II.B.7 Co-Production of Electricity and Hydrogen Using a Novel Iron-Based Catalyst

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Objectives

Develop the steam-iron process technology for the co-production of electricity and hydrogen in an integrated gasification combined cycle power plant.

Introduction

Gasification-based technology, such as integrated gasification combined cycle (IGCC), is the only environmental friendly technology that provides the flexibility to co-produce H_2, substitute natural gas (SNG), premium hydrocarbon liquids including transportation fuels, and electric power in desired combinations from coal and other carbonaceous feedstocks. Our nation has vast reserves of low-cost coal available for gasification. Rising costs and limited supply of crude oil and natural gas provide a strong incentive for the development of coal gasification-based co-production processes.

In the United States, hydrogen is viewed as the fuel of choice for the transportation fleet. Additionally, rising natural gas costs coupled with potential supply uncertainties has caused numerous problems in both the utility and the industrial sectors. It is these that provide the motivation for developing technologies for production of SNG from coal. In a central station facility, coal would be converted to hydrogen and/or SNG along with electricity. Also, the manufacture of high value chemicals and carbon products at such a facility could improve the overall economics.

The project seeks to develop a novel cost-effective application of the steam-iron process in a transport reactor for IGCC systems to co-produce hydrogen and electricity. The conventional method for H_2 production is steam reforming of natural gas. Recent techno-economic evaluations have shown that at natural gas costs of $4.50 to $4.75 per million BTU, hydrogen from coal gasification can compete with hydrogen from natural gas. These techno-economic evaluations further show that novel technologies such as warm-gas sulfur removal and membranes can reduce the cost of hydrogen even more, particularly when the plant co-produces hydrogen and electricity.

Approach

The work will be carried out in two phases with a go/no-go decision point after Phase I. During Phase I, a number of iron-based catalysts will be prepared in small quantity and characterized. Selected catalysts will be tested in a laboratory scale reactor. An engineering and economic evaluation will be carried out. During Phase II, promising catalysts will be selected from Phase I and scaled up. These catalysts will be evaluated in a large bench-scale reactor system. An optimum catalyst as determined by the results of bench-scale testing will be produced in a large batch to demonstrate scalability of catalyst preparation. A detailed engineering evaluation and commercialization assessment will be carried out.

Accomplishments

- Developed a research management plan with input from the DOE contracting officer's technical representative. The plan describes a work breakdown structure, detailed schedules, planned expenditures for each task, go/no-go decision points and decision criteria used to identify schedule and budget variances.
- Identified a precipitation method and various supports with high surface area that will achieve the required characteristics of the iron-based nanoparticle catalysts.
- Synthesized a series of catalysts with 30-40 wt% Fe_2O_3 loadings. Evaluated their redox properties by H_2-temperature programmed reduction and thermogravimetric analysis experiments.

Conclusions and Future Directions

The results indicate that about 45% reduction of iron oxide particles could be achieved in the first reduction cycle when 30% Fe_2O_3 is loaded on the transitional Al_2O_3. However, the reducibility decreased to about 22.5% when the Fe_2O_3 loading is increased from 30% to 40%. These results suggest that a relatively larger number of exposed Fe particles are available for the steam-iron redox cycle in the catalyst with lower Fe_2O_3 loading. The data also indicates that the nature of the support also plays an important role in improving the redox properties of the catalysts. Supports with higher Bruner-Emmett-Teller surface areas will be beneficial for achieving higher metal dispersion, more exposed Fe particles on the surface, and better performance. Future work is shown below:

- Design a high-pressure micro-reactor system dedicated to the steam-iron process.
- Install micro-reactor and all analytical instruments by September 2006.
- Develop and install a data acquisition system.