 810
Chicago, Illinois, 60606
Phone/Fax: (312) 929-1970
www.truckandenginemanufacturers.org

Technical Statement on the Use of Biodiesel in Compression Ignition Engines

INTRODUCTION

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

In 2009, EMA updated its "Technical Statement on the Use of Biodiesel Fuel in Compression Ignition Engines" (originally published in 2003). Increased worldwide interest in reducing reliance on petroleum-based fuels and improving air quality has prompted significant increases in the 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. For example, the U.S. EPA has designated biodiesel as an Advanced Biofuel (*i.e.*, one that provides greater than 50% reduction in greenhouse gas (GHG) emissions) because of the significant carbon reduction associated with its use. In addition to ongoing criteria emission (NO_X, HC, CO, and particulate matter) reductions, GHG emission (CO_2, etc.) reductions are required by regulatory agencies. As a result, the engine's fuel carbon intensity (CI) will continue to be a significant factor. EMA supports a standardized method for determining CI.

EMA and its members have actively participated in many public and private initiatives to understand the importance of developing new alternative fuel technologies without compromising the engine's ability to control emissions and meet user performance requirements.

This Statement, which takes into consideration data collected since the publication of the 2009 Statement, sets forth EMA's position on the use of biodiesel blendstock[1] with current engine technologies.

BIODIESEL

Biodiesel blendstocks 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"), 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 blendstock available in Europe. Palm Methyl Ester ("PME"), derived from palm oil, is the most common biodiesel blendstock available in Asia. Collectively, these fuels are sometimes referred to as "Fatty Acid Methyl Esters" ("FAME") or "Fatty Acid Ethyl Esters" ("FAEE"). In addition, new/combined feedstocks continue to be

[1] For more information, see the EMA statement entitled, "Facts You Should Know About Biomass-Based Diesel Fuels."

investigated in an on-going effort to improve economics, finished blendstock performance, and/or GHG emission benefits of biodiesel blendstocks.

Biodiesel blendstocks 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 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 as well as higher levels of unsaturation depending on the type of feedstock used to make it, and thus must be stabilized to avoid storage problems. Although most biodiesel feedstock does not inherently contain sulfur, sulfur may be present in biodiesel blends that are stored, transported, or blended using equipment or facilities that have been exposed to products containing the chemical. A significant portion of the U.S. biodiesel production has been modified to add a distillation process that may reduce the potential for additional undesirable compounds and improves cold flow performance but also may reduce inherent stability, thus requiring the addition of stability additives.

BIODIESEL SPECIFICATIONS

Biodiesel is produced in a pure form (100% biodiesel blendstock referred to as "B100" or "neat biodiesel") and is typically blended with petroleum-based diesel fuel for market distribution. 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 continuously considers revisions to its specification for B100 biodiesel blendstock 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 limit value, none of which are included in the current ASTM specification. Oxidation stability requirements also differ between the two standards, in part because ASTM D6751 is specifically intended for use as a blending stock, most commonly in B20 and lower blends. Several engine manufacturers have issued individual specifications or recommendations regarding biodiesel blends for their engines.

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 blendstock should meet the requirements of ASTM D6751, EN 14214, or individual engine manufacturer recommendations.

It should be noted that the Clean Fuels Alliance America (formerly National Biodiesel Board) has created a National Biodiesel Accreditation Commission whose purpose is to develop and implement a voluntary accreditation 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,"[2] for use in the accreditation 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.

[2] For more information, see the BQ-9000 webpage, at: https://www.bq-9000.org/documents/.

BIODIESEL BLENDS

In the United States, lawmakers and government agencies each have pursued efforts to promote and regulate the use of biodiesel blendstock. For example, the (United States) Energy Policy Act of 1992 ("EPAct") was amended in 1998 to allow covered fleets (e.g., federal, state, etc.) 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. The U.S. Energy Policy Act of 2005 (EPAct 2005) and the Energy Independence and Security Act of 2007 (EISA) required that EPA promulgate a renewable fuel standard (RFS) program that set specific, increasing requirements for minimum annual renewable fuel production, for each year from 2009 through 2022, and required that EPA set the minimum annual volumes thereafter. Notably, EISA expanded the RFS program to require minimum alternative fuel production requirements, including those for biodiesel. The statute set a minimum of 1 billion gallons annually beginning in 2012, but allowed EPA to increase that annual requirement (e.g., the 2021 annual volume standards set biomass-based diesel at 2.43 billion gallons). Several other standards that would require the increased use of renewable fuels, including biodiesel, are either in place or under review. In some cases, those may require biodiesel blends greater than B20. 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 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 middle distillate diesel fuel meeting ASTM D975. Biodiesel blends greater than B20 are not controlled by existing standards published by ASTM, creating significant concerns with regulatory efforts associated with the use of higher blends.

