IV.H Electrolysis

IV.H.1 Low-Cost, High-Pressure Hydrogen Generator

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Subcontractor:
Center for Technology Commercialization, Westborough, MA

Start Date: January 1, 2003
Projected End Date: December 31, 2005 (extension in progress)

Objectives

- Develop and demonstrate a low-cost, high-pressure water electrolyzer system for hydrogen production
  - Eliminate need for mechanical hydrogen compressor
  - Increase electrolyzer hydrogen discharge pressure to 5,000 psig
  - Reduce capital costs to meet DOE targets
  - Demonstrate a 3,300 standard cubic foot per day (scfd) high-pressure electrolyzer operating on a renewable energy source
- Perform public outreach and education

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:

- G. Capital Cost
- H. System Efficiency- replace mechanical compressor with electrochemical compression
- I. Grid Electricity Emissions
- J. Renewable Integration
- K. Electricity Costs

Technical Targets

This project is advancing the technology for a water electrolysis system for hydrogen production toward the DOE technical and cost goals. The advancements at the laboratory and prototype stage achieved in this project will aid in producing electrolysis systems that meet the following DOE 2010 targets for a 1,500 kg/day refueling station:

Power conversion, Cell Stack, Balance of Plant	Cost: 0.39 \$/gge H_2 Total cell efficiency: 76%
Compression, Storage, Dispensing	Cost: 0.19 \$/gge H_2 Efficiency: 99%
Electricity	Cost: 1.89 \$/gge H_2
O&M	Cost: 0.38 \$/gge H_2
Total	Cost: 2.85 \$/gge H_2 Efficiency: 75%

Approach

- Incrementally increase the operating pressure of the Giner Electrochemical Systems LLC (GES) differential pressure electrolyzer through improved seal and end-plate design
  - 1,000 psig in 2002; 2,000 psig in 2003
  - Planned further increases to 3,500 and 5,000 psig
- Replace high-cost metal components with lower-cost materials
- Increase the operating current density to reduce the active area and, thus, reduce stack cost
- Increase the active area per cell to decrease the number of cells, reducing the component cost and stack cost
- Develop system innovations to replace high-cost, high maintenance components

Accomplishments

- Stack Cost Reduction
  - Developed a lower cost oxygen anode side membrane support structure (ASMSS) – expected to reduce cost of this repeating component by 75%
  - Developed low-cost fabrication method for the thermoplastic cell frame – expected to reduce frame cost by 40%
- Improved Stack Efficiency and Cost Reduction
  - Demonstrated performance and life of thinner Nafion membrane – allows efficient operation at higher current density, reducing stack active cell area
  - Preliminary development of an advanced high-efficiency, high-strength membrane
- Improved the system for production of 140 scfd hydrogen at 2,000 psig
  - Increased efficiency of regenerative dryer
- Developed an economic model of electrolyzer capital and operating costs to guide development efforts
- Initiated system safety evaluation

Future Directions

<u>Remainder of FY 2005</u>

- Develop lower-cost, long-life bipolar cell separator
- Evaluate alternate sources of low-cost hydrogen cathode side membrane support structure material
- Complete testing of regenerative dryer
- Complete System Safety Study

FY 2006

- Continue reduction in stack parts count
- Develop advanced supported membrane for high efficiency operation
- Design, fabricate and evaluate stack with larger cell active area
  - Increase cell active area to 0.3 ft^2 from present 0.17 ft^2

Introduction

Electrolysis of water, particularly in conjunction with renewable energy sources, is a potentially cost-effective and environmentally-friendly method of producing hydrogen at dispersed sites. However, current electrolyzers have a high capital cost and are inefficient. In addition, the output hydrogen pressure from current electrolyzers based on either proton-exchange membrane (PEM) or alkaline electrolytes is generally limited to 200 psi. Therefore, a multi-stage mechanical compressor is required to increase the hydrogen pressure to the 5,000 psi or greater needed for storage and/or dispensing to fuel cell powered automobiles. Mechanical compressors are expensive and have high maintenance requirements and poor reliability. Elimination of mechanical compressors, or at a minimum reducing the number of compression stages required, would increase the efficiency and reliability of electrolysis systems.

