Membrane Technology for Reducing NO_x Emissions From Diesel Engines

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Environmental Problem

Nitrogen oxides (NO_x) lead to acid rain and contribute to unhealthy ground-level ozone and smog, often leading to severe respiratory problems among affected communities. Diesel engines produce unacceptably high levels of NO_x at high loads, and NO_x from nonroad diesel engines represents an increasing percentage of the environmental pollution in nonattainment regions (areas that do not meet primary environmental standards), where more than 90 million Americans live. Economical, easy-to-integrate solutions are needed to meet the NO_x reduction goals of the Clean Air and Clear Skies Acts.

SBIR Technology Solution

A promising new method of reducing NO_x emissions involves the recycling of exhaust gas in a process called exhaust gas recycle (EGR). EGR sends captured exhaust gas back into the combustion chamber of the engine, thereby increasing fuel economy and reducing emissions: a 25% EGR leads to a 50% reduction in NO_x. There are some problems, however, associated with the process, including: (1) extra pumping and cooling of the EGR stream, (2) engine wear from recirculating engine soot, and (3) high feed air water vapor levels. These issues can be avoided by the use of nitrogen-enriched air (NEA), which reduces the diesel combustion temperature and, in turn, the amount of NO_x emitted in the engine exhaust. The NO_x reductions achieved through NEA are similar to those accomplished through the EGR process, while simultaneously avoiding the pumping, cooling, wear, and water vapor issues associated with EGR.

With support from EPA's SBIR Program, Compact Membrane Systems, Inc. (CMS), in cooperation with its commercialization partners, has developed stable fluoropolymer membranes to nitrogen enrich the turbocharged intake air to diesel engines. Cooled turbocharged air is processed by an NEA membrane to supply NEA to the diesel engine intake. NEA reduces the diesel combustion temperature; in turn, the amount of NO_x produced and emitted in the engine exhaust is greatly reduced.

CMS membrane modules are designed for very high flux, harsh operating conditions, stable performance, and production of NEA in the range of 79.5% up to 84%. As a result of EPA's SBIR funding and collaborations with downstream partners and commercial membrane manufacturers, CMS has made large advances in demonstrating and commercializing NEA membranes for NO_x reduction in diesel engines.

Commercialization Information

Working with major industrial gas companies (e.g., Praxair and Air Liquide) and their membrane divisions (IMS and MEDAL), CMS has produced large, commercial-sized membrane modules. In collaboration with Caterpillar, these large commercial-sized modules have operated successfully in excess of 1 million on-road miles on five Class 8 diesel trucks. Independent laboratory testing of the membrane systems showed them to have excellent fouling resistance to ingested dust and durability to an excess of 1 million pressurization cycles while operating at high temperature (85°C) and high pressure (30 psig). Caterpillar tests over a broad cycle showed that the membranes exceeded the target NO_x emission reduction of 50%.

CMS' successful field demonstration with Caterpillar in combination with ongoing support from EPA's SBIR Program has led to additional opportunities that presently are under commercial/developmental evaluation. At present, low-speed marine diesel

Membranes within the black housing mounted over the diesel engine pictured above generate NEA from cooled turbocharged air.

engines are being tested in support of installation of CMS membranes on Scandinavian ferries and ships for NO_x reduction.

The retrofitting of installed emergency generators with CMS NEA membranes is being evaluated, and the membranes show promise for creating cost savings from peak electric power rates. These additional programs have successfully completed the feasibility phase and CMS is receiving purchase orders for outfitting engines for initial fleet and field demonstrations.

Company History and Awards

CMS was founded in 1993, based on membrane technology acquired from E.I. DuPont. CMS is located in Wilmington, Delaware. CMS' focus is on the research, development, and commercialization of membranes and thin films composed of fluorinated polymers with exceptional gas transport properties and chemical resistance.

In 1998 and 2000, CMS received the Tibbetts Award as an Outstanding Small Business in the State of Delaware. This award is given by the U.S. Small Business Administration to firms judged to exemplify the best in small business innovation and research. The company's goal is to become, in combination with its partners, the world market leader of amorphous perfluoropolymer membranes for gas transport (including NEA). Although CMS products are focused on perfluoropolymers, the company serves a broad range of markets that can utilize the unique features of CMS membranes.

SBIR Impact

- Economical, easy-to-integrate solutions are needed to meet the nitrogen oxides (NO_x) reduction goals of the Clean Air and Clear Skies Acts.
- Compact Membrane Systems, Inc. (CMS), in cooperation with its partners, demonstrated that a high-productivity nitrogen-enriched air membrane can be used to reduce diesel engine NO_x emissions by 50%.
- Field tests have shown that these membrane systems are stable related to flux and selectivity and have excellent fouling resistance.
- CMS has successfully field demonstrated commercial-sized membrane modules with Caterpillar. In these on-road tests, the membranes exceeded the target NO_x reduction of 50%.