

IV.A.9 Low-Cost Hydrogen Distributed Production Systems

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Subcontractors:

Sud Chemie, Louisville, Kentucky

Naval Research Laboratory, Washington, D.C.

Start Date: January 1, 2005

Projected End Date: January 31, 2008

Objectives

- Design, build and test a hydrogen generator with the objective of meeting the DOE cost and efficiency targets for distributed hydrogen generation from natural gas.
- Demonstrate the efficacy of producing low-cost renewable hydrogen by reforming ethanol to hydrogen at the fueling station, with the objective of meeting the DOE cost targets for distributed hydrogen generation from bio-derived renewable liquids.

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:

- A. Fuel Processor Capital Costs
- B. Fuel Processor Manufacturing
- C. Operation and Maintenance (O&M)
- D. Feedstock Issues
- E. Carbon Dioxide Emissions
- F. Control and Safety

Technical Targets

This project has two primary targets:

- To demonstrate steam methane reforming and gas cleanup technology that could meet the 2010 DOE efficiency and hydrogen cost targets in scaled-up systems.

- To demonstrate a pathway for achieving the 2010 DOE efficiency and cost targets for producing renewable hydrogen from ethanol at the fueling station.

Approach

To meet the 2010 DOE cost and efficiency targets for distributed hydrogen production from natural gas, H₂Gen will evaluate various improvements to the existing HGM (Hydrogen Generation Module)-2000 steam methane reformer system that includes a built-in PSA (pressure swing adsorption) gas cleanup system. Improvements will include (1) better heat management through new or improved heat exchangers and (2) improved catalysts that will not only increase efficiency and throughput, but also reduce maintenance costs through longer lifetimes.

Higher-capacity hydrogen generators will be required to meet the DOE hydrogen cost targets, since the costs of many reformer system parts increase less than linearly with increased hydrogen capacity. We will therefore design, build and test an HGM-10,000 based on the improvements developed for the HGM-2000 during the first phase of the project. The proposed HGM-10,000 will produce 567 kg/day of hydrogen, still approximately three times less than the 1,500 kg/day production that DOE has specified as the basis of the hydrogen cost targets. We expect that the cost of hydrogen from this HGM-10,000 will approach the DOE 2010 cost targets in terms of being competitive with gasoline at \$1.50/gallon on a per mile basis assuming increased fuel economy of hydrogen vehicles compared to conventional and hybrid gasoline vehicles. We project that a 1,500 kg/day system based on this HGM-10,000 will meet the \$1.50/gge target on a range-equivalent basis.

To produce low-cost renewable hydrogen, H₂Gen will experimentally investigate the reforming of different grades of ethanol using our proprietary reforming and shift catalysts. We will obtain ethanol samples from various stages of the ethanol production plant to determine if we can eliminate many of the distillation/drying steps, providing a less expensive feedstock for hydrogen production. We will analyze the tradeoffs between reduced ethanol plant costs and the cost of transporting ethanol by tanker truck with increased levels of water content.

Accomplishments

H₂Gen has made rapid progress toward accomplishing the DOE goals for producing low-cost hydrogen. Several of the main objectives of the DOE work have already been achieved. For example, H₂Gen had the goal of developing a new reforming catalyst support that would improve performance and greatly increase the service life of the catalyst. Working with our catalyst development partner, Süd-Chemie Inc., we developed the new catalyst formulation prior to the start of the DOE contract. Since the January 1, 2005 start time for this DOE contract, we have tested the formulation extensively at the pilot scale, with ~7,000 hours of cumulative test time, to determine the aging characteristics of the new reforming catalyst. The pilot tests were successful, demonstrating almost no loss in support surface area and little loss in catalyst activity after over 1,000 hours on stream at full process temperature and pressure using line-natural gas feed, not pure methane. The improved reforming catalyst formulation has already been implemented in a full-scale H₂Gen HGM that has run for over 700 hours. The unit has successfully produced 2,000 scfh of hydrogen with a purity of 99.999% as measured by an outside analytical laboratory.

In addition to improvements in the reforming catalyst, H₂Gen has also been working with Süd-Chemie to improve the activity and selectivity of the water gas shift (WGS) catalysts. A major goal of H₂Gen's DOE contract is to reduce the amount of methanation that occurs in the WGS section of H₂Gen's patented single reactor system that combines reforming and WGS functions. There are two WGS zones in the H₂Gen process, an ultra-high temperature shift zone and a high-temperature shift zone. A new WGS catalyst has been developed for each zone. Through testing a number of samples of the new WGS formulations under a range

of conditions, we have accumulated over 5,000 hours of pilot test time on each catalyst. The pilot tests have shown that the new WGS formulations greatly improved the selectivity of the catalysts. The onset of methanation occurred at temperatures 100°C higher than in the previous generation of WGS catalysts, dramatically reducing the methanation seen at our operating temperatures. The new WGS catalysts have been implemented in a second full-scale HGM that will be under test in early July. Initial calculations indicate that the improved WGS catalysts could improve the system thermal efficiency by ~5%, given the higher net methane conversion achieved by suppressing methanation, while the lower carbon monoxide (CO) concentration in the reformat will allow for higher PSA recoveries.

In addition to the catalyst work, H₂Gen has made significant progress in a number of other areas to achieve higher operating efficiency and reduce costs. A new heat exchanger to recover additional heat from the reformat gas has been designed, fabricated, implemented in a full-scale HGM unit, and tested. The heat exchanger takes heat from the reformat, which had previously been rejected to cooling water or air as waste heat, and uses it to preheat the compressed natural gas stream entering the reactor. This exchanger allows us to recover heat from the reformat and also preheats the natural gas to the appropriate temperature for our one-step sulfur removal process.

Our demonstrated ability to take improvements developed as part of the DOE contract and to immediately implement them in new generations of full-scale HGM-2000 hardware not only provides us with reliable test data that will greatly reduce the development time of the HGM-10,000 unit to be designed and built in FY 2006, but it also helps to reduce the price of hydrogen now.