II.B.7 Advanced Alkaline Electrolysis

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Contract Number: DE-FC-0706-ID14789

Subcontractors:
- Entergy Nuclear, Jackson, MS
- GE Energy Nuclear, Wilmington, NC
- National Renewable Energy Laboratory (NREL), Golden, CO

Project Start Date: September 30, 2006
Project End Date: December 30, 2008

Objectives

Study the feasibility of using alkaline electrolysis technology with current-generation nuclear power for large-scale hydrogen production:

- Economic Feasibility: Market study of existing industrial hydrogen users
- Technical Feasibility: Developing pressurized low cost electrolyzer
- Codes and Safety: Environmental and regulatory impact assessment

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
(I) Grid Electricity Emissions (for distributed)
(H) System Efficiency

Technical Targets

The goal of this project is to develop a low-cost alkaline electrolysis system. The relevant DOE hydrogen production targets are:

	Units	DOE 2012 Target	Project
Cell Efficiency	%	69%	68% (1.8V)
System Cost	$/kg H2	$0.24 ($400/kW)	$0.29 ($450/kW)
Hydrogen Cost	$/kg H2	$3.11	$3.17

The "Project" values shown are estimated using the H2A model V1.08 changed to 480 kg/day (reflecting 1 MW industrial scale electrolyzer) with the following assumptions:

- Electricity cost: $0.05/kWh
- Stack cost based on full production extrapolation from known prototype costs incurred during actual build
- Balance of system cost same as current state-of-the-art mega-Watt (MW) scale system (approximately $300/kW)
- Operating and capital costs do not include dispensing to vehicles
- Internal rate of return is 0%
- Stack replacement every 10 years

Accomplishments

- Designed and built a 10 x 2,500 cm^2 cell demonstration plastic stack module for operation at 15 bar, which has verified material, manufacture, and assembly cost estimates.
- Demonstrated target efficiency of electrodes that utilize high surface area, low-cost in situ electrodeposition process at the bench scale.
- Results of accelerated material and joining method tests indicate promise for use of polysulfone plastics for this application.
- Completed nuclear regulatory assessment of commercial and industrial scale plant.
- Completed industrial scale cost assessment.

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Introduction

On-site hydrogen production has many advantages over delivered or piped in hydrogen due to regulatory and safety issues related to storage as well as significant infrastructure costs. On-site production using alkaline electrolysis has traditionally high capital costs as well as operation and maintenance costs, which includes the cost of electricity needed for the process. GE has developed technology for an electrolyzer made primarily of advanced plastics which significantly lowers the cost of the stack module. On-site production of hydrogen on a nuclear site using electrolysis has the combined benefits of making hydrogen for needed processes (i.e. generator cooling) while making use of a very low cost source of electricity compared to fossil fuels.

Approach

GE evaluated the feasibility of nuclear electricity and electrolysis for large-scale hydrogen generation by leveraging the joint experience of GE, Entergy, and NREL in low-cost electrolyzer stack technology, nuclear electricity markets, and modeling expertise, respectively.

Results

This year, the GE team completed design and construction of a pressurized stack that utilizes a plastic stack core containing the electrodes and separation diaphragms. GE developed a system that has significantly lower material, machining, and assembly costs compared to existing state-of-the-art electrolyzers. This was achieved by designing a bi-polar stack constructed from thin, injection-molded plates, welded together. Since there are many complicated internal passages, we have developed a proprietary low-cost joining method for the demonstration stack. Extensive material tests indicate the weld used to construct the stack is capable of achieving strength comparable to the baseline strength of the plastic.

Significant progress in development of an in situ deposition process was achieved this year. This process has been optimized, and the performance has been demonstrated at the bench-scale, which is shown in Figure 1. Preliminary tests completed on the full-scale demonstration stack containing electrodes with active surfaces applied using this technology indicate that the performance is equal to or greater than that achieved at the bench scale. Additional tests are underway to confirm early results.

