II.C.4 Advanced Alkaline Electrolysis

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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

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 (1.8 V/cell)
System Cost	$/gge $/kW	0.70 400	0.72 400
Hydrogen Cost	$/gge	3.70	3.64

The "Project" values shown are estimated using the H2A model with the following assumptions:

- Electricity cost 5¢/kWh
- Stack cost based on full production extrapolation from known prototype costs
- Balance of system cost same as current state-of-the-art mega-Watt (MW) scale system (approximately $300/kW)

Accomplishments

- Built and tested ambient pressure 18 x 4,600 cm^2 cell plastic monolithic stack. Developed a design for a 30 bar plastic monolithic stack.
- Achieved improved electrode performance over previous work by electrodeposition of the catalyst surface on a three-dimensional substrate.
- Performed market survey for existing industrial hydrogen economy. Determined that a significant opportunity exists for electrolyzers in the 5-20 kg per hour range.
- Completed economic model for industrial-scale hydrogen electrolyzers. Determined that low-cost construction can make electrolysis hydrogen competitive with delivered hydrogen.
- Surveyed pricing for nuclear electricity in a variety of regions and markets.

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Introduction

Hydrogen may be produced from water in an electrolyzer at the point of use or sale, eliminating the need for a delivery network. One barrier to such distributed production of hydrogen is the capital cost of the electrolysis equipment. Another is the price of electricity, because hydrogen production by electrolysis is energy-intensive. GE has invented a low-cost electrolyzer made primarily of advanced plastics that addresses the capital cost problem. Nuclear power, because of its low operating costs compared to fossil fuels, has the potential to be a very low cost source of electricity. The reduced costs of both the electrolyzer equipment and the electric power will make the cost of hydrogen produced on-site at a filling station or industrial facility competitive.

Approach

Combine GE's low-cost electrolyzer stack technology, Entergy's experience in nuclear electricity markets, and NREL's economic modeling expertise to evaluate the feasibility of nuclear electricity and electrolysis for large-scale hydrogen generation.

Results

The GE team built a large ambient pressure plastic electrolyzer stack under the DOE Hydrogen Fuel Cells Infrastructure Technology program in 2004-2005 (Figure 1). This year, the GE team created a conceptual design and preliminary cost model for a pressurized stack. The conceptual design features a plastic stack core containing the electrodes and separation diaphragms. As was demonstrated in the ambient pressure stack, the complex flow passages necessary for operation will be molded into the plastic housing for maximum cost savings. A thin-walled metal pressure vessel shell will enclose the plastic core, as this was determined to be more cost effective than a plastic pressure vessel. Small-scale tests are underway to develop electrode manufacturing and plastic joining techniques necessary for a 10-cell pressurized stack module, which will be tested later this year.

FIGURE 1. Ambient Pressure Plastic Electrolyzer stack

GE's electrode technology applies a high effective surface area, nickel-based coating to the base metal bipolar plate for high performance at low cost. In 2005, we achieved our target performance using a wire-arc spray deposition technique. In the present project we are researching electrodeposition of the electrode surface as a way to further improve performance and lower cost. Electrodeposition has several potential advantages over wire-arc (Figure 2). It allows the use of thinner bipolar plates without warping, and is capable of coating a three dimensional electrode surface instead of a simple flat plate. This permits much closer spacing of the electrodes for reduced ohmic losses and higher efficiency at a given hydrogen production rate.

Our experiments so far have focused on the development of a technique to deposit the high-surface area coating on an electrode surface such as mesh. We have demonstrated the technique in a small single cell of approximately 160 cm^2, on both a flat plate electrode and a simple mesh.

