OXYGENATES FOR DIESEL EMISSIONS REDUCTION

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The U.S. Department of Energy has been conducting a broad research program on options for meeting Tier 2 passenger car emissions regulations with a combination of advanced diesel engine design, exhaust aftertreatment technology, and fuel reformulation. These activities complement the industrial efforts coordinated through the government/industry Partnership for a New Generation of Vehicles (PNGV) Program. As a part of this activity, Southwest Research Institute (SwRI) has been conducting an evaluation of the impact that fuel reformulation could have in diesel engine emission reduction. Part of that work has focused on the inclusion of oxygen-containing compounds in diesel fuel and the resulting impacts on particulate and gaseous emissions, as well as unregulated toxicologically relevant compounds.

Oxygen Addition Effects on Emissions

A review of recent literature, including a series of engine tests at SwRI, demonstrates that oxygenated diesel fuels reduce engine-out PM emissions, with a 3-5 percent reduction in PM with each 1 percentage increase in fuel oxygen concentration. Thus, 6-7 percent oxygen addition, particularly when combined with complementing fuel modifications, can reduce particulate emissions by over 50 percent, and oxygen concentrations of 30 percent or more (such as use of dimethyl ether, or DME) can completely eliminate fuel-derived PM.

In addition, recent measurements at SwRI have found that oxygenated diesel fuel blends generally reduce engine-out polyaromatic hydrocarbon compounds in both the gas phase and the soluble particulate matter.

While data have shown oxygen addition has no consistent impact on engine-out NO_x, preliminary data developed at SwRI has shown that engine recalibration can “trade off” some of the particulate reduction in order to substantially reduce NO_x emissions. These initial results indicate that substantial NO_x reductions may be possible with oxygenated diesel fuels, particularly as it appears that these fuels are more tolerant of high levels of exhaust gas recirculation than conventional all-hydrocarbon diesel fuel.

Options for Oxygenated Diesel Fuels

While adding oxygen-containing compounds to diesel fuel appears to offer opportunities for exhaust emission reduction, most of this research work has been conducted using low molecular weight oxygenated compounds, such as DME, ethanol, or dimethoxymethane (DMM). The resulting fuels would be difficult to incorporate and handle within the existing diesel fuel infrastructure or current diesel-powered vehicle fuel systems due to problems with volatility, material compatibility, and safety.

SwRI, in conjunction with the U.S. Department of Energy and the Coordinating Research Council (CRC), identified 71 oxygenate-containing compounds and established a series of criteria and characteristics desirable for use as a blending component in diesel fuel. Physical and chemical properties of the compounds were obtained from the literature, or through actual measurements as appropriate, and the list of potential compounds culled to select a subset for engine screening. Of the various criteria, which were applied sequentially, flash point and solubility in hydrocarbons eliminated the largest fractions of the compounds.

A single engine operating condition was used to evaluate the eight most promising compounds. The DaimlerChrysler OM611 light-duty diesel engine was used for the evaluations, with individual cylinder beginning of injection timing adjusted for each fuel in order to hold peak cylinder pressure to 7° after top center timing, and with the fueling rate varied to keep BMEP constant across the fuels. Gaseous and particulate emissions were measured, and the particulate was analyzed by measuring by fractionating into a volatile and non-volatile portion.

Although there were differences among fuels, all the oxygenates substantially reduced particulate emissions, primarily through the reduction of the non-volatiles. Based on these evaluations, and

considering relative differences in probable production cost, two compounds were recommended for further evaluation and inclusion in other DOE oxygenated fuel programs.