Accelerated material tests have been conducted on Noryl™ formulation used in the demonstration stack, in addition to other plastics in the polysulfone group such as Udel™ and Radel™. Currently, Radel™ exhibits no degradation in an oxidative environment. In tensile tests, Udel™ has shown some reduction in ductility but no reduction in yield strength. Noryl™ has been ruled out as unsuitable in applications requiring life of five years or more due to significant reduction in ductility.

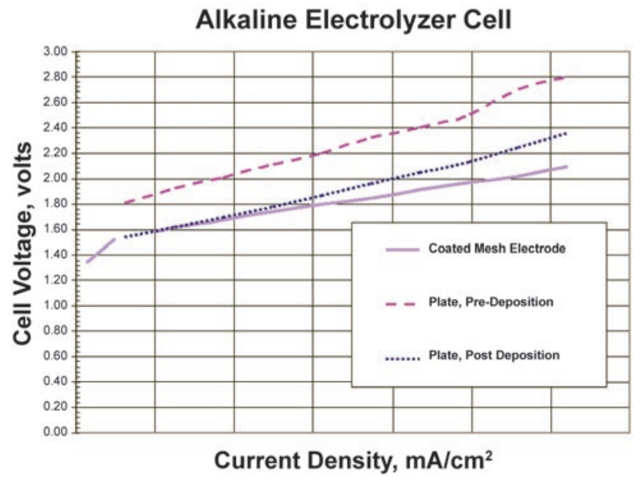

FIGURE 1. Bench-Scale Test Results

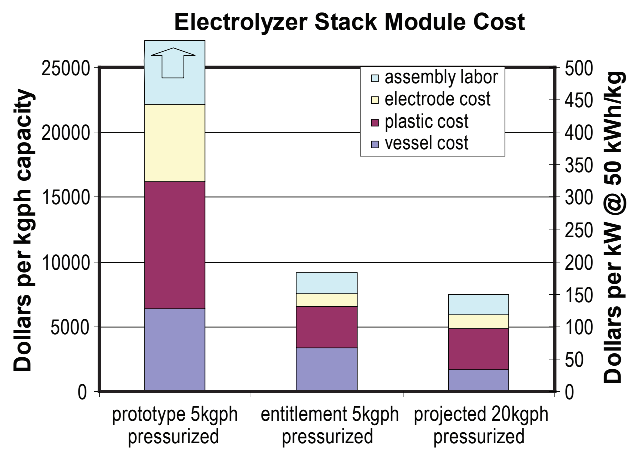

FIGURE 2. Electrolyzer Stack Module Cost

A summary of the projected electrolyzer stack module costs based on the construction of the 10-cell demonstration stack is shown in Figure 2. Labor costs in Figure 2 are assumed to be $40 per hour. Additional information can be found in Ref. [1]. The costs for a prototype 5 kilogram per hour stack module are based on a direct scale-up of the cost to produce the 10-cell demonstration stack. This stack module is assumed to be 200 cells in a single pressure vessel.

Entitlement costs for the same pressure vessel are estimated in the next column. The pressure vessel cost is reduced by high volume production. The cost of plastic is estimated at an entitlement cost of two times the raw material cost for high-grade industrial plastic, plus a set-up cost per cell for the automated joining process. Electrode costs assume a high volume process for stamped metal. Labor costs in the automated joining process are shown assuming one hour of work per cell. This includes final plastic part preparation and stacking.