Giner Electrochemical Systems, LLC (GES) has developed technology for producing hydrogen directly in the electrolyzer stack at high-pressure. The GES technology uses high-differential pressure across the PEM, so the oxygen is evolved at near-atmospheric pressure while the hydrogen is produced at high-pressure. The goal of the present DOE project is to increase the pressure of hydrogen production in the electrolyzer stack to 5,000 psi, while reducing the cost of the stack and system. This will provide a cost-efficient reliable system for generating high-pressure hydrogen.

Approach

GES has designed a focused project to increase the pressure capability of the PEM electrolyzer, decrease system costs, and increase electrical efficiency. The project plan consists of a sequential progression of laboratory experiments and engineering prototypes with each generation demonstrating increased pressure, improved designs or materials that are lower-cost and increased efficiency.

To increase the hydrogen production pressure GES is evaluating alternative materials and designs for: 1) end-plates, 2) internal cell components that support the membrane, and 3) cell frames that provide sealing. To reduce cost, GES is developing replacements for the expensive cell supports/current collectors. The parts count per electrolyzer cell is being decreased through advances in materials and fabrication methods. Improving electrolyzer electrochemical performance reduces cost by decreasing the number of cells required to produce a given quantity of hydrogen, while maintaining high efficiency. Performance is being improved through use of thinner, less resistive membranes and advanced lower-cost catalysts and electrode structures. To further reduce cost, GES is evaluating advanced system concepts.

Results

Membrane Development and Evaluation

According to the GES electrolyzer cost model, high stack efficiency is critical to achieving the DOE cost target. Use of a thinner membrane having lower resistance will decrease stack voltage at a given current density, thus, improving efficiency. However, the operating life of thin membranes is a concern, particularly at the high differential pressures employed in the GES electrolyzers. To address this, GES is evaluating the suitability of: (1) commercially available thinner Nafion membranes, and (2) an advanced thin supported membrane with superior mechanical properties that is being developed by GES under another project.

A life-test of a membrane-electrode assembly (MEA) having the thinner Nafion 115 (0.005 in. thick, compared to a standard 0.007 in.) membrane was promisingbut more extensive testing is required. As shown in Figure 1, the performance of the Nafion 115

MEA was stable over 2,280 hours, when testing was voluntarily terminated. The membrane appeared to be in very good condition at the conclusion of the testing.

In the second approach, GES is developing a supported membrane that has shown excellent mechanical characteristics including:

- Strength higher than hydrated Nafion by an order of magnitude (Figure 2)
- Low (near zero) MEA expansion with hydration

Performance of this membrane, shown in Figure 3, is comparable to that of a Nafion 112 (0.002 in.) membrane up to a current density of 3,000 mA/cm^2.

Electrolyzer Stack Cost Reduction

Significant stack cost reductions were achieved through redesign of the two most expensive cell components, the ASMSS and the cell frame.

The present ASMSS is an assembly of nine distinct parts that are individually cut, cleaned, plated, welded, cut again and then assembled. GES designed an ASMSS assembly that eliminates five of these parts and we believe a vendor could produce a single piece part using this design. This design is expected to reduce ASMSS costs by up to 75% in production volumes. A test of a prototype ASMSS, Figure 4, indicated that performance nearly matched that of a standard model.

The thermoplastic frame used to conduct fluids into and out of the active parts of the cell and to help contain the pressure loads is a very expensive part, due to extensive post-mold machining. We worked with a Tier 1 automotive component supplier to

