Hybrid Membrane-Absorption CO2 Capture Process

Brice Freeman¹, Tim Merkel¹, Richard Baker¹
Eric Chen², Junyuan Ding³, Yue Zhang³, Gary T. Rochelle³,

¹Membrane Technology & Research, Inc., 39630 Eureka Dr., Newark, CA 94560
²CO₂ Capture Pilot Plant Project, The University of Texas at Austin, 10100 Burnet Rd., Bldg 133, CEER, Austin, TX
³Texas Carbon Management Program, McKetta Department of Chemical Engineering, The University of Texas at Austin, 200 E. Dean Keeton St., C0400, Austin, TX 78712-1589

Abstract

To date, the development of CO₂ capture systems has largely focused on single separation technologies (absorption, adsorption, membranes, cryogenics, etc.) Few studies have examined the merits of combining multiple separation technologies into a hybrid capture system. Membrane Technology & Research, Inc. (MTR) has developed a hybrid, post-combustion CO₂ capture system consisting of a membrane-based separation step combined with a second capture technology (hybrid partner).

In the hybrid capture system design, a membrane gas separation contactor uses boiler combustion air as a sweep gas on the membrane permeate side while passing carbon dioxide-rich flue gas at the same pressure across the membrane feed side. In this way, the partial pressure of the carbon dioxide on the permeate side is maintained lower than on the feed side. Carbon dioxide then passes from the flue gas into the sweep air stream that goes to the boiler. The result is to enrich the CO₂ content in the flue gas from a coal fired power plant from 13% to ~22%. The resulting higher CO₂ flue gas concentration provides for a lower energy, and by extension, lower cost, CO₂ separation for the hybrid partner (Figure 1).
In October 2013, DOE-NETL awarded MTR a development agreement (DE-FE0013118) to evaluate and demonstrate a bench-scale (0.1 MWe), hybrid capture system consisting of MTR’s membrane contactor and a piperazine based CO₂ capture system developed by the University of Texas at Austin (UT Austin). The UT Austin’s advanced flash stripper (AFS) capture process builds upon the technology previously developed from the two-stage flash and warm-rich bypass configuration tested in pilot plant campaigns at UT Austin.

This project is evaluating two configurations of the hybrid membrane-absorption capture system; hybrid-series and hybrid-parallel. In the series configuration (hybrid-series), the absorber removes ~50% of the CO₂ in the flue gas, followed by additional separation by the membrane contactor to achieve 90% total removal of CO₂ by the hybrid capture system. In this arrangement, the absorber can operate at a higher lean-loading state and at a reduced capture rate. In the hybrid-parallel configuration, the flue gas leaving the power plant is split and treated by each system in a parallel arrangement. The principal advantage here is that the absorber can be roughly half the size it would normally be. In both configurations, the AFS capture system will treat a more concentrated CO₂ stream.

This presentation will review how the UT Austin AFS system was optimized to take advantage of the new capture conditions for both the hybrid-series and hybrid-parallel configurations, and explain the relative advantages and disadvantages of each. It will also review the techno-economic costs for the least cost design and review test results from operating the membrane contactor and AFS system at the ~0.1 MWe scale.

This program will provide important insights into hybrid post-combustion CO₂ capture systems. Integration of the two technologies offers a new opportunity to explore further reductions in the cost of capture. With a successful outcome, this program will bring the hybrid membrane-absorption system through TRL 4 and the new technology will be ready for future 1 MWe scale-testing and design (TRL 5-6).