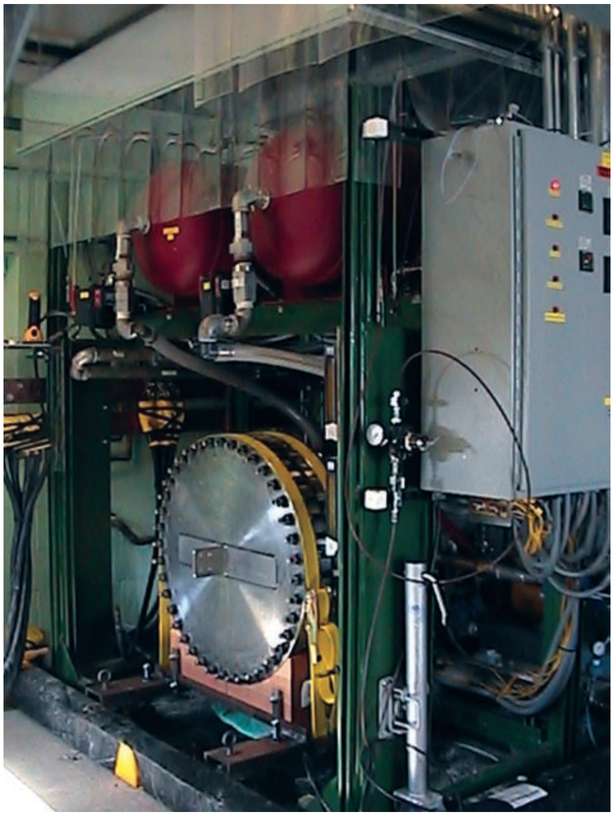

FIGURE 3. 1 kgph Hydrogen Production Demonstration System

Labor costs may be lower in large-scale production, and this represents an opportunity to drive stack module costs down further.

Finally, costs are projected for a 20 kilogram per hour (480 kg/day) stack module. This stack of 800 cells is in two pressure vessels. Labor and material costs are otherwise the same as for the 5 kg per hour case. These assessments include only the stack module itself. The complete system will include circulating pumps, separator tanks, the power rectifier, and other control and process hardware. Balance of system costs will range from a few hundred dollars per kW for large systems to thousands of dollars per kW for smaller systems of approximately 5 kg per hour.

The completed stack module has been installed into the 1 kgph capable system shown in Figure 3, which has been upgraded to 15 bar operation. Early tests indicate that the electrode performance is equal to or greater than performance observed in bench scale tests at ambient pressure. Further testing is underway to confirm performance at ambient pressure, and at pressures up to 15 bar. Experience gained from operation and maintenance of this system will be used to inform report-out of representative industrial and commercial scale plant cost and designs currently underway.

Conclusions and Future Directions

The work performed in Fiscal Year 2008 builds on work completed in FY 2007. Successful design, construction, and efficiency benchmark testing of the full-scale, 10-cell prototype provides confidence that low capital cost electrolyzers can meet all necessary performance targets. Market research and discussions with electrolyzer makers shows that the GE electrolyzer can be successfully commercialized in the near-term. Our work for the remainder of the year will focus on continued demonstration of the prototype pressurized electrolysis stack and completing all tasks related to reference designs for distributed industrial and large scale commercial applications.

Special Recognitions & Awards/Patents Issued & Pending

1. Popular Mechanics Breakthrough Award Recipient, 2006.
2. Electrolysis System for Fertilizer Synthesis and Carbon Capture, 226133 DOE#S-112,474.
3. Electrolyzer Assembly Method and System, 226674, DOE #S-113,160.
4. Pressurized Electrolysis Stack with Thermal Expansion Capability, 227342 DOE #S-113, 342.
5. Methods and Systems for In-Situ Electroplating of Electrodes, 232538, DOE#S-116, 636.
6. Methods and Systems for Assembling Electrolyzer Stacks, 231431 (Pending).

FY 2008 Publications/Presentations

1. Advanced Alkaline Electrolyzer Quarterly Progress Report, Q1FY2008.
2. Advanced Alkaline Electrolyzer Quarterly Progress Report, Q2FY2008.
3. Poster Presentation PDP#14, DOE HFCIT 2008 Annual Merit Review.
4. Bourgeois, R; Swalla, D.R.; Ramsden, T.; "Low Cost Electrolyzer Technology for Industrial Hydrogen Markets", National Hydrogen Association Conference, March 31 – April 4, 2008, Sacramento, CA.

References

1. Bourgeois, R; Swalla, D.R.; Ramsden, T.; "Low Cost Electrolyzer Technology for Industrial Hydrogen Markets", National Hydrogen Association Conference, March 31 – April 4, 2008, Sacramento, CA.