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TECHNICAL STATEMENT ON THE USE OF BIODIESEL FUEL IN COMPRESSION IGNITION ENGINES

Introduction

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

In 1995, EMA published a "Statement on the Use of Biodiesel Fuels for Mobile Applications." Since that time, increased worldwide interest in reducing reliance on petroleum-based fuels and improving air quality has led many stakeholders, including engine manufacturers, to continue to investigate the use of alternative, renewable fuels, including biodiesel fuels, as a substitute for conventional diesel fuel. In addition, recent government proposals in the United States and Europe have called for incentives or mandates to increase the production and use of such renewable fuels.

This Statement, which takes into consideration additional laboratory and field research conducted since the publication of the 1995 Statement, sets forth EMA's position on the use of biodiesel fuels with current engine technologies. It should be noted, however, that only limited data 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") 2004 heavy-duty on-highway emission standards. Moreover, because of the absence of available data, the Statement does not address the potential use of biodiesel fuels with advanced emission control technologies, including aftertreatment systems designed for future ultra-low emission engines.

Biodiesel

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

"Soy Methyl Ester" diesel ("SME" or "SOME"), derived from soybean oil, is the most common biodiesel in the United States. "Rape Methyl Ester" diesel ("RME"), derived from rapeseed oil, is the most common biodiesel fuel available in Europe. Collectively, these fuels are sometimes referred to as "Fatty Acid Methyl Esters" ("FAME").

Biodiesel fuels are produced by a process called transesterification, in which various oils (triglycerides) are converted into methyl esters through a chemical reaction with methanol in the presence of a catalyst, such as sodium or potassium hydroxide. The by-products of this chemical reaction are glycerols and water, both of which are undesirable and need to be removed from the fuel along with traces of the methanol,

unreacted triglycerides and catalyst. Biodiesel fuels naturally contain oxygen, which must be stabilized to avoid storage problems. Although biodiesel feedstock does not inherently contain sulfur, sulfur may be present in biodiesel fuel because of contamination during the transesterification process and in storage.

Biodiesel Specifications

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

Several standard-setting organizations worldwide have recently adopted biodiesel specifications. Specifically, ASTM International recently approved a specification for biodiesel referenced as D 6751. In addition, German authorities have issued a provisional specification for FAME under DIN 51606. And, Europe's Committee for Standardization ("CEN") is in the final stages of setting a technical standard for biofuels to be referred to as EN 14214. The European specifications include more stringent limits for sulfur and water, as well as a test for oxidation stability, which is absent from the current ASTM specification.

Depending on the biomass feedstock and the process used to produce the fuel, B100 fuels should meet the requirements of either ASTM D 6751 or an approved European specification, such as DIN 51606 or EN 14214 (once adopted).

In addition, it should be noted that the National Biodiesel Board has created the National Biodiesel Accreditation Commission to develop and implement a voluntary program for the accreditation of producers and marketers of biodiesel. The Commission has developed a standard entitled, "BQ-9000, Quality Management System Requirements for the Biodiesel Industry," for use in the accreditation process.

Biodiesel Blends

Public and private bodies recently have taken positions regarding the use of biodiesel blends. For example, the (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 Fuel Use Credits provisions, covered fleets are allocated one biodiesel fuel use credit (the equivalent of a full vehicle credit) for each 450 gallons of B100 purchased and consumed. Such credits are awarded only if the blended fuel contains at least 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.

During the same time period, however, a consortium of diesel fuel injection equipment manufacturers ("FIE Manufacturers") issued a position statement concluding that blends greater than B5 can cause reduced product service life and injection

equipment failures.[1] According to the FIE Manufacturers' Position Statement, even if the B100 used in a blend meets one or more specifications, "the enhanced care and attention required to maintain the fuels in vehicle tanks may make for a high risk of non-compliance to the standard during use." As a result, the FIE Manufacturers disclaim responsibility for any failures attributable to operating their products with fuels for which the products were not designed.

Based on current understanding of biodiesel fuels and blending with petroleum-based diesel fuel, EMA members expect that blends up to a maximum of B5 should not cause engine or fuel system problems, provided the B100 used in the blend meets the requirements of ASTM D 6751, DIN 51606, or EN 14214. If blends exceeding B5 are desired, vehicle owners and operators should consult their engine manufacturer regarding the implications of using such fuel.

