IV.B.5 Hydrogen Production for Fuel Cells via Reforming of Coal-Derived Methanol

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Eastman Chemical

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Objectives

- Experimentally investigate production of hydrogen from coal-based methanol utilizing the latest reforming technologies for use in a polymer electrolyte membrane (PEM) fuel cell.
- Demonstrate hydrogen production from a coal-derived fuel and test the resulting hydrogen gas, if of sufficient quality, in an existing PEM fuel cell stack.

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
- S. Cost

Technical Targets

Table 1 lists the targets that the project will attempt to meet during its implementation.

Approach

- Demonstrate fuel conversion change over time (degradation) with both coal-derived and baseline fuel.
- Identify the limiting steps in the reformation processes.
- Identify ways of overcoming the limiting steps in the reformation processes.

- Determine the relative magnitudes of the effects of each process variable, including fuel type, on the reformation outputs.

Accomplishments

- Quantified the differences between coal-derived and fuel cell grade methanol.
- Demonstrated hydrogen production from steam reforming and autothermal reforming of coal-derived methanol.

Future Directions

- Demonstrate and characterize operation of a hydrogen fuel cell fed by coal-derived methanol.
- Finish degradation rate tests for fuels in an autothermal reactor.
- Quantify fuel cell performance with coal-derived vs. fuel cell grade fuel.

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.

Introduction

In 1997, a viable method of creating methanol from high-sulfur coal was established. Recent interest in hydrogen fuel cells and fuel cell vehicles has prompted the investigation of using this coal-derived methanol as a primary source for hydrogen production. Initial testing has indicated that hydrogen can be derived from this coal-based fuel, but impurities were seen as problematic, especially for utilization in fuel cells. The coal-derived methanol has since been further refined and distilled, yet no full analysis of reforming this high-grade coal-derived methanol using the latest reforming methods has yet taken place.

Eastman Chemicals of Kingsport, Tennessee, has agreed to supply the University of California, Davis with sufficient quantity of plant-produced coal-derived methanol for use in this investigation. Baseline investigations and comparisons will take place with reference to high-grade methanol used in fuel cell vehicles, supplied by Methanex.

Approach

First, this project will demonstrate fuel conversion change over time (degradation) with both coal-derived and baseline fuel. Then, the limiting steps in the reformation processes and ways of overcoming the limiting steps in the reformation processes will be identified. Finally, the relative magnitudes of the effects of each process variable, including fuel type, on the reformation outputs will be determined.

Results and Conclusions

Coal-derived methanol was found to have more hydrocarbon impurities than fuel cell grade methanol, and the relative levels of chlorides and sulfur are similar. Coal-derived methanol can be used as a hydrogen feedstock with both steam reformation and autothermal reformation (ATR), and overall performance with the two processes is comparable (see Figure 1). In steam reformation with copper-based catalysts, the performance degradation with coal-derived methanol was greater than that when using fuel cell grade methanol. However, reactor geometry seems to have a much greater role in degradation than fuel impurities at this level. Passive flow disturbance within the steam reforming catalyst bed was also investigated (see Figure 2). From the temperature profile and fuel conversion data, it was proven that the flow disturbance made a significant heat transfer enhancement and increased the capacity of the steam reformer. ATR of fuel cell grade methanol has been investigated, and ATR of coal-derived methanol is underway. Chemical equilibrium accurately predicts output composition above the light-off point. The upper end of flow rate has not yet been determined, but it is greater than 77,000 h^{-1} gas hourly space velocity.

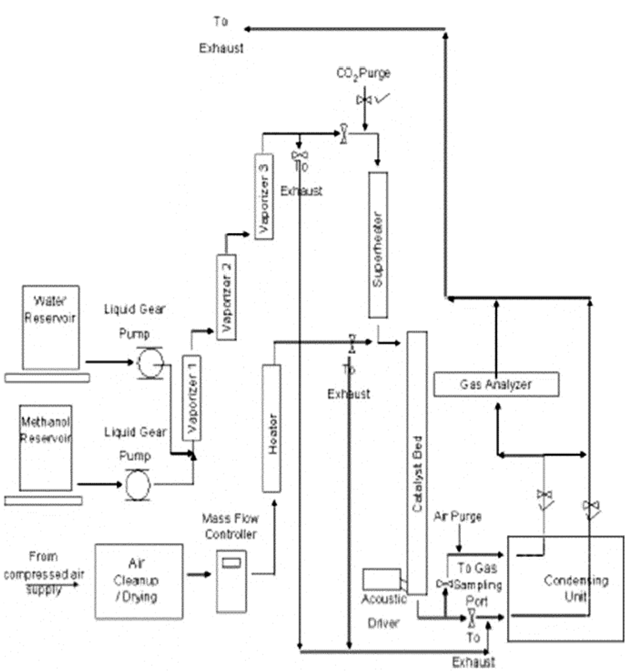

Figure 1. Schematic of the Authothermal Reformation

FY 2005 Publications/Presentations

1. Dorr, J. L., "Methanol Autothermal Reformation: Oxygen to Carbon Ratio and Reaction Progression," Masters Thesis, University of California, Davis, December 2004
2. Beerman, M. J., "Improving the Transient Response of Steam Reformers Through the Use of Acoustic Waves," Masters Thesis, University of California, Davis, June 2005
3. Dorr, J. L. and Erickson, P. A., "Preliminary Modeling and Design of an Autothermal Reformer," Proceedings of IMECE: 2004 International Mechanical Engineering Congress and Exposition, November 13-19, 2004, Anaheim, California, IMECE 2004-59892 pp. 1-9
4. Liao, C.-H. and Erickson, P. A., "Heat Transfer Enhancement of Steam-Reformation by Passive Flow Disturbance Inside the Catalyst Bed" (Technical Paper), 2005 ASME Summer Heat Transfer Conference, San Francisco, California, Paper Number: HT 2005-72043
5. Erickson, P. A. and Yoon, H.C., "Hydrogen from Coal-Derived Methanol: Experimental Results," 3rd International Energy Conversion Engineering Conference, San Francisco, California, Paper Number: IECEC 2005-5567

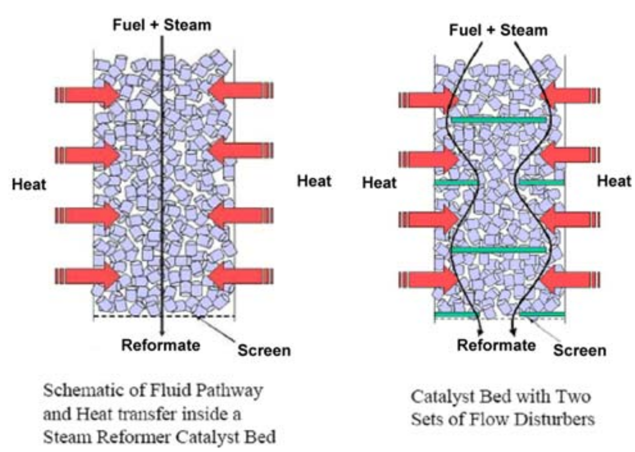

Figure 2. Enhancing the Steam-Reformation Process