New Membrane Technology Boosts Efficiency in Industrial Gas Processes

Challenge

Membrane technology was first commercialized in the 1960s and 1970s for well-known applications such as water filtration and kidney dialysis. Membranes offered inexpensive, compact, and energy-efficient separations for other processes as well—such as industrial gas processing. For example, chemical feedstocks—in this case, monomers (e.g., ethylene and propylene) are the single largest operating cost in the manufacture of polyolefins. Due to the intensely competitive nature of the industry, monomer losses in vent streams are a major concern for producers. These vent streams represent a significant opportunity for recovery and recycling of raw materials.

To help achieve the potential of membranes for this and other gas separation processes, innovation was needed. In addition to membrane material research, development of robust industrial membrane module devices was required, followed by process design and scale-up for commercial application. This required a multi-year, multi-step research and development (R&D) effort.

UPDATE!

As described in this case study, DOE EERE Small Business Innovation Research (SBIR) support enabled MTR to complete development of their VaporSep® process, which separates and recovers organic vapors from air and nitrogen. The process is now widely used to minimize monomer losses in polyolefin plant vent streams.

Building on that research, MTR has been working on membrane separation for greenhouse gas mitigation and sustainable energy processes. In late 2010, MTR received an SBIR Phase III XLERATOR award from DOE to build a complete pilot-scale system that will simultaneously produce turbine-ready hydrogen and high-pressure CO_2 (for sequestration), using a real syngas feed. A successful long-term field test of the membrane modules in an operating environment will help MTR gain initial customer acceptance and commercialize this new technology more rapidly.

Innovating Solutions

MTR was founded in 1982 as an R&D company with a long-term goal of developing marketable membrane technologies, especially in the newly-emerging field of industrial gas separations. For a small company, the initial challenges were daunting. However, with funding from the SBIR programs of several agencies, including the Departments of Energy (DOE), Defense, and Agriculture (USDA), the Environmental Protection Agency (EPA), and the National Science Foundation, the company was able to succeed in developing these technologies.

Because MTR was competing against firmly-entrenched technologies in well-established industries, Phase II SBIR support of early field testing was essential to commercial acceptance of the new membrane technologies. The outcome was their process to remove organic vapors from air and nitrogen, leading to the first of MTR's R&D efforts that resulted in a commercial product.

An early version of this system was first sold in the early 1990s; since then, more than 100 units have been installed worldwide in chemical and petrochemical plants. In 1997, the first VaporSep® system—which has 10 times the capacity of most of the prior systems—was installed to treat ethylene- and propylene-containing nitrogen purge gas streams in polyolefin plants. Similar systems continue to be sold worldwide and have been used to recover a variety of chemicals, including vinyl chloride monomer, isopentane, and 1-hexene, in addition to ethylene and propylene. For a world-scale polyolefin plant, a VaporSep® unit typically recovers about 2,000 to 200,000 tons/year of monomer, valued at $1-10 million/ year.

MTR's VaporSep® systems have recovered about 2.1 million tons of volatile organic compounds (VOCs) since 1992, which has saved over 115 trillion Btus in fuel. The value of fuel savings in 2008 was estimated at 33 trillion Btus and is expected to grow in subsequent years. Considering data available for VaporSep® systems installed between 1992 to 2008, the capital investment has typically been recovered in one to two years from the fuel value alone of the recovered monomer.

Membrane Technology and Research, Inc. (MTR), based in Menlo Park, CA, is a privately-owned developer, manufacturer, and supplier of customized membrane process solutions. Currently, the company's principal membrane products are

- VaporSep® systems to remove organic vapors from air and nitrogen
- NitroSep™ and fuel gas conditioning systems for natural gas treatment
- Hydrogen recovery systems for refinery and other applications

MTR's current R&D is extending use of membranes to carbon sequestration and biofuels separations.

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A case study from the DOE/EERE SBIR Program portfolio, 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.

Membranes for Industrial Gas Separations

Over the last decade, with support from SBIR and DOE follow-on funding, MTR has been able to conduct the R&D needed to add membrane separation products for the oil and gas and refinery businesses to its product portfolio, and is now working on greenhouse gas/sustainable energy applications. The inherently energy-efficient, environmentally-friendly nature of membrane separation processes make them particularly good candidates for such applications. DOE, EPA, and USDA are all contributing funds to advance early-stage development for such applications as carbon capture and sequestration, alcohol/water separations in biofuel production, coal-bed methane recovery, and biogas.

Benefits of membrane technology over other gas separation processes include:

- Greater energy efficiency
- Lower operating costs
- Shorter payback times
- Simpler, often unmanned operations
- No or few moving parts
- Smaller footprint
- Easier expansion due to their modular nature

SBIR Impacts

Benefits of VaporSep® Membrane Technology[1]

		Realized Benefits 1992 to 2008	Potential Benefits 2009 to 2020
Energy	Fuel value (energy content) of cumulative recovered VOCs (1 quad is 1 quadrillion Btus)	0.115 quads	0.78 quads
Economic	Estimated value of cumulative recovered VOCs	$1 billion[2]	$6.2 billion
Environmental	VOC recovery	2.1 million tons	14.1 millions tons
	NO_X emissions saved	3,500 tons	23,900 tons
	CO_2 emissions saved	19,300 tons	130,300 tons

Innovation

A complete skid-mounted VaporSep® unit includes membrane modules, compressor, heat exchangers, piping, instrumentation, and controls. Unit dimensions are 10m (L) X 3.5m (W) X 5m (H); the compressor is mounted on a separate skid of similar size. Key system facts:

- Suitable for vent streams from 135 to 4,550 kg (300 to 10,000 pounds) per hour, with monomer concentration from 10 to 80 volume%
- Monomer recovery up to 99+%
- Nitrogen recovery up to 99+% with purities of 99+ volume

Company Success

As of 2009, cumulative VaporSep® sales and bookings exceeded $140 million and total company revenues in 2009 were about $30-35 million.

Development of the VaporSep® process with SBIR support allowed MTR to expand from an R&D focus to commercial success, and enabled it to bring a simple, energy-efficient, environmentally-friendly industrial gas separations technology to the petrochemical, natural gas, and refining industries. The company is now pursuing exciting new opportunities for the technology in greenhouse gas mitigation and sustainable energy processes that can bring economic and environmental benefits to the company, their customers, and energy consumers worldwide.

In recognition of the innovative nature and importance of this process, MTR received *Chemical Engineering Magazine's* Kirkpatrick Award, the first small business to be so recognized.

[1] Calculations are based on approximately 100 units in operation to date, recovered VOCs valued at approximately $0.20/lb, EPA emissions data, and projected growth rate of 10%/year.

[2] Note the estimated installation capital cost during the period was $100 million, indicating a significant return on investment.

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