



the **ENERGY** lab

PROJECT FACTS

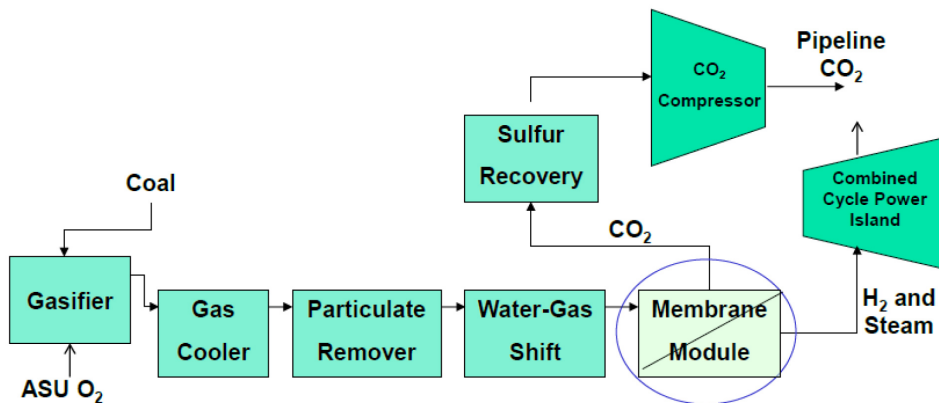
Carbon Capture

Development of a Precombustion Carbon Dioxide Capture Process Using High Temperature Polybenzimidazole Hollow-Fiber Membrane

Background

The mission of the U.S. Department of Energy Office of Fossil Energy (DOE FE) Carbon Capture Research & Development (R&D) Program, implemented through the National Energy Technology Laboratory (NETL), is to develop innovative carbon dioxide (CO₂) emissions control technologies for fossil fuel-based power plants. The Carbon Capture R&D Program portfolio of pre- and post-combustion CO₂ emissions control technologies and related CO₂ compression is focused on advancing technological options for new and existing power plants to enable cost-effective CO₂ capture for beneficial use or storage of CO₂ 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 CO₂ 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.

Pre-combustion CO₂ capture technologies are applicable to integrated gasification combined cycle (IGCC) power plants, where solid fuel is converted into gaseous components (synthesis gas, or syngas) by applying heat under pressure in the presence of steam and oxygen. The carbon is captured from the syngas before combustion and power production occurs. Pre-combustion carbon separation and capture is relatively simple and less expensive compared to post-combustion capture, as it has a greater driving force, with the processed syngas at a much lower volume, at a higher



Block flow diagram of the membrane-based CO₂ capture system in an IGCC plant.

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PROJECT DURATION

Start Date	End Date
10/01/2013	10/31/2016

COST

Total Project Value
\$2,812,501
DOE/Non-DOE Share
\$2,249,997 / \$562,504

PROJECT NUMBER

DE-FE0012965

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pressure, and containing a higher concentration of CO₂. Polybenzimidazole (PBI) shows promise as a membrane material for the pre-combustion based capture of CO₂ by separating hydrogen (H₂) and CO₂ at elevated temperatures [200 to 250 degrees Celsius (°C)].

Project Description

SRI International, along with its team members, will further advance a system for the high-temperature separation of CO₂ from a syngas stream by conducting slipstream testing at bench scale. The CO₂ capture system was developed under a previous DOE-funded project (FC26-07NT43090). Separation of CO₂ at elevated temperature (above the dew point of the gas stream) increases the efficiency of electric power generation from coal.

The project entails the high-temperature separation of CO₂ from a syngas stream containing CO₂, H₂, carbon monoxide, steam, and other trace-level gases. The separation process is based on a high-temperature stable PBI polymer that has been fabricated into asymmetric hollow-fiber membranes. The PBI hollow asymmetric fibers will then be assembled into membrane modules to separate hydrogen and steam from test syngas streams representative of those from an oxygen-blown gasifier. An existing 50 kilowatt thermal (kWth) test skid will be modified to separate a pre-combustion gas stream into a hydrogen-rich permeate stream and a retentate stream consisting mainly of high-pressure CO₂. The modules will be inserted into high-pressure vessels and assembled along with syngas feed, retentate, and permeate connections and instrumentation. The skid will be transported to the National Carbon Capture Center (NCCC) where it will be tested at 225 °C and 30 bar under various operating conditions, including long-term steady-state conditions. The data collected from these tests will be used to update the techno-economic and environmental health and safety (EH&S) assessments.

Primary Project Goal

The primary project goals are to evaluate, at bench scale, a technically and economically viable CO₂ capture system for an IGCC plant based on a high-temperature PBI polymer membrane separation system, and to optimize the process for integration of that system into an IGCC plant. The goal of this project aligns directly with DOE's goal to demonstrate second-generation technologies that can capture 90 percent of the CO₂ at less than \$40 per tonne in the 2020–2025 timeframe.

Objectives

The specific project objectives are to (1) collect laboratory data for separating hydrogen from simulated syngas using PBI-based membrane modules at temperatures and pressures relevant to a pre-combustion CO₂ capture technology; (2) produce design and steady-state performance data for membrane modules using syngas from an operating coal gasifier; (3) fabricate membrane modules of sufficient capacity to process a syngas stream (50 kWth equivalent of a shifted gas from an oxygen-blown gasifier) using equipment of industrial relevance; (4) transfer the membrane fabrication technology to an industrial firm that specializes in the manufacture of

hollow fiber membranes for making the above mentioned membrane modules; and (5) estimate the cost of CO₂ capture from pre-combustion gas streams.

Planned Activities

- Modify an existing 50 kWth bench-scale membrane skid to permit testing of fabricated hollow-fiber membrane bundles using simulated syngas mixtures at temperature and pressure conditions representative of a membrane-based gas separation process with pre-combustion capture of CO₂.
- Conduct preliminary scoping tests with a sub-scale membrane module using simulated syngas to establish a performance database relevant to the process scheme.
- Modify the 50 kWth test unit to conform to the requirements of the NCCC, conduct a process safety review and hazard and operability study, and commission the test unit to operate at steady-state and boundary conditions.
- Conduct parametric testing and analyze the results to evaluate how well performance meets set targets.
- Operate the test unit under steady-state conditions for an extended period of time (initial estimate: 400 – 1000 hours) to validate membrane performance.
- Perform a process design and engineering study to show how the high-temperature hollow-fiber PBI membrane process concept would be incorporated into a nominal 550 MWe gasification-based power plant with carbon capture.
- Complete an updated techno-economic analysis and EH&S assessment.

Accomplishments

- Project awarded in October 2013.
- Kick-off meeting held in June 2014.

Benefits

Successful deployment of carbon capture technologies hinges on the technical performance and economics of the process, with the ultimate achievement being the production of a CO₂-rich stream at a pressure suitable for pipeline transportation and sequestration. This project will produce design and performance data for a CO₂ capture technology by testing the membrane modules using a slipstream from a coal gasifier under realistic conditions and continuous long-term operation. A successful outcome will result in project data that will be used to advance the CO₂ capture technology toward commercial deployment.