the ENERGY lab

PROJECT FACTS

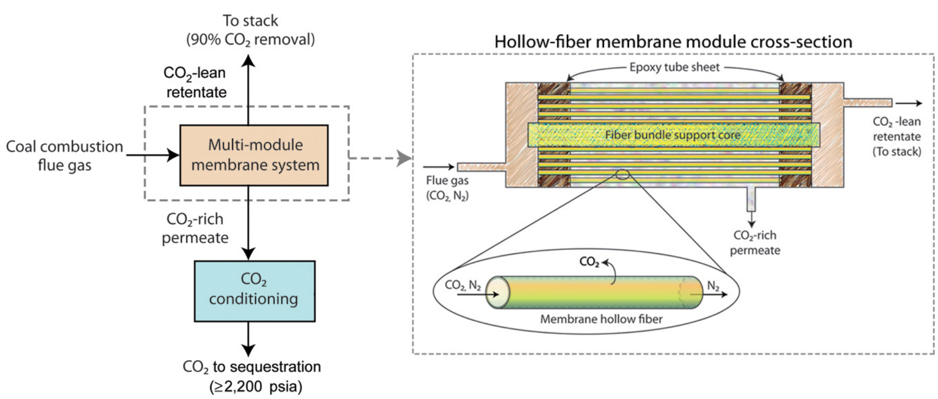
Existing Plants, Emissions & Capture

CO_2 Capture Membrane Process for Power Plant Flue Gas

Background

The mission of the U.S. Department of Energy's (DOE) Existing Plants, Emissions & Capture (EPEC) Research and Development (R&D) Program is to develop innovative environmental control technologies to enable full use of the nation's vast coal reserves, while at the same time allowing the current fleet of coal-fired power plants to comply with existing and emerging environmental regulations. The EPEC R&D Program portfolio of post- and oxy-combustion carbon dioxide (CO_2) emissions control technologies and CO_2 compression is focused on advancing technological options for the existing fleet of coal-fired power plants in the event of carbon constraints.

Pulverized coal (PC) plants burn coal in air to raise steam and comprise 99 percent of all coal-fired power plants in the United States. CO_2 is exhausted in the flue gas at atmospheric pressure and a concentration of 10-15 volume percent. Post-combustion capture of CO_2 is a challenging application due to the low pressure and dilute concentration of CO_2 in the waste stream, trace impurities in the flue gas (nitrogen oxides [NO_x], sulfur oxides [SO_x], particulate matter [PM]) that affect removal processes, and the parasitic load associated with the capture and compression of CO_2.



RTI's CO_2 capture membrane process and hollow-fiber membrane module design.

Description

As part of the effort to develop post-combustion CO_2 emissions control technologies, RTI International is leading a research team to develop and integrate a polymer-based membrane process for capturing flue-gas CO_2 from existing PC power plants. Broadly, the project will focus on new, high-performance membrane materials, improved hollow-fiber membrane module design, and process development for cost-effectively retrofitting a CO_2 capture membrane system into coal plants. New fluoropolymer chemistries and microstructures will be developed as improved CO_2 capture membrane

CONTACTS

Jared P. Ciferno
Technology Manager
Existing Plants, Emissions & Capture
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-5862
jared.ciferno@netl.doe.gov

Andrew O'Palko
Project Manager
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4715
andrew.opalko@netl.doe.gov

Lora Toy
Project Manager
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709-2194
919-316-3393
ltoy@rti.org

PARTNERS

RTI International
Generon IGS, Inc.
Arkema Inc.
Arcadis G&M

PERIOD OF PERFORMANCE

10/01/2008 to 03/31/2011

COST

Total Project Value
$2,431,027

DOE/Non-DOE Share
$1,944,821 / $486,206

AWARD NUMBER

NT0005313

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materials by leveraging the polymer synthesis and engineering expertise of project partner Arkema. Improved membrane hollow fibers and membrane modules for CO_2 capture will be developed and fabricated by project partner Generon from the next generation of their baseline membrane. Membrane process engineering design and integration strategies will be developed by RTI to identify optimum process operating conditions and guide the membrane materials and module research and development efforts. RTI will also evaluate the separation performance of new polymers, membrane hollow fibers, and membrane modules with simulated flue gas with and without flue gas contaminants (SO_2, NO_X) in the laboratory and with a flue-gas slipstream from an operating coal-fired combustion unit.

