II.A.7 Hydrogen by Wire – Home Fueling System

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Project Start Date: August 15, 2010
Project End Date: August 14, 2012

Overall Objectives

- Develop enabling technologies for 350-bar hydrogen home fueling
- Design key electrolysis cell stack and system components
- Fabricate, inspect and assemble prototype components
- Demonstrate prototype 350-bar hydrogen generation
- Demonstrate prototype 350-bar home fueling technologies

Fiscal Year (FY) 2013 Objectives

Complete demonstration of prototype 350-bar home fueling technologies including full characterization of the prototype and start/stop cycles to simulate tank fill operation

Technical Barriers

This project addresses the following technical barriers from the Hydrogen Production section of the Fuel Cell Technologies Office Multi-Year Research, Development, and Demonstration Plan:

(F) Capital Cost

(G) System Efficiency and Electricity Cost

(H) Footprint

(I) Grid Electricity Emissions (for distributed)

(K) Manufacturing

(L) Operations and Maintenance

(M) Control and Safety

Technical Targets

Table 1 presents the technical targets for this project.

TABLE 1. Progress towards Meeting Technical Targets for Hydrogen Production via Distributed Water Electrolysis

Characteristics	Units	2013 Status	2015 Target	2020 Target
Hydrogen Levelized Cost (Production Only)	$/kg	5.99[a, b]	3.90	2.30
Electrolyzer System Capital Cost	$/kg	2.62[a,b]	0.50	0.50
System Energy Efficiency	% (LHV)	57[b]	72	75
Stack Energy Efficiency	% (LHV)	66[b]	76	77
Compression, Storage, and Dispensing	$/kg	0.00	1.70	1.70
Total Hydrogen Levelized Cost (Dispensed)	$/kg	5.99	5.60	4.00

[a]Based on H2A model modified for residential (non-commercial) application
[b]Includes generation and compression to 350 bar
LHV – lower heating value

FY 2013 Accomplishments

- Demonstrated 350-bar (5,000 psig) differential pressure electrolysis
- Demonstrated several cycles from start to 350-bar generation to stop
- Demonstrated comparison of stack performance at 350 bar vs. 13 bar

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INTRODUCTION

Based upon the results of the Phase 1 study, the fundamental requirements for a hydrogen home fueling appliance have been defined. The conclusion of the Phase 1 study indicated that an overnight-fill proton exchange membrane (PEM) electrolysis device that fills the vehicle directly to a maximum of 350 bar with no mechanical compressor or secondary hydrogen storage can cost effectively supply the daily hydrogen for a typical commuter operating a fuel cell vehicle. The case for including the hydrogen home fueling concept in the overall mix of fueling infrastructure is strong. The home fueler can grow in production volume and geographic distribution with individual vehicles as they are placed in the market with more flexibility than centralized fueling stations. Existing utility infrastructure (water, electricity) can be utilized within their existing capacities to cover the distribution aspect of the fueling infrastructure.

The goal of this Phase 2 project was to design and demonstrate the key hardware for 350-bar hydrogen home fueling based on PEM electrolysis. Proton Energy Systems has previously demonstrated durable PEM electrolysis equipment generating hydrogen at 165 bar. In addition, Proton has also demonstrated the ability of sub-scale prototypes to seal at the required proof pressure for 350-bar operation. Building upon this past work, designs have been developed utilizing Proton's reliable PEM electrolysis cell stack and system technologies for hydrogen generation and vehicle fueling at 350 bar.

APPROACH

The approach to the Phase 2 project was threefold. First, utilize the data and modeling results from the Phase 1 project to provide approximate sizing for the hydrogen generation rate. Second, build upon Proton's proven cell stack design and development experience to undertake the designs required for 350-bar operation. Third, utilize Proton's strong engineering processes that rely on a phased approach, with stage reviews, key written guidelines, and design output documentation to guide the successive levels of design refinement and demonstration. To that end, the project was organized into four main tasks: (1) Prototype System Design and Fabrication, (2) Prototype Stack Design, (3) Prototype Component Verification, and (4) Prototype System Testing.

