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PROGRAM INFORMATION BULLETIN NO. P11-39

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SUBJECT: Reissue of P09-38 - Information on Use of Biodiesel Fuel in Underground Diesel-Powered Equipment; Availability of Report

Scope

Metal and nonmetal underground mine operators, miners and miners' representatives, manufacturers of diesel-powered underground mining equipment, Mine Safety and Health Administration (MSHA) Metal and Nonmetal enforcement personnel, MSHA Technical Support personnel, and other interested parties should receive this bulletin.

Purpose

MSHA is issuing this Program Information Bulletin (PIB) to provide updated information to the mining community on the technological feasibility of biodiesel fuels as an effective control method for reducing miners' exposures to diesel particulate matter (DPM) pursuant to Title 30 Code of Federal Regulations (30 C.F.R.) §§ 57.5060(b)(3) and 57.5060(d) of the DPM standard.

Information

Biodiesel is a registered fuel and fuel additive with the Environmental Protection Agency (EPA) that meets clean diesel standards established by the California Air Resources Board and qualifies as an ultra-low sulfur diesel fuel. It is a fuel derived from vegetable oils or animal fats and meets the fuel specifications contained in the ASTM D6751 standard. Products that do not meet the ASTM D6751 standard are not biodiesel. Biodiesel may be blended in any proportion with standard petroleum-based diesel fuel. Biodiesel blends are usually referred to by the volume percentage of biodiesel in the blended product; e.g. B20 is a blend consisting of 20% biodiesel and 80% petroleum diesel by volume.

MSHA DPM compliance sampling has shown significant reductions in total carbon (TC) exposures at mines that use a high biodiesel content fuel blend. This result is consistent with previously published laboratory and in-mine data addressing particulate matter emission reductions when diesel engines are operated on these types of fuels.

MSHA further analyzed this data to separately assess the elemental carbon (EC) and organic carbon (OC) emissions associated with biodiesel fuels. EC and OC combine to form TC, which is a major component of DPM and is regulated by MSHA in underground metal and nonmetal mines. MSHA found that, although the EC tended to be lowered significantly when biodiesel was used, some sampling data and research findings suggest that biodiesel could cause OC emissions to increase. MSHA became concerned that the reduction in EC emissions from use of biodiesel could be offset by a corresponding increase in OC emissions. Based on the available data, however, MSHA was unable to quantify the net effect of reduced EC emissions and increased OC emissions on TC exposures of miners.

Therefore, MSHA conducted a series of diesel emission tests to measure TC, EC, OC, and various exhaust gases resulting from the use of three different petroleum diesels, three different biodiesels, and a 50:50 blend of petroleum diesel and biodiesel. The three petroleum diesels tested included certified versions of low sulfur diesel (LSD) and ultra-low sulfur diesel (ULSD), representing the two fuel types currently used for engine approval testing by MSHA. Certified LSD is a diesel fuel meeting the specifications of 30 C.F.R. Part 7.86, Table E-1, with a total sulfur content of 0.03% to 0.05%. Certified ULSD is a diesel fuel meeting the specifications of EPA Title 40, Part 1065.703, Table 1, with a total sulfur content of 0.0007% to 0.0015%. A highway ULSD fuel was also tested as received from a local distributor, representing a typical fuel available commercially. The non-petroleum based fuels included two pure soy-based biodiesels and a blend of soy-based and animal fat-based biodiesels. MSHA also tested a B50 blend of soy biodiesel and ULSD.

MSHA conducted the testing at its Approval and Certification Center diesel laboratory using an Isuzu 4JG1T engine. Although MSHA's testing was limited to this single engine model, the test results are expected to be qualitatively transferable to most other EPA Tier 2 or later off-road engine makes and models because of common design features affecting emissions, such as direct injection, high injection pressures, and turbocharging. For each fuel, MSHA tested the engine with and without a diesel oxidation catalyst (DOC, also known as an oxidation catalytic converter or OCC) installed in the engine's exhaust. Engine performance and emissions were measured using the procedures and criteria established by MSHA under 30 C.F.R. Part 7, Subpart E (1996) addressing engine test procedures (based on ISO-8178 C-1, 8 mode test). MSHA also included gaseous emission measurements for carbon monoxide (CO), carbon dioxide (CO_2), nitric oxide (NO) and nitrogen dioxide (NO_2). MSHA analyzed the samples for TC (EC + OC) using NIOSH Analytical Method 5040 at its laboratory in Bruceton, Pennsylvania.

The testing demonstrated that biodiesel produced a modest reduction in TC emissions when a DOC was not used. When a DOC was used, TC emissions from biodiesel were reduced significantly compared to petroleum diesel. Significant reductions in TC were observed using both B50 blend and 100% biodiesel. The highest TC reductions observed during the tests were achieved using 100% biodiesel in combination with a DOC. Analysis of the carbon components of DPM for the tests conducted showed several significant items that explain the resulting TC emissions:

- Biodiesel produced significant reductions in EC emissions.
- Biodiesel increased OC emissions compared to petroleum diesel when a DOC was not used. This increase partially offset the EC reduction, but not enough to cause a net TC increase.
- Use of a DOC did not have a net effect on EC emissions for any fuel.
- Use of a DOC produced a significant reduction in OC emissions for all fuels.
- The significant reduction in TC when using biodiesel with a DOC results from the EC reduction produced by biodiesel in combination with the DOC eliminating a significant portion of the OC emissions.

