the ENERGY lab

PROJECT FACTS

Gasification Technologies & Hydrogen and Clean Fuels

Scale-Up of Hydrogen Transport Membranes

Background

In the gasification process, carbon-based feedstocks, such as coal, are converted into gaseous components, called synthesis gas (syngas), a mixture of hydrogen (H_2) and carbon monoxide (CO). The syngas can be further processed in a water-gas shift (WGS) reactor, which converts CO into carbon dioxide (CO_2) while producing additional H_2, thus increasing the CO_2 and H_2 concentrations. Carbon dioxide is present at much higher concentrations in shifted syngas than in flue gas, as well as at a higher pressure, and thus, can be more efficiently separated into H_2 and CO_2 gas streams. The hydrogen is used in a combustion turbine to generate clean electricity while the CO_2 gas stream may be captured for reuse or storage.

The Gasification Technologies Program at the National Energy Technology Laboratory (NETL) supports research and development (R&D) in the area of Advanced Gas Separation. The NETL R&D efforts of the Gasification Technologies Program for advanced gas separation research focus on the potential for substantial improvements in process efficiency and environmental and cost performance of gasification systems. Several novel approaches are being investigated for H_2 and CO_2 separation under varying operating conditions.

Specifically, Eltron Research & Development Inc. (Eltron) has been developing a Hydrogen Transport Membrane (HTM), a reaction-separation system, for energy efficient hydrogen production and carbon capture. This project is funded in part by the funds from the American Recovery and Reinvestment Act (ARRA) for accelerating the scale-up of an HTM technology system for energy-efficient hydrogen production and carbon capture, and to enable early technology commercialization by reducing time, technology risk, and cost.

Project Description

The Eltron HTM technology uses composite metal alloy materials for separating H_2 at practical rates from coal-derived syngas, which is a mixture of H_2, CO, CO_2, and steam. Carbon dioxide on the feed side of the membrane remains at high pressure and in a concentrated form suitable for capture and re-use or storage. The Eltron HTM system is an enabling module for the production of high purity H_2 and the capture of CO_2 at high pressure, which is applicable to future integrated gasification combined cycle (IGCC) and central station H_2 production plants. These novel membranes have an operating temperature of 280 to 440 degrees Celsius (°C), which is well-matched with emerging coal gas cleaning technologies and can significantly improve the overall

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PARTNERS

Eastman Chemical Company

PROJECT DURATION

Start Date
10/01/2005

End Date
09/30/2015

COST

Total Project Value
$87,662,900

DOE/Non-DOE Share
$82,547,725 / $5,115,175

Government funding for this project is provided in whole or in part through the American Recovery and Reinvestment Act.

efficiency and process economics for future gasification-based power, fuels, and chemical production plants. Eltron's membranes can withstand high differential pressures of up to 1,000 pounds per square inch gauge (psig) without structural failure, allowing for successful integration into advanced, high-pressure coal gasification plants.

Eltron is currently executing the project in two distinct parts: Part 1, titled "Scale-up of Hydrogen Transport Membranes for IGCC and Coal-to-Hydrogen Production Plants," is the base project; and Part 2, titled "Scale-up of Hydrogen Transport Membranes (HTM)," is the ARRA-funded extension of the project. In Part 1, Eltron has sub-contracted Eastman Chemical Company for scale-up of this technology and tests on coal-derived syngas. Eltron and Eastman will design, construct, and operate a nominally 12-lb/day scaled-up HTM module on coal-derived syngas. In Part 2, Eltron will accelerate the design, construction, and operation of a 250-lbs/day module and further scale the technology up to a nominal 4 to 10 tons/day hydrogen production module. Eltron has sub-contracted URS as the Engineering, Procurement, and Construction firm.

Goals and Objectives

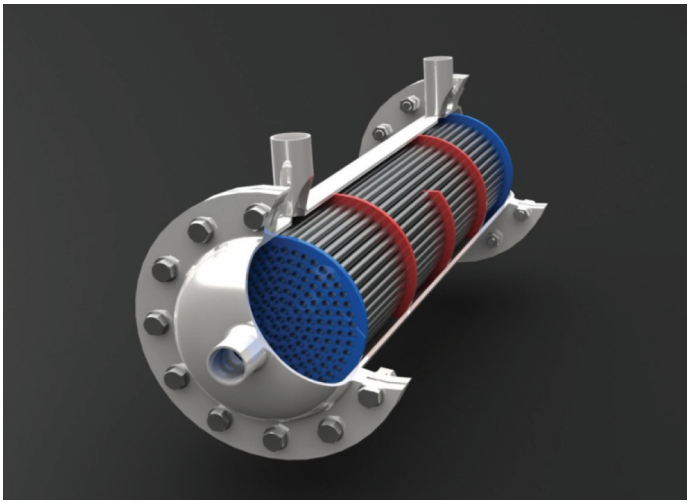
The project will develop and scale up the HTM technology to cost-effectively separate H_2 from shifted coal derived syngas at practical rates and retain CO_2 at high pressure, up to 1,000 psig, to minimize capital and compression costs for carbon capture and storage (CCS) applications. The HTMs are capable of producing pure H_2 at temperatures that approach commercial WGS reaction conditions, thus allowing process intensification via integrated reaction-separation system, with the potential to significantly improve the cost and efficiency of relevant industrial applications. The project will ready the HTM technology for early commercial deployment by accelerating the construction and test schedule of a 250-lbs/day prototype H_2 separation module and, in parallel, continue activities for a 4- to 10-ton/day pre-commercial module (PCM). The ARRA-funded R&D efforts will significantly accelerate the design, construction, and operation of the prototype PCM and provide a head start on analyses of cost, performance, and engineering data for future integrated clean energy systems, as well as accelerating the transfer of an enabling technology to the manufacturing sector.

Accomplishments

- Eltron engineered novel HTM materials for producing pure hydrogen from coal-derived synthesis gas. In bench-scale tests, the materials met DOE 2015 targets for sulfur tolerance, economic life, and operating conditions and surpassed those for hydrogen production rate, product purity, and cost.
- Eltron demonstrated the HTM hydrogen production technology at a 1.5 lb/day-scale, meeting designed hydrogen production rate and product purity.
- Demonstrated improved economics for scenarios utilizing HTM technology in coal-based IGCC plants with a refined process flow sheet.
- Successfully scaled manufacturing and catalyst deposition to 5-foot-long tubes. Designed, constructed, and operated a 12-lb/day reactor to test the hydrogen membrane tubes under 16 different sets of pressure, temperature, and flow rate conditions, using a slip stream of coal-derived syngas at Eastman Chemical's gasifier in Kingsport, Tennessee.

Benefits

An HTM device separates H_2 from coal-derived shifted syngas, generates capture-ready CO_2, and serves as an enabling CCS module for future IGCC power plants integrated with CCS. The Eltron HTM achieves high H_2 recoveries approximating 90 percent, with essentially 100 percent H_2 purity at high pressures, and provides a viable step forward for the H_2 fueled energy economy by using abundant domestic coal feedstocks. In addition, the Eltron HTM system separates and maintains CO_2 at high pressure, thereby minimizing compression costs for pipeline transportation to storage sites.



Conceptual design of a commercial membrane unit