the ENERGY lab

PROJECT FACTS

Carbon Capture

Bench-Scale Development of a Hybrid Membrane-Absorption CO_2 Capture Process

Background

The mission of the U.S. Department of Energy Office of Fossil Energy's (DOE FE) Carbon Capture Research & Development (R&D) Program, implemented through the National Energy Technology Laboratory (NETL), is to develop innovative carbon dioxide (CO_2) emissions control technologies for fossil fuel-based power plants. The Carbon Capture R&D Program portfolio of pre- and post-combustion CO_2 emissions control technologies and related CO_2 compression is focused on advancing technological options for new and existing power plants to enable cost-effective CO_2 capture for beneficial use or storage of CO_2 and ensure that the United States will continue to have access to safe, reliable, and affordable energy from fossil fuels. The DOE FE/NETL goal is to demonstrate second-generation technologies that can capture 90 percent of the CO_2 at less than $40 per metric ton (tonne) in the 2020-2025 timeframe. DOE is also committed to extend R&D support to even more advanced transformational carbon capture technologies that will increase competitiveness of fossil based energy systems beyond 2035.

Post-combustion CO_2 capture technologies are applicable to conventional pulverized coal (PC)-fired power plants, where the fuel is burned with air in a boiler to produce steam that drives a turbine generator system to produce electricity. The CO_2 is exhausted in the flue gas at atmospheric pressure and a concentration of 10–15 percent by volume. Post-combustion separation and capture of CO_2 from PC-fired plants is a challenging application due to the low driving force resulting from the low pressure and dilute concentration of CO_2 in the waste stream, trace impurities in the flue gas that affect removal processes, and the parasitic energy cost associated with the capture and compression of CO_2. Carbon capture technologies developed by the DOE program may also be applied to natural gas power plants after addressing the R&D challenges associated with the relatively low concentration of CO_2 in the flue gas, typically 3-4 percent, of natural gas plants. Novel carbon capture approaches combining more than one CO_2 separation technology in synergistic hybrid configurations hold potential to reach improved performance above that of the individual technologies.

Project Description

Membrane Technology and Research (MTR) will collaborate with the University of Texas at Austin (UT Austin) to develop and evaluate at bench-scale a novel hybrid CO_2 capture system combining membrane and amine absorption technologies. This project builds on other promising DOE-funded work supporting the underlying individual post-combustion capture processes. The project will use Polaris™ membranes (low-pressure-drop, large area, plate-and-frame modules) developed by MTR, and an improved amine solvent-based capture system developed by UT Austin that uses a piperazine (PZ) solvent and advanced high-temperature and high-pressure regeneration.

The project team will evaluate two variations of a hybrid design consisting of the cross-flow Polaris membrane (which enriches flue gas to approximately 20 percent CO_2) and a 5 molal PZ advanced flash stripper with cold-rich bypass that has been

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PARTNERS

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PROJECT DURATION

Start Date	End Date
10/01/2013	09/30/2016

COST

Total Project Value
$3,749,780

DOE/Non-DOE Share
$2,999,824 / $749,956

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optimized to take advantage of the higher CO_2 concentration. The first variation will consist of the two systems arranged in series with the absorber removing 50 percent of the CO_2 in the flue gas followed by additional separation by the membrane into an air sweep gas that is sent to the boiler. This configuration results in the absorber operating with a higher CO_2 concentration input stream and the downstream membrane mitigating fugitive amine emissions. The second variation splits the flue gas flow for treatment by each system in a parallel arrangement. This configuration results in the absorber system being roughly half the size it would normally be. It is anticipated that the energy and capital cost savings achieved by pre-concentrating the CO_2 contained in the flue gas sent to the absorber/stripper is sufficient to outweigh the expected capital cost and energy requirements of the membrane unit. Preliminary calculations suggest the combined processes could reduce the energy cost of CO_2 capture by up to 30 percent compared to the cost of using a monoethanolamine system.

The 0.1 MWe SRP Pilot Plant located at UT Austin, to be modified for the hybrid bench-scale testing.

An integrated process model will be generated and a preliminary techno-economic assessment conducted for both hybrid configurations. MTR will manufacture and test a low-pressure drop, large-area membrane module and UT Austin will modify their existing 0.1 megawatt electric (MWe) Separation Research Program (SRP) pilot plant CO_2 capture facility and operate it under simulated series and parallel configurations. The most promising configuration will be identified based on the model and test results. The membrane module will be shipped to UT Austin and integrated into the SRP pilot plant where the fully integrated hybrid system—in its most promising cost-optimized configuration—will be tested on simulated flue gas to demonstrate the potential of the membrane technology to meet DOE capture targets.

Primary Project Goal

The primary project goal is to evaluate a hybrid post-combustion CO_2 capture process combining the latest developments in membrane and amine absorption/stripping technology and establish its progress toward meeting the DOE goal to demonstrate second-generation technologies that can capture 90 percent of the CO_2 at less than $40 per tonne in the 2020–2025 timeframe.

Objectives

The project objectives are to (1) evaluate and optimize the best process configuration of the hybrid process with the membrane in series or in parallel with the amine absorber, (2) fabricate the membrane system at MTR, (3) install the membrane system at the UT Austin SRP pilot plant, (4) perform a comprehensive parametric test program on the combined membrane-absorption unit, and (5) obtain a reliable estimate of the technical and economic benefits of the combined processes.

Planned Activities

- Create a predictive computer simulation model of the total hybrid process and vary process designs and operating conditions to select the most promising hybrid configuration. An initial techno-economic analysis will be performed based on the model results.
- Design and build a 2–4 tonnes CO_2 per day membrane capture system.
- Complete parametric testing of the membrane and absorption/stripper units separately to evaluate key parameters over the full range of expected conditions.
- Modify the computer simulation model to incorporate experimental results and select the best processes.
- Install the membrane absorber/stripper unit at the UT Austin SRP pilot plant.
- Perform an integrated parametric study of the best hybrid process optimization, as needed.
- Complete the final techno-economic analysis based on experimental results.
- Complete a preliminary environmental, health, and safety assessment.

Accomplishments

Project awarded in September 2013.

Benefits

This project will provide important insights into hybrid post-combustion CO_2 capture systems. While each underlying capture system has benefited from previous NETL-sponsored research, the integration of the two offers a new opportunity to explore further reductions in the cost of capture. The benefits of this hybrid process include the pre-concentration of the CO_2 feed to the absorber at a minimal energy cost, 30 percent lower reboiler energy, and reduced capital expense of the absorber/stripper that is sufficient to cover the added cost of the membrane unit. The results of this project will be used to prepare the hybrid membrane-absorption system for future 1 MWe scale testing and design.