As is typical of most catalytic converters, the testing showed that for all fuels, the DOC nearly eliminated CO emissions and increased NO_2 emissions. Adequate mine ventilation can control NO_2 exposures to below the ceiling limit for NO_2.

The study also documented the importance of engine duty cycle in influencing TC reduction from biodiesel fuel when a DOC was not used. Under a heavy duty cycle, the increase in OC due to the use of biodiesel was at a minimum. At lighter load conditions, the resulting OC emissions increased, both as a percentage of TC and as an absolute value. Since biodiesel is effective at reducing EC significantly at all load conditions, but produces the most OC increases at light loads, biodiesel is most effective in reducing TC when the engine works hard. At both heavy and light engine load conditions, TC emissions were reduced when biodiesel was used together with a DOC, compared to petroleum-based diesel with or without a DOC.

As noted above, this testing was limited to a single engine model. However, due to design features affecting emissions common with most other makes and models of Tier 2 or later off-road engines, use of biodiesel fuel would be expected to produce qualitatively similar results with other engines. The exact percentage increases or decreases in emissions observed in this study using an Isuzu 4JG1T engine would not necessarily be expected with other engines, just as differences in fuel blend, duty cycle, or other sources of variability (see study report) would be expected to affect engine-out emissions. But similar upward and downward trends in the various emissions would be expected for most makes and models of Tier 2 or later off-road engines.

Bakground

MSHA's DPM standard at 30 C.F.R. § 57.5060(b)(3) restricts an underground metal and nonmetal miner's permissible exposure limit to 160 micrograms of total carbon per cubic meter of air (160_{TC} $\mu g/m^3$). In addition, 30 C.F.R. § 57.5060(d) includes requirements for mine operators to install, use, and maintain all technologically and economically feasible controls to reduce a miner's exposure to the DPM Permissable Exposure Limit (PEL). Mine operators have the flexibility to use engineering or administrative controls, or a combination of both, to reduce a miner's exposure to or below the PEL.

Since the 1960s, underground mine operators using diesel-powered equipment have employed DOCs, either installed by the original equipment manufacturer (OEM) or retrofitted at the mine to reduce concentrations of harmful gaseous emissions discharged into the mine environment, primarily CO and unburned hydrocarbons. While still used for this purpose, DOCs are now also used on diesel fleets in the underground and surface mining industries, as well as non-mining surface fleets to reduce the OC component of DPM.

DOCs are readily available to the mining industry as OEM standard or optional equipment, or for retrofitting almost any piece of diesel-powered equipment. DOC costs range from approximately $1,000 to $3,000. They are essentially maintenance free and last the life of an engine. Many equipment manufacturers routinely install a DOC as a standard exhaust system component on diesel equipment sold for underground use. Many diesel particulate filters (DPFs) also have a catalyzed coating similar to a DOC, or a DOC can be installed upstream of a DPF in the exhaust system on a piece of diesel-powered equipment to reduce both gaseous and OC emissions.

In the 2001 DPM final rule (66 Fed. Reg. 5706), MSHA concluded that engineering controls, such as increased mine ventilation, low DPM emission engines, better diesel engine maintenance, DOCs, DPFs, alternative fuels, and enclosed cabs with filtered breathing air were technologically and economically feasible. In the 2006 DPM rule, MSHA noted that the wider availability of alternative fuels, particularly biodiesel, improved DPF technology, and impending availability of the EPA compliant 2007 on-road diesel engines with integral DPFs would further reduce miners' exposure to DPM.

Use of biodiesel fuel is becoming more common in underground metal and nonmetal mines because of its wider availability and its effectiveness in significantly reducing DPM and other harmful emissions. Underground metal and nonmetal mines are currently using biodiesel fuel in blends with standard petroleum diesel ranging from B5 to B99, but blends with less than about 30 percent biodiesel do not appear to significantly reduce TC concentrations.

MSHA's Technical Support is available to assist mine operators with questions concerning the application of biodiesel fuel blends and DOCs on underground mining equipment.

Authority
The Federal Mine Safety and Health Act of 1977, as amended, 30 U.S.C. § 801 et seq.; and 30 C.F.R. §§ 57.5060(b)(3) and 57.5060(d).

Internet availability
This PIB may be viewed on the Internet by accessing the MSHA home page at (http://www.msha.gov) "Compliance Info" and "Program Information Bulletins."

The Report titled "Diesel Fuel Testing on an Isuzu 4JG1T Engine With and Without a Diesel Oxidation Catalyst," dated June 2009, is available on the Internet by accessing the MSHA home page at (http://www.msha.gov) "Diesel Particulate" "Metal/Nonmetal Mining Related."

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