II.I.1 Scale-Up of Hydrogen Transport Membranes for IGGC and FutureGen Plants

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Partners:
- NORAM Engineering
- CoorsTek
- Praxair

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Objectives

- The project will further develop, scale-up, and demonstrate an advanced hydrogen separation technology for separating hydrogen from coal-derived synthesis gas, thereby enabling a cost-effective, commercially viable coal-to-hydrogen production process.
- Develop high-throughput, low-cost H_2 separation system suitable for application with coal-based synthesis gas, including improved tolerance to contaminants (S, Hg, etc.) and enabling cost effective capture of CO_2 for sequestration.
- Select candidate mechanical configuration (tube vs. plate; metallic alloy vs. cermet) considering cost, performance, and manufacturability of membrane and system.
- Scale-up membrane and system from 0.45 lb/day of H_2 using lab gases to 220 lb/day in coal-derived syngas.
- Integrate membrane design into a 4 ton/day H_2 production unit.
- Determine optimum process design and cost and compare versus other technologies.

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Introduction

Significantly high hydrogen fluxes exceeding 250 ml/min-cm^2 have been achieved in bench-scale tests for separating hydrogen from simulated coal gasification-derived, water-gas shifted synthesis gas mixtures by advanced hydrogen transport membranes. The high separation flux can be achieved at temperatures potentially compatible with warm gas (480-750°F) clean-up operations of coal gasification systems. However, significant issues remain requiring further development and scale-up of these membrane systems in order to demonstrate technical and economic requirements for commercial applications. Engineering R&D is needed for cost-effective, commercial manufacturing methods of the hydrogen separation membranes and modules and determining the best methods for managing coal-derived impurities to allow long engineering life time for commercial operation of the membranes. These methods should be demonstrated in a process development unit using both simulated coal gasification fuel and real slip streams from small gasifiers at a scale suitable to obtain design, engineering, cost, operating, and performance data for technology demonstration at a sub-engineering scale and, eventually, at a pre-commercial scale.

Approach

- Eltron will first design, construct, and evaluate a 1.3 lb/day hydrogen separation membrane module. Following successful tests of the 1.3 lb/day unit, the project will build a 220 lb/day subscale engineering prototype facility and will obtain cost, engineering design, scale-up, performance, and operating data to develop a 4 ton-per-day FutureGen test module. The design will serve as the basis for development of a commercial-scale unit capable of producing 35 tons per day of hydrogen.
- Examine membrane and catalyst compositions and develop appropriate preparation techniques.
- Evaluate flux, life and impurities effects using water-gas shift (WGS) compositions and establish a range of operating conditions.
- Evaluate tubular versus planar configurations and assess manufacturing costs and maintenance issues.
- Integrate the system into integrated gasification combined cycle (IGCC) flow sheets, with and without co-production of H_2 and power, and

determine appropriate methods for impurity management.

Accomplishments

- Developed a membrane separation system that meets the 2010 DOE target for flux and selectivity.
- Developed cermet materials with comparable performance to Pd membranes. These materials were tested for more than 500 hours without a loss in permeability.
- Established optimum operating conditions for metal membranes to achieve DOE 2010 flux, selectivity, and cost targets and selected candidate membranes for scale-up and tests in the sub-scale engineering prototype.
- Completed fabrication of new alloy materials and selected candidate metal materials for further scale-up and tests in the sub-scale engineering prototype.
- Identified a lower cost route for fabrication of the materials.
- Conducted preliminary design and cost estimates that indicate that these materials are competitive with El100 membranes.
- Process economic studies show that the high temperature membrane system is competitive with conventional technology show 2% improvement on a higher heating value basis.
- Constructed and operated a 1.3 lbs/day high pressure unit with initial operations demonstrated at 1.46 lbs/day at full WGS conditions. Details of the reactor design are presented in Figures 1 and 2.
- Evaluated four different pre-treatment conditions to improve membrane performance, lifetime and resistance to embrittlement.

Future Directions

- Continue development of effective scale-up manufacturing procedures.
- Further optimize the system to operate at 1,000 psi, utilize warm gas cleaning and increase CO_2 capture.

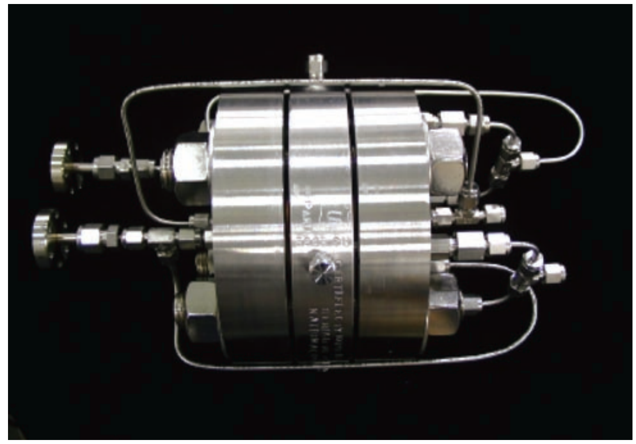

FIGURE 1. A 1.3 pounds/day Hydrogen Separation Unit Designed by NORAM.

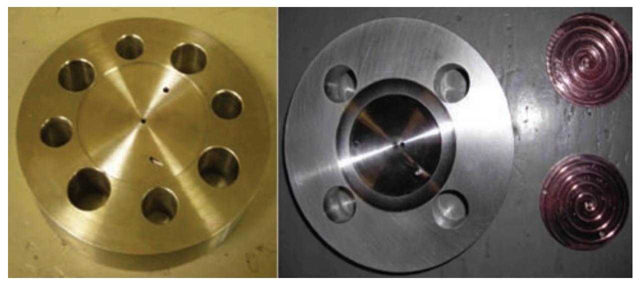

FIGURE 2. Internal Design of the Hydrogen Membrane Separator

- Continue work on co-production of hydrogen and power.
- Increase the focus on analytical capabilities to understand decay mechanisms and improve membrane performance.
- Continue studies on embrittlement including further alloy development.
- Develop more sophisticated process engineering and economic tools for system optimization.
- Continue scale-up efforts through work with materials suppliers and fabricators, warm gas cleaning technology providers and identify potential sites for scale-up.