IV.B.2 Robust Low-Cost Water-Gas-Shift Membrane Reactor for High-Purity Hydrogen Production from Coal-Derived Syngas

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Objectives

- Develop a lower cost, robust water-gas-shift (WGS) membrane reactor that can be used to process coal-derived syngas for the production of high-purity hydrogen
- Develop and demonstrate a contaminant-tolerant, highly active WGS catalyst
- Develop and demonstrate a highly-selective hydrogen membrane with improved durability
- Construct and demonstrate a bench-scale WGS membrane reactor
- Demonstrate the scalability of the technology by constructing a 500 L hydrogen/hr production capacity unit
- Perform a study on the economic feasibility of the WGS membrane reactor

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Production section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- L. Durability
- M. Impurities
- O. Selectivity
- Q. Flux
- S. Cost

The project also addresses one or more of the barriers described in Section 5.1.5.1., *Technical Barriers – Central Production Pathway* in the Hydrogen from Coal – Research, Development, and Demonstration Plan, which was issued by the DOE Office of Fossil Energy.

Technical Targets

This project is conducting studies to develop a low-cost, robust WGS membrane reactor that can be used to process coal-derived syngas for the production of high-purity hydrogen. Insights gained from these studies will be applied toward the design, construction, and operation of a 500 L hydrogen/hr production unit that can meet the DOE's 2010 and 2015 hydrogen separation targets, particularly with respect to membrane/module cost, durability, operating pressure, hydrogen recovery, and hydrogen quality.

Tables 1 and 2 list the targets that the project will attempt to meet during its implementation.

Table 1. Technical Targets: Ion Transfer Membranes for Hydrogen Separation and Purification.[a]

Performance Criteria	Units	2003 Status	2005 Target	2010 Target	2015 Target
Flux Rate	scfh/ft^2	60	100	200	300[b]
Cost	$/ ft^2	2,000	1,500	1,000	<$500
Durability	Hours	<8,760	8,760	26,280	>43,800
ΔP Operating Capability	psi	100	200	400	400-1000
Hydrogen Recovery	% of total gas	60	>70	>80	>90
Hydrogen Purity	% of total (dry) gas	>99.9	>99.9	>99.95	99.99

[a] Targets are derived from Table 3.1.5. from the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan, March 2005.

[b] Flux upper limit for ion transport membranes.

Table 2. Technical Targets for the Water Gas Shift Reaction[a]

Performance Criteria	Units	Current Status	2005 Target	2010 Target	2015 Target
Reactor Type	–	Multiple fixed beds	To be determined		
Catalyst Form	–	Pellets	To be determined		
Active Metal	–	Cu/Zn or Fe/Cr or Co/Mo	To be determined		
Temperature	°C	200-550	300-450	300-500	200-600
Pressure	psia	450-1150	450	750	>1,000
Approach to Equilibrium	°C	8-10	10	6	>4
Min Steam/CO Ratio	Molar	2.6	3.0	2.5	<2
Sulfur Tolerance	–	Varies	Low	Moderate	High
Chloride Tolerance	–	Varies	Low	Moderate	High
Water Tolerance	–	Varies	Low	Moderate	High
Stability/Duraability	Years	3-7	3	7	>10
Reactor Cost Reduction	%	–	–	>15%	>30%

[a] Targets are derived from Table 6 of the Hydrogen from Coal RD&D Plan, June 10, 2004.

Approach

- Prepare, test, and demonstrate the operation of a contaminant-tolerant, highly active WGS catalyst.
- Prepare, test, and identify a highly-selective hydrogen membrane with improved durability for development and demonstration.
- Using data from tests conducted in steps (1) and (2), construct and demonstrate a bench-scale WGS membrane reactor.
- Show that WGS membrane reactor technology is scalable by constructing a 500 L hydrogen/hr system and performing an economic feasibility study of the WGS membrane reactor.

Introduction

There exists a need to develop a lower cost, robust WGS membrane reactor that can be used to process coal-derived syngas for the production of high-purity hydrogen. The required characteristics of this WGS membrane reactor are a contaminant-tolerant, highly active WGS catalyst and a highly-selective membrane with improved durability. Such a membrane reactor should be constructed and demonstrated at bench-scale to demonstrate the scalability of the technology, preferably at 500 L hydrogen/hr production capacity unit. The demonstration should be completed with a study on the economic feasibility of the WGS membrane reactor.

Approach

The first step is to prepare, test, and demonstrate the operation of a contaminant-tolerant, highly active WGS catalyst. A highly-selective hydrogen membrane with improved durability will then be identified for development and demonstration. Using data from these tests, a bench-scale WGS membrane reactor will then be constructed and demonstrated. Finally, to show that the WGS membrane reactor technology is scalable, a 500 L hydrogen/hr system will be built and an economic feasibility study of the WGS membrane reactor will then be performed.

Accomplishments

This project is newly initiated and no there are no accomplishments to report to date.