Engineering Design of a Polaris Membrane CO_2 Capture System at a Cement Plant

primary project goal

Membrane Technology and Research Inc. (MTR), partnered with Sargent & Lundy (S&L) and CEMEX, is performing an initial engineering design of a full-scale Polaris membrane carbon dioxide (CO_2) capture system (approximately 1 million metric tonnes of CO_2 per day) applied to the CEMEX Balcones cement plant located in New Braunfels, Texas. This study will produce estimates of the cost and performance of a first-of-its-kind industrial membrane capture plant at a cement plant. The technical activities include completing a project design basis and process design; estimating the cost of the capture plant construction and installation; performing an environmental health and safety (EH&S) review, permitting and constructability reviews, and a hazard and operability study (HAZOP); and preparing a techno-economic analysis (TEA). S&L, an engineering, procurement and construction management contractor, will have the lead role in conducting the design study. CEMEX is the owner and operator of the cement plant and will provide plant-specific information on the Balcones facility for this study.

technical goals

- Complete an initial engineering design of the MTR membrane CO_2 capture process applied to the CEMEX Balcones cement plant located in New Braunfels, Texas.
- Complete a detailed engineering study for the membrane capture plant, including the process design with appropriate engineering drawings, system cost, constructability plan, and project execution schedule.
- Complete a TEA and Technology Maturation Plan (TMP) for the membrane capture system at the cement plant prepared per U.S. Department of Energy (DOE) guidelines.
- Complete an EH&S risk assessment and an environmental and permit review for the CEMEX host site.

technical content

MTR has developed a composite membrane called Polaris that sets the standard for post-combustion capture membranes. With an average CO_2 permeance of 1,000 gas permeation units (GPU) and a CO_2/N_2 pure-gas selectivity of 50, Polaris was a step-change improvement over typical commercial CO_2-selective membranes used for natural gas treatment. This improvement is illustrated in Figure 1, where membrane performance is compared in the form of a trade-off plot of CO_2/N_2 selectivity versus CO_2 permeance. Better membranes will have properties that move up and to the right on this plot.

In addition to showcasing the benefits of Polaris over conventional membranes, Figure 1 also shows some of the more recent improvements in the performance of Polaris membranes. A second-generation (Gen-2) version of the membrane has been scaled-up to pilot production, and an advanced Polaris membrane has been

program area:
Point Source Carbon Capture

ending scale:
Pre-FEED

application:
Post-Combustion Industrial PSC

key technology:
Membranes

project focus:
Membrane Technology for Cement Plant

participant:
Membrane Technology and Research Inc.

project number:
FE0031949

predecessor projects:
N/A

NETL project manager:
Carl Laird
carl.laird@netl.doe.gov

principal investigator:
Tim Merkel
Membrane Technology and Research Inc.
tim.merkel@mtrinc.com

partners:
CEMEX Inc.; Sargent & Lundy

start date:
10.01.2020

percent complete:
88%

produced at the lab scale. These developments demonstrate that the Polaris membrane technology continues to improve.

