II.H.5 Alkaline, High Pressure Electrolysis

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Objectives

Develop and construct an alkaline hydrogen generator to meet following objectives:

- Higher overall efficiency
- Low maintenance cost
- DFMA (design for manufacture and assembly)
- Reduce cost of produced hydrogen as per DOE objectives

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Generation by Electrolysis section (3.1.4.2.2) of the Hydrogen, Fuel Cells and Infrastructure Technologies (HFCIT) Program Multi-Year Research, Development and Demonstration Plan:

(G) Capital Cost
(H) System Efficiency
(J) Renewable Integration

Technical Targets

This project is conducting engineering studies and testing to achieve DOE H_2 production targets as described in section 3.1.4 of DOE's HFCIT Multi-Year Research, Development and Demonstration Plan. The specifics are summarized in Table 1.

The water electrolysis system under investigation is broken down into two critical components:

- electrolysis module
- balance-of-plant (BOP)

For each of the areas, efforts are underway to improve efficiency and minimize production cost, utilizing benefits associated with production in economies of scale.

TABLE 1. Summary of Specific 2010 DOE Targets Addressed by this Project

Segment	Cost (per gge H_2)	Efficiency
Power Conversion, Module, BOP	$0.39	76%
Compression, Storage & Dispensing	$0.19	99%
O&M	$0.38	-
Total	$2.85	75%

Accomplishments

The following are listed in chronological order:

- Molded components for the electrolysis module have been procured. This allows consolidation of parts and cost reduction.
- Membrane fabrication hardware has been installed at the Teledyne Energy Systems Inc. (TESI) facility. Membrane samples have been successfully produced and preliminary membrane testing in an electrolysis stack has been performed.
- The Aerovironment Power supply DFMA study has been completed.
- Fabrication of the single-cell high-pressure module has been completed. The design has been hydrostatically tested up to 1,500 psig.
- The Benchtop I system (pressure control), has been tested. Pressure control logic and hardware has been finalized for use in Benchtop II.
- Hazards and Operability Analysis (HAZOP) on Benchtop II has been completed and system design has been modified for safety.
- Benchtop II (sub-scale electrolysis system) has been fabricated and is now ready for debugging and testing.

Introduction

This project will contribute to the enabling and acceptance of technologies where hydrogen is the energy carrier between renewable energy resources and clean energy consumers. There are many opportunities for expanding from traditional industrial applications to transportation and stationary use in a more common setting. The lowering of capital costs driven by DFMA efforts and lowering of operating costs resulting from efficiency improvements will make systems more feasible for early adopters and will help U.S. manufacturers maintain a competitive position in traditional and future markets.

Specific goals of the project involve moving towards DOE's technical targets as outlined in Table 3.1.4 of the HFCIT Multi-Year Research, Development and Demonstration Plan. This includes aggressive improvements in cost, efficiency, operation and maintenance of the electrolysis system.

Approach

The main objective of this project is to design, manufacture, test and demonstrate a low-cost, electrolysis system capable of delivering 99.99% pure hydrogen. The proposed system will have a capacity of 70,000 scfd. The project places critical emphasis on DFMA and on developing a production strategy for these rates, which are about 100 times those demanded by the current worldwide industrial market.

A substantial effort in the scope of work is focused on manufacturing technology, collecting and analyzing cost data, designing and optimizing production processes, and performing a financial analysis of the production line and its facility. The prototype system will include only those features and components which meet the per unit cost objective when high quantities are assumed.

Ongoing key elements of this project include safety, reliability, and quality engineering. These will assure a safe system design, a reliability program and quality control aspects to address the prototype unit as well as the quality engineering, material controls and automation needed for a large production operation. The safety efforts include application of traditionally applied codes for flammable and compressed gases, and new codes/standards being developed for renewable energy situations.

The generator design will build on TESI's 30+ years commercial product experience base with improvements in conversion efficiency and a design to reach an electrolysis system operating pressure of 150 psig.

Results

TESI is utilizing small-scale systems to study and develop critical control algorithms, and operational procedures for the hydrogen generator. The Benchtop I system was the primary vehicle used to develop effective and safe high-pressure gas control hardware and logic. This system did not contain an electrolysis module and utilized nitrogen to replace oxygen. This approach allowed control algorithms to be developed and tested, while minimizing the hazard level of the system. The Benchtop I system (pressure control) has been tested and pressure control logic and hardware has been determined. The results derived from this system are being applied to the Benchtop II system.

Benchtop II will operate a small-scale electrolysis module and will serve as a tool to study module operation at elevated pressures. Inferences from this system will include membrane life and performance at operating pressures. The design work has been performed in consideration of manufacturability and safety. The fabrication of the Benchtop II system has been completed.

Analysis of the Benchtop II pressure vessels utilized the design intent of ASME Code Section VIII, division 2 codes. Supporting finite element analysis work was performed to evaluate discontinuity stresses. A HAZOP (hazards & operability) analysis was then performed on the Benchtop II system, instrumentation, and control design. This process resulted in the identification of some potential hazards in certain operational scenarios. Design modifications were then implemented to mitigate the risks improving system safety.

TESI has worked with the integration of electrolysis cell components to reduce part count to achieve DFMA objectives. Mixed results have been obtained with work pending to resolve part tolerances and related issues.

TESI has purchased and setup hardware in its plant to facilitate the production of more consistent membranes. This equipment is operational and membranes have been successfully fabricated and tested at TESI's standard operating pressures. Testing at elevated pressures will be performed on the Benchtop II system.

Conclusions and Future Directions

A new electrolysis system is being developed at TESI to support DFMA. This module and associated BOP will be a high efficiency system with a final hydrogen output pressure of 150 psig.

Future work will include testing the newly designed cell and module, along with the newly developed fabrication techniques. Benchtop systems are being used to study module lifetime and validate control techniques and strategies. HAZOP/FMEA studies have been performed to drive any safety related engineering. TESI will then finalize design of the prototype system including consolidation of sensors and controls between its various components, along with engineering considerations to minimize the capital, operational and maintenance costs.

The project will proceed in two parallel paths.

- Path A:
  - Debugg and test the Benchtop II system.
  - Use the Benchtop II system to generate electrolysis data at elevated pressures to study system performance and module efficiency.
- Path B:
  - Perform DFMA Engineering on 150 psig electrolysis system. TESI has determined that this system is the preferred method to move towards DOE's cost targets.
  - Finalize design of prototype system and present details to DOE.

FY 2006 Publications/Presentations

1. S. Ibrahim "Alkaline Electrolysis" 2006 DOE Program Review Presentation, Arlington, VA (2006).