Project status: Completed

PROJECT FACT SHEET

DME Shuttle Bus Demonstration

Goal

The goal of this demonstration project was to improve the viscosity and lubricity of DiMethyl ether (DME) by creating a fuel-blend of DME and diesel. The result provided the benefits of DME and circumvented the need for major engine modifications.

Team

Organizations that worked with the EMS Energy Institute included: Air Products and Chemicals Inc., Allegheny Truck, Caterpillar, Clean Air Technologies, Columbia Propane, U.S. Department of Energy National Energy Technology Center Laboratory (NETL), DuPont Fluorochemicals, DuPont-Dow Elastomers, Dana/Long Manufacturing, F&L Fluid Components, Manchester Tank, Master Flow Pumps, Michigan Custom Machines, Navistar/International Truck, National Instruments, Penn State Office of the Physical Plant Service Garage, Penn State Earth and Mineral Sciences Machine Shop, Penn State Fleet Operations, Pennsylvania Department of Environmental Protection, Pittsburgh Valve and Fitting, Ray Murray Inc., Sierra Monitor Corporation, The Parker Store -- Racor Filtration, The Pennsylvania Transportation Institute, The RG Group, and Tuthill.

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Project Discussion

DiMethyl ether (DME) is a simple hydrocarbon. Its most common use is as an aerosol propellant, known by the trade name DYMEL A, which is manufactured by DuPont Fluorochemicals.

Chemically DME consists of two methyl groups linked together by an oxygen atom. At room temperature it is an odorless and colorless gas, and can be easily and safely stored as a liquid in pressurized containers similar to the storage of propane. Interestingly, while its molecular structure is different, it has the same overall chemical formula as ethanol (C_2H_6O).

The DME molecule contains an oxygen atom, and its presence serves to oxygenate the diesel fuel. Increasing the amount of oxygen present in the diesel fuel means more of the fuel can burn to completion, thereby reducing the amount of particulates (small pieces of incompletely burned fuel) released into the atmosphere.

The calorific value (the amount of energy per unit mass and volume of fuel) is lower for DME than for diesel fuel. This means a larger volume of DME is needed to go the same distance as on diesel fuel. However, since DME burns so much cleaner than diesel fuel, the environmental gain outweighs the energy density issue.

Background

The concept of converting a fleet vehicle to utilize DME arose at Air Products and Chemicals, Inc. This led to a joint proposal by Air Products and Penn State in 1996 to the Alternative Fuel Incentive Grant Program, which was administered by the Pennsylvania Department of Environmental Protection. Subsequently, the National Energy Technology Laboratory of the U.S. Department of Energy provided additional support for the project. The project was initiated in the summer of 1998. The vehicle conversion was the last phase of the shuttle bus project.

The system that was used on the shuttle bus was first constructed and tested in the Diesel Combustion and Emissions Laboratory of the EMS Energy Institute. This design was then modified for use in a fleet vehicle. The system, consisting of more than 80 feet of tubing and close to a hundred connections, and was in operation on the Faculty-Staff Loop from June 2002 to October 2002.

Penn State's DME-Fueled Staff Shuttle Bus

Results

This demonstration began with the development of a conversion strategy for an engine to operate on blends of DME and diesel fuel. Subsequently, the system developed in the laboratory was adapted for use in the shuttle bus. Together, the two phases of the project have yielded results from laboratory work and fieldwork.

The laboratory studies have included combustion and emissions analyses in an engine test cell and fuel property studies in fuel characterization instruments at the EMS Energy Institute. Laboratory engine tests were completed at 5 and 10 wt.% oxygen addition by blending DME and diesel fuel, which is equivalent to 15 vol.% (12.5 wt.%) and 30 vol.% (25 wt.%) DME addition, respectively. The combustion and emissions studies demonstrated reduced particulate emissions with increasing DME blend ratio. However, the other emissions showed scattered results across the test modes. One reason for scatter in the gaseous emissions data was that the injection timing and injection pressure were changing as DME content increased at a particular speed and load. The fuel characterization tests focused on measurements of the viscosity of the fuel mixtures, because viscosity falls sharply as DME content increases. At 25-weight percent addition of DME, the viscosity of the fuel blend is near the lower limit of the allowable viscosity for diesel fuels. The combination of these laboratory studies provided the testing parameters and the expectations for the field demonstration.

The fieldwork began with a detailed design process for implementation of the fuel blends and the fueling strategy on the shuttle bus. The rigorous design process for the system on the shuttle bus included a complete Failure Modes Effects Analysis, performed in collaboration with Air Products and Chemicals. The outcome was a fuel system design that anticipated and accounted for a variety of failure modes and potential hazards. This ensured maximum safety for the shuttle bus and its occupants. The successful operation of the shuttle bus during 2002 using blends of DME and diesel fuel made this a unique project the world over. No other vehicle in operation has used DME- diesel blends, and only a handful of vehicles have run on DME at all. Moreover, this was the first transit vehicle to be in service and carrying passengers that has operated in whole or in part on DME.

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Key Publications

- Chapman, E. M.; A. L. Boehman; P. Tijm; and F. Waller; "Emission Characteristics of a Navistar 7.3L Turbodiesel Fueled with Blends of Dimethyl Ether and Diesel Fuel," Society of Automotive Engineers Technical Paper No. 2001-01-3683.
- Bhide, S., D.; Morris, J. Leroux; K.S. Wain; et.al.,"Characterization of the Viscosity of Blends of Dimethyl Ether with Various Fuels and Additives," *Energy & Fuels*, 17, 1126-1132 (2003).
- Eirich, J.; E. Chapman; H. Glunt; et.al., "Development of a Dimethyl Ether (DME)-Fueled Shuttle Bus," Society of Automotive Engineers Technical Paper No. 2003-01-0756.