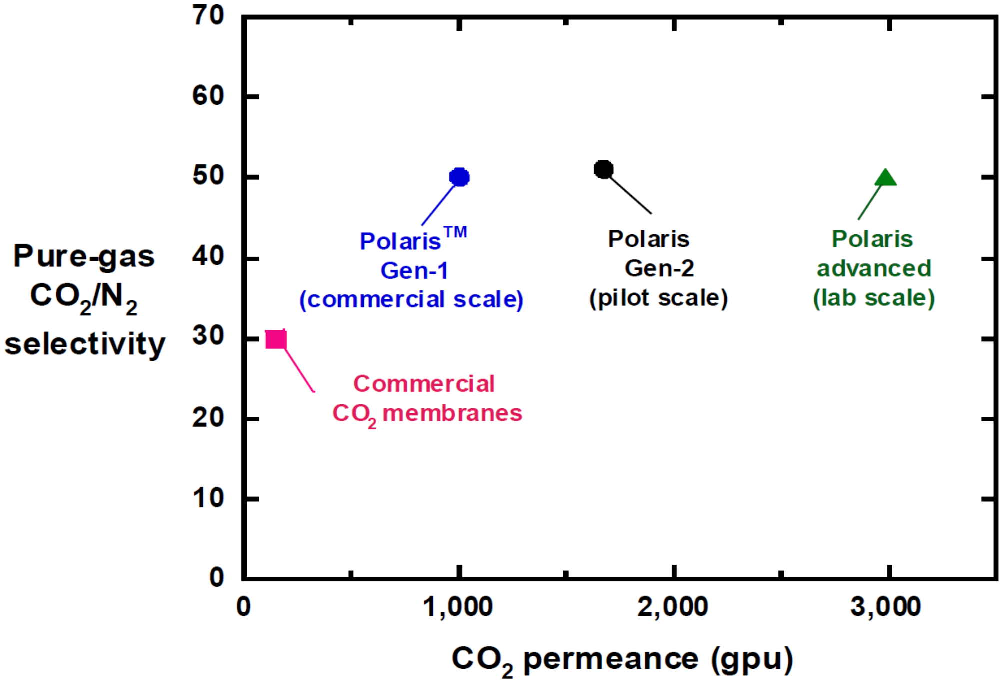

Figure 1: A CO_2/N_2 trade-off plot showing data for several generations of MTR Polaris, compared with the properties of the standard commercial natural gas membrane. Data are pure-gas values at room temperature.

The Gen-1 Polaris membranes were initially validated in field testing at the National Carbon Capture Center (NCCC), and are now being used in commercial natural gas and refinery membrane applications. The Gen-2 Polaris membrane has also been tested at the NCCC, and will be used on an upcoming engineering-scale field test at the Technology Centre Mongstad (TCM) in Norway (under DE-FE0031591).

As part of earlier MTR development programs, a low-pressure-drop membrane module specifically designed for a flue gas CO_2 capture process was created. Figure 2a shows a photo of a prototype of this planar module during testing at the NCCC. The simple straight-flow path of the new module results in a pressure-drop that is four-times lower than that measured for a conventional spiral-wound module (Figure 2b). This reduced pressure drop represents savings in fan power, equivalent to about 20–25 kWe/tonne of CO_2 capture. In addition to testing at the NCCC, the performance benefits of the planar module were verified in testing at Babcock & Wilcox and the University of Texas at Austin in separate DOE programs.

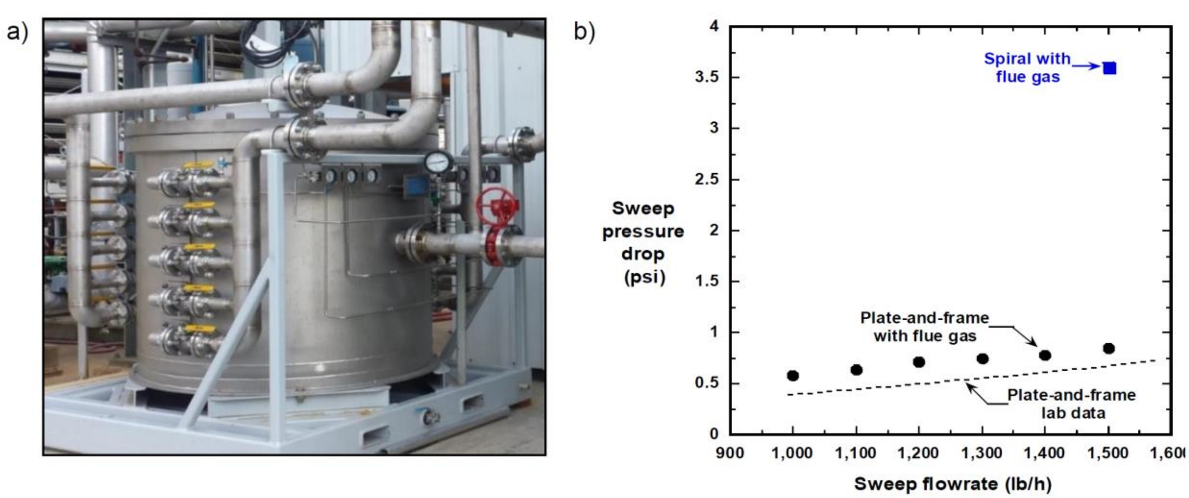

Figure 2: (a) Photo of the prototype planar module during testing at the NCCC, and (b) measured pressure drop in the module, compared to a conventional spiral-wound module.

The prototype planar module shown in Figure 2 was built in a local shop with machined parts and a stainless steel pressure vessel, resulting in relatively high costs. With the concept proven, the project team has transitioned to a lower-cost design based on reusable aluminum or single-use injection-molded, fiber-reinforced thermoplastics to form a stackable membrane module complete with integrated internal gas distribution. These low-cost modules are being used at the TCM field test in Norway. The low-cost planar modules are designed to fit one on top of the other to create a module stack. The module stack will have a pressure rating, which eliminates the need for a stainless steel pressure vessel and further reduces skid costs. A drawing of a standard shipping container housing several stacks is shown in Figure 3. This containerized skid will be assembled in the fabrication shop with all the required feed, residue, and permeate piping. The completed module skids will be positioned onsite by a crane. Several skids can be stacked on top of one another to minimize capture plant footprint. The containerized skid is the final unit building block for the MTR membrane CO_2 capture process.