Task 1 utilized engineering best practices to design and fabricate the prototype fueling system. This includes producing the plumbing and instrumentation diagram, electrical schematics, bills of materials, control schemes and component specifications for the prototype system. In addition, Task 1 included the procurement, fabrication, and acceptance testing of the prototype system. Task 2 included producing the component designs and assembly models for the cell stack in three-dimensional computer-aided design format. Moreover, it included completing design feasibility pressure testing using both sub-scale and full-scale active area components. Task 3 incorporated work on verifying the functionality of key components within the cell stack design and one or two custom components within the system design. Task 4 included assembling and checking the first electrolysis-ready version of the new prototype stack design. Furthermore, it includes integrating the prototype stack into the prototype system and operating in electrolysis to generate hydrogen at 350 bar.

RESULTS

As of last year's annual report, the project had completed all of Tasks 1, 2, and 3, and 80% of Task 4. The project is now complete and all of the goals of the project have been met.

The prototype system design is based upon Proton's commercial HOGEN® HP high-pressure hydrogen generator which delivers hydrogen at pressures of up to 2,400 psi. This high-pressure system is also derivative of Proton's highly successful HOGEN® S-series product with over 400 units now in operation. The prototype system has gone through a complete prototype design process, including schematics, drawings, and controls definition. A picture of the completed system is shown in Figure 1. System acceptance testing included leak checking, ground continuity testing, and hi-pot testing.

The final activity during Task 3 was the fabrication of an operational single-cell stack suitable for integration and testing in the prototype test bed. Leading up to the operational single-cell stack, an equivalent test article was built for cross-cell diffusion testing. The operational single-cell stack went through a complete acceptance test protocol as is typical for all of our commercial product electrolysis stacks. This acceptance test protocol included cross-cell diffusion testing up to the full operating pressure. The results of the high pressure diffusion tests for the pre-operation test article and the operational single cell are shown in Figure 2 in comparison with previously reported data.

All of the preparation, build, and acceptance testing of the complete system was described in the previous annual report. After the operational single-cell 350-bar stack was installed, the initial milestone of hydrogen production at 350-bar pressure and full differential pressure was achieved (Figure 3). Continued testing with the stack and system allowed the full tuning of system operating parameters as well as cycle testing of the stack and system through