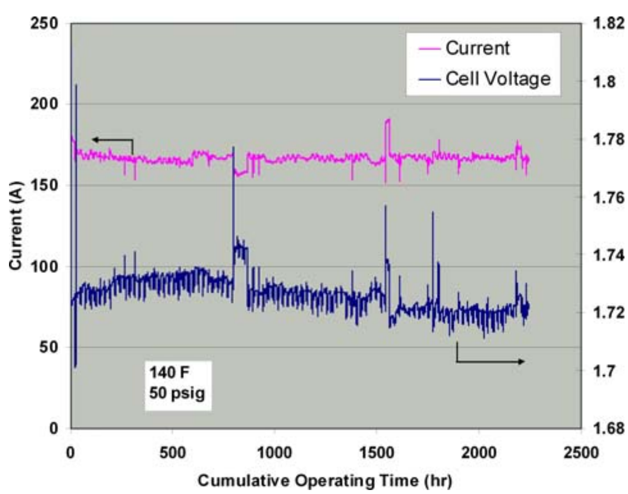

Figure 1. Life-Test of a Nafion 115 MEA

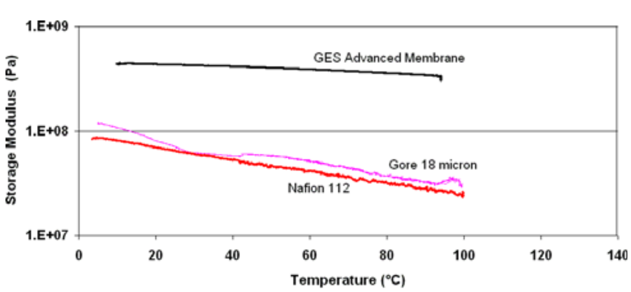

Figure 2. Mechanical Properties of Advanced Membrane

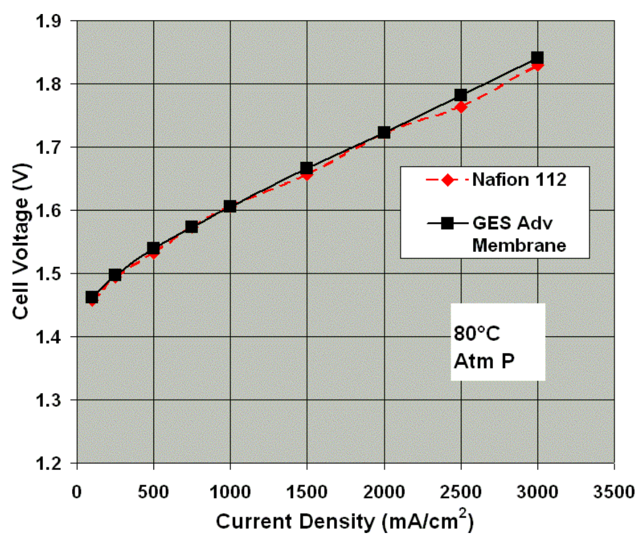

Figure 3. Performance of GES Advanced Membrane

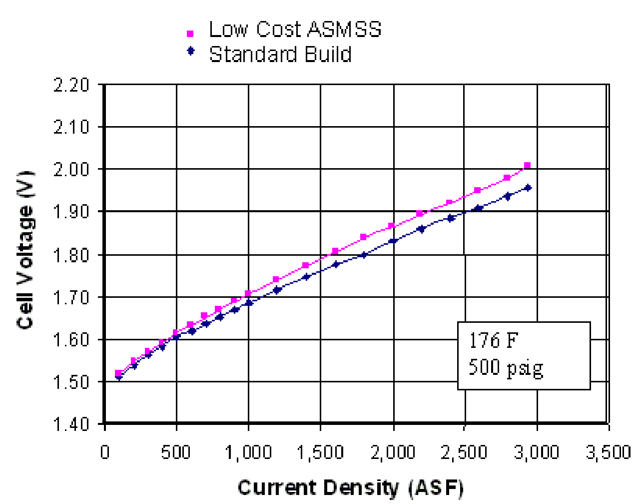

Figure 4. Performance of Electrolyzer with Low-cost ASMSS

design frames and manufacturing methods to eliminate or combine parts, increase component reliability, and reduce costs. Several designs and manufacturing methods were evaluated, resulting in a frame design that will be tested in a stack.

Successful development of the new designs and manufacturing techniques for the frame and the ASMSS are projected to save approximately 40% of the present cell cost.

Additional Studies

GES developed an economic model of electrolyzer systems to guide our cost-reduction efforts. The prototype 2,000 psig electrolyzer system was recommissioned and modified to incorporate a regenerative hydrogen dryer. Improvements in dryer efficiency, reliability and safety were achieved. A complete hydrogen generator system safety review was initiated.

Conclusions

GES is developing a low-cost electrolyzer system for direct production of hydrogen at pressures up to 5,000 psig. Advances in electrolyzer stack design leading to significant reductions in electrolyzer capital cost and improvements in stack efficiency were developed. The electrolyzer system was also improved.

Special Recognitions & Awards/Patents Issued

1. "Low Cost Electrolyzer System" (T. Norman and E Schmitt); Provisional Patent Application No. 60/27,788; Filed: October 2004.

FY 2005 Publications/Presentations

1. Presentation at 2005 Hydrogen Fuel Cells Technology Infrastructure Review Meeting, C. Cropley