Initial tests of the small electrolysis cell have been very positive. The coated mesh electrode matched the best performance achieved with the wire-arc technique. There is room for further improvement in the performance. The overvoltage reduction for electrodeposition-coated electrodes was not as large as the reduction in wire arc electrodes. A significant part of the performance gain is due to the higher surface area

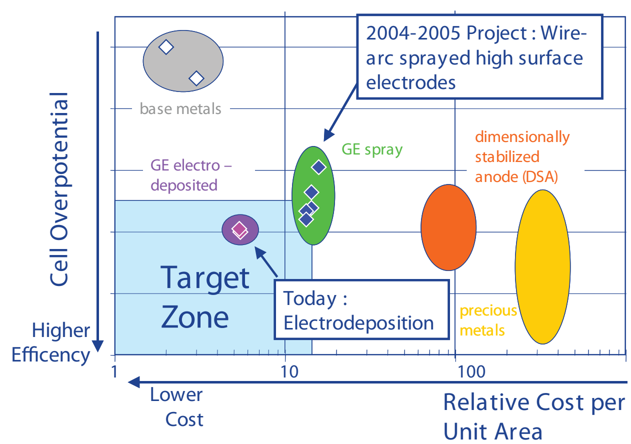

FIGURE 2. Comparison of Alkaline Electrolyzer Electrodes

of the mesh and the smaller gap between electrodes. It is possible that we will observe some additional performance gains as we further develop the technique, and the quality of the electrodeposited coating approaches that of the wire-arc sprayed coating.

This project studies alkaline electrolysis using nuclear electricity at scales of up to a kilogram per second. This scale is appropriate for existing large commercial applications as well as central generation of hydrogen for vehicle fuel. Today's market for hydrogen is very large, over $34 billion per year worldwide. The market is at present dominated by industrial hydrogen use. We performed a study to determine potential market segments for industrial electrolyzers (Figure 3). Two major segments exist: very large-scale commercial facilities for ammonia production and oil refining, and medium-scale industrial facilities using hydrogen for a variety of needs and end products. Most of these industrial applications involve using the hydrogen for a process in a reducing atmosphere, for example in metal treating or float glass manufacturing. As electrolyzer capital costs come down and specific pricing arrangements can be made to take advantage of the low-cost potential of nuclear power, electrolysis can become cost competitive with delivered hydrogen in these markets. Industrial hydrogen generation can therefore be seen as a stepping-stone to transportation applications, or as a stand-alone market.

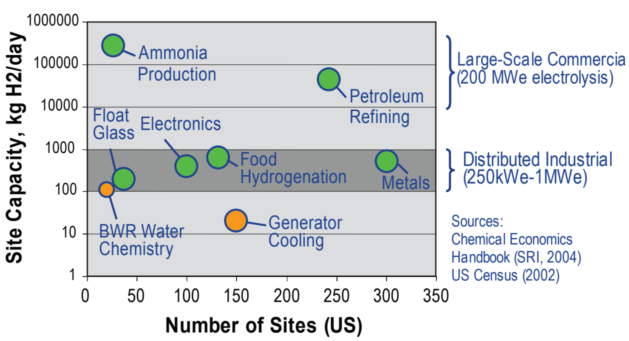

FIGURE 3. Industrial Hydrogen Market Segments

Conclusions and Future Directions

The work performed in FY 2007 brings us confidence that low capital cost electrolyzers can be produced at industrial scales and meet all necessary performance targets. Our market research shows that such an electrolyzer, especially when paired with low-cost electric power, can compete in the existing industrial hydrogen market. Our work for the remainder of the year and in 2008 will focus on demonstrating the prototype pressurized electrolysis stack and completing reference designs for distributed industrial and large scale commercial applications.

2007

- Regulatory assessment of nuclear power integration with electrolysis.
- Complete electrolyzer stack technical development.
- Build and begin testing of 10-cell pressurized stack.

2008

- Conceptual design of reference plants at industrial and commercial scales.

Special Recognitions & Awards/Patents Issued

1. Popular Mechanics Breakthrough Award Recipient, 2006.

FY 2007 Publications/Presentations

1. Advanced Alkaline Electrolyzer Quarterly Progress Report, Q1FY2007.

2. Advanced Alkaline Electrolyzer Quarterly Progress Report, Q2FY2007.

3. Poster Presentation PDP#16, DOE HFCIT 2007 Annual Merit Review.

References

1. Chemical Economics Handbook, SRI 2004.

2. 2002 Economic Census, US Census Bureau.