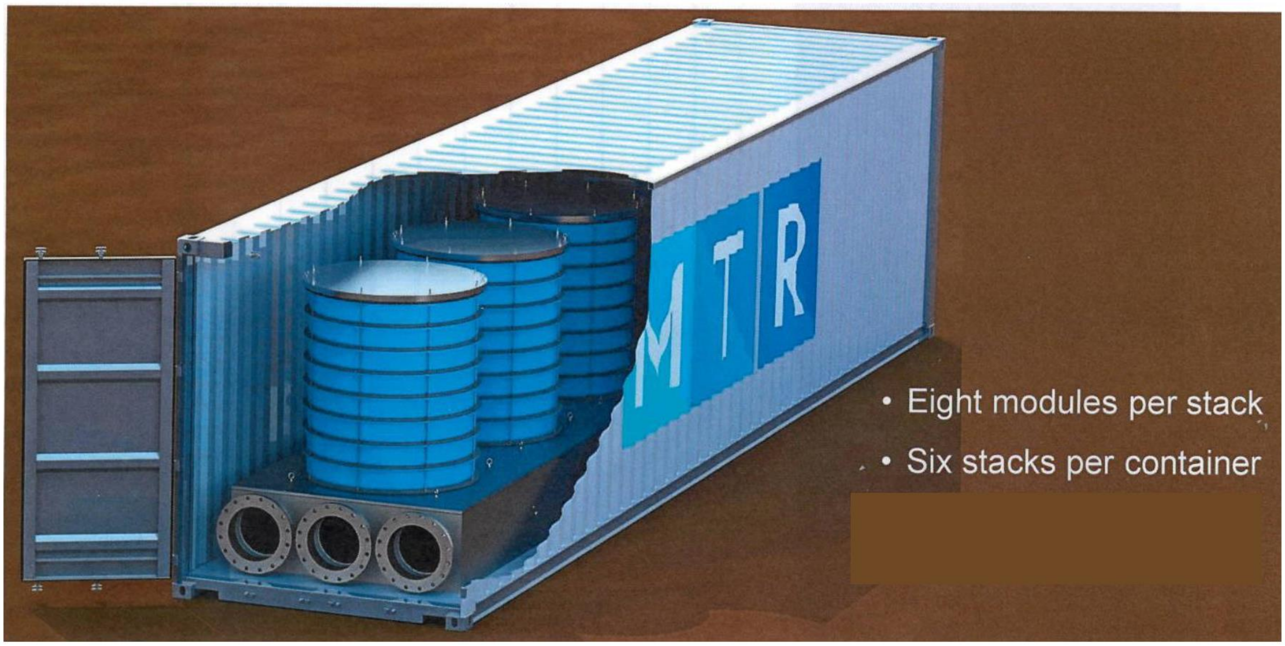

Figure 3: SolidWorks drawing showing the form of a containerized skid housing six membrane module stacks. Each stack is composed of eight modules.

technology advantages

- Capture cost is about 20% lower for cement compared to coal.
- Modular design membrane stacks ideal for scale-up for industrial CO_2 capture.
- High-purity CO_2 (greater than 99.5%) available for offtake at 150 bar.

R&D challenges

Integration and testing of membrane stack at CEMEX testing site.

status

MTR has completed the engineering study and membrane capture of 75% of CO_2 emissions from Kiln 2 at the CEMEX Balcones cement plant. The project is on schedule; the preliminary process design is completed, the capture plant location has been selected, and the design basis is set. The detailed design, costing, and environmental/permitting review has been completed. Reporting of project findings will occur in 2022. The next step is for a pilot demonstration test at Balcones and the completion of the TEA.

available reports/technical papers/presentations

Brice Freeman and Tim Merkel, "Engineering Design of a Polaris Membrane CO_2 Capture System at a Cement Plant," Project kickoff meeting presentation, Pittsburgh, PA, November 2020. *http://www.netl.doe.gov/projects/plp-download.aspx?id=11038&filename=Engineering+Design+of+a+Polaris+Membrane+CO2+Capture+System+at+a+Cement+Plant.pdf*.

Alicia Breen, Brice Freeman, Pingjiao Hao, Tim Merkel, Dana Pierik and Kevin Lauzze, Lucia Renau and Nestor Mora, "Engineering Design of a Polaris Membrane CO_2 Capture System at a Cement Plant," 2021 NETL Carbon Management Research Project Review Meeting, Pittsburgh, PA, August 2021. *https://netl.doe.gov/sites/default/files/netl-file/21CMOG_CCUS_Merkel.pdf*