Primary Project Goal

The primary goal of this project is to develop an advanced polymeric membrane-based process that can be cost-effectively, easily, and reliably retrofitted into existing PC power plants to separate and capture at least 90 percent of the CO_2 from the plant's flue gas at 50-60 °C, with no more than a 35 percent increase in cost of electricity (COE).

Objectives

Specific project objectives include:

- Developing two or three new chemistries/structures of fluorinated polymer membrane materials that have (i) excellent chemical stability to moisture and SO_2 and NOx contaminants present in flue gas; (ii) high selectivity for CO_2 over N_2 [30-50 selectivity targeted]; and (iii) high permeance to CO_2 [3×10^{-4} to 3×10^{-3} cm3(STP)/(cm_2•s•cmHg) targeted].
- Identifying candidate membrane process design(s) for integrated CO_2 capture in PC plants, and more definitive membrane CO_2 permeance and selectivity targets through process simulations.
- Fabricating polymer candidate(s) into defect-free membrane hollow-fibers with high CO_2/N_2 selectivity and high CO_2 permeance.
- Fabricating field-test membrane modules from membrane hollow fibers.
- Demonstrating CO_2 capture performance and reliability of membrane modules in a field test with real coal-fired process flue gas.

Benefits

This project could provide PC power plants with a cost-effective membrane process technology option for controlling flue-gas CO_2 emissions and, thus, aiding in greenhouse gas mitigation. Membrane processes for CO_2 capture are advantageous because they are simple and can be integrated downstream of existing flue-gas cleanup systems (i.e., the flue-gas desulfurization unit) in coal plants without requiring modification of major plant infrastructures, such as fuel processing, boiler, and steam turbine subsystems. Compared to regenerable, adsorption- and absorption-based CO_2 capture approaches (i.e., solid sorbents and liquid solvents), membrane processes are more attractive in that no parasitic adsorption or absorption losses due to heat required to regenerate and release CO_2 from the spent sorbent or solvent are associated with their operation. Given the relative compactness and simple operation of the membrane process, it is anticipated that the technology can fit both niche and large-scale CO_2 separation applications. The membranes' modular design allows for use as a single module or several hundred modules depending on the scale of the CO_2 removal required. Overall, this technology should expand the options utility companies have to produce electrical power in a carbon-constrained world.

Accomplishments

- Baseline testing of CO_2 separation performance for the laboratory-scale standard hollow fiber membrane modules was completed.
- Novel polymers and membrane films were synthesized and tested. Preliminary results demonstrate increased CO_2 permeability and stable CO_2/N_2 selectivity.
- Next-generation laboratory-scale hollow fiber membrane modules were fabricated and tested with simulated flue gas to characterize the permeation properties.
- A preliminary engineering design package describing RTI's three-stage membrane process for flue-gas CO_2 capture was prepared; a more detailed engineering cost analysis and a refined estimate of cost of electricity is underway.

Planned Activities

Future activities will continue investigation and evaluation of different process design flow schemes to identify promising process design configurations. Work will be conducted to fabricate and field-test final polymer candidate(s) into defect-free membrane hollow-fibers with high CO_2/N_2 selectivity and high CO_2 permeance. A membrane test skid will be designed and constructed for field testing and the prototype membrane modules will be tested with a slipstream of real coal-fired process flue gas for an extended time (e.g., 300 hours). Additionally, a techno-economic evaluation of the "best" integrated/retrofitted CO_2 capture membrane process package will be finalized.

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