Advanced Membrane Systems: Recovering Wasteful and Hazardous Fuel Vapors at the Gasoline Tank

Challenge

A typical gasoline station can release over 3,000 gallons of fuel as vapor each year. These vapors represent an economic loss as well as pose a hazard for health, safety, and the environment. One of the constituents of gasoline vapor (benzene) is a carcinogen, and hydrocarbon vapors contribute to low-level ozone and smog formation.

Gasoline stations store fuel in underground storage tanks, which are filled from tanker trucks and then emptied slowly as fuel is pumped into customer vehicles. Gasoline vapor escapes during both filling and emptying, and Stage I and Stage II vapor recovery systems are used for these operations. In Stage I systems, vapor displaced from the underground storage tank during filling is directed to the tanker truck, so the truck leaves with a tank full of vapor that would otherwise have been vented. In Stage II systems, vapor from refueling customer vehicles is directed back to the underground storage tank.

As gasoline stations were installing Stage II vapor recovery systems, the California Air Resources Board (CARB) and the Environmental Protection Agency (EPA) required new cars to be equipped with another approach to solving the same problem: on-board refueling vapor recovery (ORVR) systems to capture vapors at the vehicle. However, testing subsequently showed that these ORVR systems caused Stage II systems to release more fugitive emissions through tank vents.

In response to this problem, CARB required gasoline stations to reduce fugitive emissions using equipment compatible with ORVR systems. It was believed that gasoline stations could meet the regulations with vent processors that remove fuel vapor from the air passing out of tank vents. However, fugitive emissions can also escape from other system leaks, so some vent processors needed to be designed to maintain fuel tanks at a slightly negative pressure. Any leak in a negative-pressure tank will draw air in rather than release emissions.

Innovating Solutions

CMS saw vent processors as a natural application for their proprietary fluorinated polymer membrane. The CMS membrane is well suited for use with solvents and other aggressive chemicals. It is also unique in that it lets air pass through and retains volatile organic compound (VOC) vapor. Other membranes used for vent processors work in a reverse manner, permitting vapors to pass and retaining air, thus requiring systems that are more complicated.

CMS began research on VOC-air separation with EPA SBIR Phase I funding in 1993, followed by a Phase II award the following year. This funding supported a feasibility study, initial testing, and economic evaluation. DOE EERE SBIR funding, beginning in 2000, allowed CMS to continue developing the membrane and improve its vapor recovery efficiency by about 75%. The State of Delaware augmented DOE's Phase I and II funding.

During the DOE SBIR-funded work, CMS partnered with Innovative Membrane Systems, Inc., a subsidiary of Praxair, Inc., to develop the membrane and double its efficiency. CMS chose Innovative Membrane Systems as a supplier for the membrane fiber because of their well-established expertise in producing membranes for air separation and gas processing.

The DOE SBIR project also allowed CMS to develop the rest of the vapor processing system in collaboration with Vapor Systems Technologies, Inc. This relationship began during the EPA SBIR project when Vapor Systems contacted CMS and introduced them to the gasoline recovery application. While developing the system with Vapor Systems Technologies during the DOE SBIR project, CMS was again able to double the system's performance.

DOE Small Business Innovation Research (SBIR) support enabled CMS to develop a membrane vapor processor that recovers fuel vapors from gasoline refueling with 99 percent efficiency. This membrane system enables gasoline stations to surpass environmental regulations while reducing fuel losses.

Compact Membrane Systems, Inc. (CMS) was founded in 1993 in Wilmington, DE, with the acquisition of rights to certain DuPont polymer membrane patents. CMS focuses on research, development, and commercialization of these polymer membranes and thin films, which offer high gas transport properties and chemical resistance. SBIR programs have funded much of CMS' feasibility and prototype work. To commercialize their technology, CMS licenses, sells membrane products, and partners with other companies to develop specific applications.

www.compactmembrane.com

A case study from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy SBIR program, providing competitive grants for scientific excellence and technological innovation to advance critical American priorities and build a strong national economy – one small business at a time.