Engine Operation, Performance and Durability

The energy content of neat biodiesel fuel is about eleven percent (11%) lower than that of petroleum-based diesel fuel (on a per gallon basis), which results in a power loss in engine operation. The viscosity range of biodiesel fuel, however, is higher than that of petroleum-based diesel fuel (1.9 – 6.0 centistokes versus 1.3 – 5.8 centistokes), which tends to reduce barrel/plunger leakage and thereby slightly improve injector efficiency. The net effect of using B100, then, is a loss of approximately five to seven percent (5-7%) in maximum power output. The actual percentage power loss will vary depending on the percentage of biodiesel blended in the fuel. Any adjustment to the engine in service to compensate for such power loss may result in a violation of EPA's anti-tampering provisions. To avoid such illegal 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 filter plugging, injector coking, piston ring sticking and breaking, elastomer seal swelling and hardening/cracking, and severe engine lubricant degradation. At low ambient temperatures, biodiesel is thicker than conventional diesel fuel, which would limit its use in certain geographic areas. In addition, elastomer compatibility with biodiesel remains unclear; therefore, when biodiesel fuels are used, the condition of seals, hoses, gaskets, and wire coatings should be monitored regularly.

There is limited information on the effect of neat biodiesel and biodiesel blends on engine durability during various environmental conditions. More information is needed to assess the viability of using these fuels over the mileage and operating periods typical of heavy-duty engines.

[1] See, "Diesel Fuel Injection Equipment Manufacturers Common Position Statement on Fatty Acid Methyl Ester Fuels as a Replacement or Extender for Diesel Fuels" (May 1, 1998).

Emission Characteristics

In October 2002, U.S. 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.

Use of neat biodiesel and biodiesel blends in place of petroleum-based diesel fuel may reduce visible smoke and particulate emissions, which are of special concern in older diesel engines in non-attainment areas. In addition, B100 and biodiesel blends can achieve some reduction in reactive hydrocarbons ("HC") and carbon monoxide ("CO") emissions when used in an unmodified diesel engine. Those reductions are attributed to the presence of oxygen in the fuel. Oxygen and other biodiesel characteristics, however, also increase oxides of nitrogen ("NOx") in an unmodified engine. As a result, B100 and biodiesel blends produce higher NOx emissions than petroleum-based diesel fuel. As such, EMA does not recommend the use of either B100 or biodiesel blends as a means to improve air quality in ozone non-attainment areas.

Storage and Handling

Biodiesel fuels have shown poor oxidation stability, which can result in long-term storage problems. When biodiesel fuels are used at low ambient temperatures, filters may plug, and the fuel in the tank may thicken to the point where it will not flow sufficiently for proper engine operation. Therefore, it may be prudent to store biodiesel fuel in a heated building or storage tank, as well as heat the fuel systems' fuel lines, filters, and tanks. Additives also may be needed to improve storage conditions and allow for the use of biodiesel fuel in a wider range of ambient temperatures. To demonstrate their stability under normal storage and use conditions, biodiesel fuels, tested using ASTM D 6468, should have a minimum of 80% reflectance after aging for 180 minutes at a temperature of 150°C. The test is intended to predict the resistance of fuel to degradation at normal engine operating temperatures and provide an indication of overall fuel stability.

Biodiesel fuel is an excellent medium for microbial growth. Inasmuch as water accelerates microbial growth and is naturally more prevalent in biodiesel fuels than in petroleum-based diesel fuels, care must be taken to remove water from fuel tanks. The effectiveness of using conventional anti-microbial additives in biodiesel is unknown. The presence of microbes may cause operational problems, fuel system corrosion, premature filter plugging, and sediment build-up in fuel systems.

Health & Safety

Pure biodiesel fuels have been tested and found to be nontoxic in animal studies. Emissions from engines using biodiesel fuel have undergone health effects testing in accordance with EPA Tier II requirements for fuel and fuel additive registration. Tier II test results indicate no biologically significant short term effects on the animals studied other than minor effects on lung tissue at high exposure levels.

Biodiesel fuels are biodegradable, which may promote their use in applications where biodegradability is desired (e.g., marine or farm applications).

Biodiesel is as safe in handling and storage as petroleum-based diesel fuel.

Warranties

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

Economics

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

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

Conclusions

- Depending on the biomass feedstock and the process used to produce the fuel, B100 fuels should meet the requirements of either ASTM D 6751 or an approved European specification.

- Biodiesel blends up to a maximum of B5 should not cause engine or fuel system problems, provided the B100 used in the blend meets the requirements of ASTM D 6751, DIN 51606, or EN 14214. Engine manufacturers should be consulted if higher percentage blends are desired.

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

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

- Neat biodiesel and biodiesel blends reduce particulate, HC and CO emissions and increase NOx emissions compared with petroleum-based diesel fuel used in an unmodified diesel engine. Neither B100 nor biodiesel blends should be used as a means to improve air quality in ozone non-attainment areas.
- Biodiesel fuels have generally been found to be nontoxic and are biodegradable, which may promote their use in applications where biodegradability is desired.
- Individual engine manufacturers determine what implications, if any, the use of biodiesel fuel has on the manufacturers' commercial warranties.
- Although several factors affect the cost of biodiesel fuel, its average cost exceeds that of petroleum-based diesel fuel. The relative cost of converting an existing fleet to biodiesel blends, however, is much lower than the cost of converting to other alternative fuel.

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