FIGURE 1. Prototype Test System and Data Acquisition

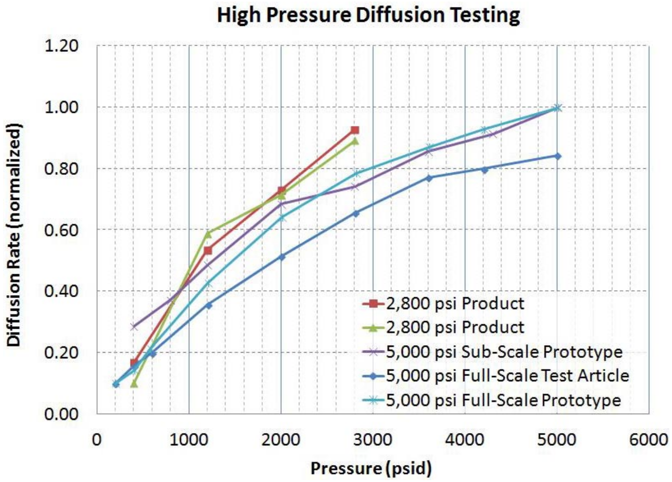

FIGURE 2. Cross-Cell Diffusion Testing at up to 350-Bar Differential Pressure

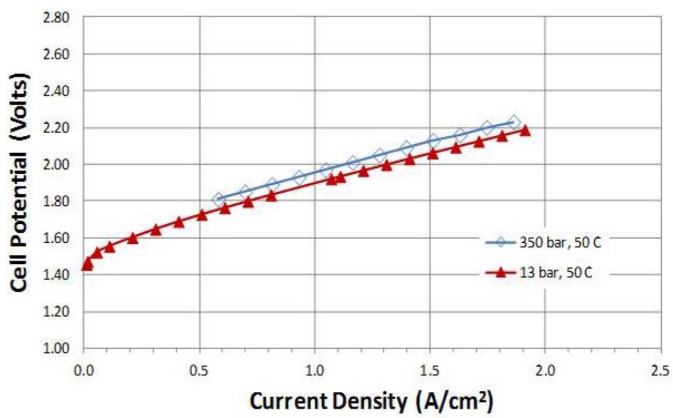

FIGURE 3. Polarization Data during 350-bar (5,000 psig) Hydrogen Generation Compared with 13-Bar Hydrogen Generation

simulated tank fills starting from zero pressure through full pressure and return to system standby (Figure 4). The key high-pressure components including the stack and high-pressure phase separator worked well throughout the test. The test was stopped due to the failure of one sensor that was newly designed for this operating pressure. The redesign of that sensor by the component supplier was beyond the scope of the project.

CONCLUSIONS AND FUTURE DIRECTIONS

All of the diligent design and development work of the project team resulted in achievement of the initial demonstration of a 350-bar capable electrolysis stack and system. This accomplishment creates a foundation from which the hydrogen output and pressure can be scaled up and also design improvements can be made to improve the efficiency and economics of this small-scale, high-pressure hydrogen generator system.

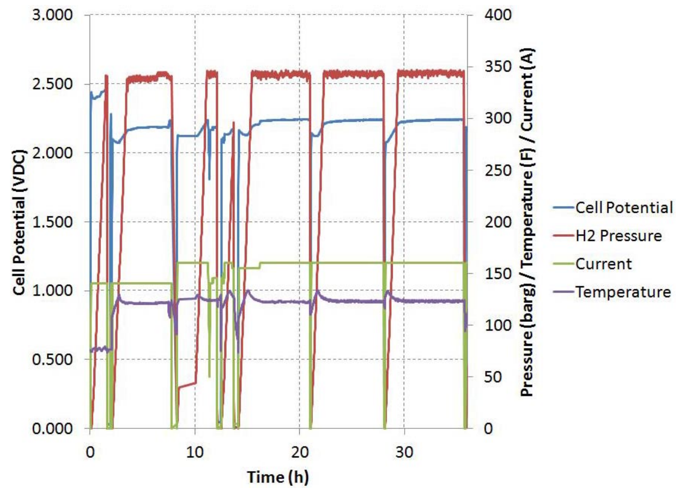

FIGURE 4. Start, Pressurization, and Return to Standby Cycle Test Data with 350-Bar (5,000 psig) Hydrogen Generation

In summary, the following tasks have been completed for the 350-bar electrolysis fueling system development effort and the parallel 350-bar electrolysis cell stack development:

- All prototype system components have been ordered and procured
- The prototype system is complete, including full system operational checkout
- The high-pressure cell stack design is finalized including overboard seal testing to proof pressures above 500 bar
- All prototype cell and stack embodiment components have been ordered and procured
- Design and verification of cell stack components is completed, including seal and active area full differential pressure testing
- The operational prototype cell stack has been assembled and acceptance tested
- The prototype system and operational stack have been integrated and operationally tested
- 350-bar hydrogen generation from water electrolysis at full differential pressure has been achieved
- Multiple cycles from start to 350 bar to stop with full system operation

FY 2013 PUBLICATIONS/PRESENTATIONS

1. Phase II Final Report.

2. "Electrochemical Compression and Purification to Enable Hydrogen Fuel Distribution, Storage, and Use", Fuel Cell Seminar, November 2012.

3. "Bridging the Infrastructure Gap: Cost Effective Generation of Hydrogen from Water", Department Seminar, Colorado School of Mines, November 2012.

4. "Proton Exchange Membranes for H_2 Generation: A Tutorial on Research Needs and Challenges for PEM Electrolysis vs. Fuel Cells", Spring ECS Meeting, Toronto, Canada, May 2013.