Advanced Membrane Systems for Vapor Recovery

The CMS membrane system retains vapor in the storage tank and prevents further evaporation. By contrast, some lower-cost vapor processors simply flare the vapor, creating additional fuel losses and greenhouse gas emissions. Other competing membrane systems have been developed as alternatives to combustion-based systems. These differ from the CMS system in that they pass the hydrocarbon vapor through the membrane and vent the retained gas. Such systems are more complex, requiring a condenser and extra safeguards to prevent the system from releasing vapor if it fails. The CMS polymer membrane retains the hydrocarbon vapor and passes air through the membrane to the vent—a simpler, safer system.

Field tests conducted by Vapor Systems Technologies established that the system reduces vapor emissions to about 0.08 pounds per 1,000 gallons of liquid gasoline dispensed—well below the CARB limit of 0.38 pounds per 1,000 gallons dispensed (based on an average unmitigated emissions of 7.6 pounds/1,000 gallons dispensed). The complete system—including special fuel dispensing equipment—recovers about 1,800 gallons of fuel per year for a typical gas station. In addition, it requires little maintenance, due to the simple design and durable membranes.

Gasoline stations began purchasing units from Vapor Systems Technologies, and the first began operation in 2006. Vapor Systems Technologies tested the system for CARB certification and was certified in mid-2007—the only membrane system to be certified in California. Certification is important in accessing the primary market of nearly 200,000 U.S. retail gasoline stations.

SBIR Impacts

Projected Benefits of the ENVIRO-LOC™ System: 2009 to 2020

Energy	Potential gas recovery (all US)[1]	1.6 billion gallons or 0.3 quadrillion Btus
Economic	Savings from recovered fuel (all US)[2]	$3.6 billion
	Direct capital, operating, and maintenance cost savings over 5 years compared to typical system (per installation)[3]	$50,000
Environmental	Potential VOC capture (all US)[4]	5 million tons

Innovation

ENVIRO-LOC™ Vapor Recovery System

- Primary Application: Underground storage tanks at gasoline stations
- Vapor Recovery Efficiency: 99%
- Average Emissions Level: 0.08 lb per 1,000 gallons of dispensed gasoline
- Air-Vapor Separator: Hollow-fiber, polymer membrane
- Fuel savings for a typical gas station estimated to pay for the system in less than two years[3]

Company Success

Thanks to SBIR funding, CMS was able to conduct initial development and later improve their membrane system's performance for commercialization. In addition, the EPA and DOE SBIR awards provided CMS with critical exposure to industry stakeholders.

CMS has grown from a staff of 15 and annual revenue of $2.1 million in 2000 to 26 staff and $3.8 million in revenue in 2008.

Vapor Systems Technologies, Inc. learned of the CMS technology through an SBIR project publication, launching their relationship and successful commercialization partnership. Vapor Systems Technologies worked with CMS during final development of the system and has invested heavily in developing their vent processor product, the ENVIRO-LOC™ system, based on the CMS membrane, which they are now marketing to gasoline stations.

[1] Based on average 9 million barrels/day and 5.253E6 Btu/barrel (Energy Information Administration.) The portion of fuel savings retained by the membrane vapor processor depends on how many cars using the gasoline station have ORVR systems. As new cars with ORVR systems replace older vehicles, vapor processors will become responsible for most of the fuel savings, as well as reduced emissions.

[2] Based on estimated gas recovery over the period at $2.30/gallon (estimated current price per Energy Information Administration).

[3] Vapor Systems Technologies estimate, comparison of ENVIRO-LOC™ to typical Healy system ("The $50,000 Decision", http://www.vsthose.com).

[4] Based on Vapor Systems Technologies ENVIRO-LOC™ fact sheet and Energy Information Administration information.

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