Based on their current understanding of blending biodiesel 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 are accepted for use by many engine manufacturers, provided that the finished fuel meets the requirements of ASTM D7467, engine and vehicle owners and operators should nonetheless consult engine manufacturer recommendations 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 as broadly recommended as lower percentage blends; however, some individual engine manufacturers have approved up to B100 for some of their products in certain applications, provided the fuel meets that engine manufacturer's specification. In all cases, users should refer to their individual engine manufacturer's technical publications to determine what, if any, blend is acceptable for a particular engine.

ENGINE OPERATION, PERFORMANCE AND DURABILITY

The energy content of neat biodiesel (B100) blendstock is about eleven percent (11%) lower than that of petroleum-based diesel fuel (on a per gallon basis). The actual power loss for biodiesel blends will vary depending on the percentage of biodiesel blended in the fuel but is generally not noticeable 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 have been known to cause a variety of engine performance problems with some manufacturers, including fuel filter plugging, injector coking, elastomer seal swelling and hardening/cracking, and 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 appropriately to avoid use of warm area fuel in cold climates. 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, biodiesel blends that have not been treated and stored appropriately, as described below in "Storage and Handling" are not recommended for use in equipment that is used infrequently (e.g., standby electrical power generators) or seasonally (e.g., snow removal equipment, agricultural equipment, etc.) that experience extended fuel storage times. For specific guidelines, please refer to individual engine manufacturer recommendations.

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, generally associated with older engines that do not have advanced emission control systems. 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 non-attainment 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 blendstocks 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 blendstocks, tested using Rancimat Induction Period test method 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 blendstock anticipated to be utilized for blends exposed to cold ambient temperatures.

Biodiesel blendstock and higher biodiesel blends can act as solvents, removing historical deposits accumulated when using 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. Additional fuel filters should be available to replace plugged filters until the systems are cleaned; typically, two or three low-hour filter changes suffice.

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 blendstock 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, ongoing industry survey results indicate that a blend intended to be B20 ranged from less than B5 to greater than B50. Thus, care should be taken to ensure that biodiesel blendstock 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 evaluated for blend rate control.

Biodiesel blendstock and biodiesel blends are excellent media for microbial growth. Water, more prevalent in biodiesel than in petroleum-based fuels, accelerates microbial growth. Care must therefore 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. The presence of microbes may cause operational problems because they are linked to fuel system corrosion, premature filter plugging, and sediment build-up in fuel systems.

In the U.S., the Underwriters Laboratory (UL) serves as an approval body for fuel handling and dispensing equipment such as service station pumps. UL has verified that biodiesel blends up to B20 are compatible with traditional service station pumps.

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 in animal studies and found to be nontoxic. 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, per 40 CFR Part 79 – Registration of Fuels and Fuel Additives.

Biodiesel blendstocks are biodegradable, which may be advantageous 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). Most manufacturers also provide commercial warranties. Individual engine manufacturers determine what consequences, if any, the use of biodiesel blends has on the manufacturers' warranties. In general, engine manufacturers warrant materials and workmanship. Consumables, including any fuel used in the engine, are not warranted, but use of those fuels (including biodiesel) does not void the warranty. It is unclear what implications the use of biodiesel blends has on emissions warranty, in-use liability, anti-tampering provisions, and the like.

ECONOMICS

The cost of biodiesel blendstock varies depending on the basestock, geographic area, variability in crop production from season to season, 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 virtually all biodiesel blendstock 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 some other alternative fuels, because the required engine, vehicle, or dispensing system modifications required for biodiesel blend usage are typically less costly.

[3] https://afdc.energy.gov/files/u/publication/biodiesel_handling_use_guide.pdf

CONCLUSIONS

- Regardless of the biomass feedstock and the process used to produce the fuel, B100 blendstock should meet the requirements of ASTM D6751, EN 14214, or individual engine manufacturer specifications/recommendations.
- Biodiesel blends up to a maximum of B5 are not expected to 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 blends above B5.
- Biodiesel blends may require additives to improve storage stability and enable use in a wider range of temperatures. In addition, the condition of seals, hoses, gaskets, and wire coatings should be monitored regularly when biodiesel blends are used. Consult the engine owners' manual or manufacturer to understand the durability impacts. When converting from a petroleum-based diesel to a biodiesel blend, fuel tanks should be cleaned, and more frequent engine fuel 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 11% 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 NO_X emissions compared with operation on 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 NO_X emissions when using biodiesel blends, but more testing is required to determine the interaction between the emission reduction strategies and biodiesel blends. Biodiesel use does reduce life cycle GHG emissions based on the carbon intensity of the biodiesel utilized.
- Biodiesel blendstocks 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 may have on their warranties.
- Although several factors affect the cost of biodiesel blendstock, 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.

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