V.I.1 Development and Test of Low-Cost Co-Production of Hydrogen and Electricity*

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Subcontractor:
University of Alaska, Fairbanks, AK

Vendor:
H2 Pump LLC, Latham, NY

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Project End Date: May 31, 2009

*Congressionally directed project

Objectives

- Demonstrate cost-effective, efficient, reliable and durable solid oxide fuel cells for stationary applications.
- Determine the feasibility of a delivered cost of hydrogen below $2.50 per gasoline gallon equivalent (gge).
- Determine the economics of hydrogen and electricity co-production for comparison to stand alone hydrogen production facilities.

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(I) Hydrogen and Electricity Co-Production

Contribution to Achievement of DOE Technology Milestones

This project will contribute to achievement of the following DOE Technology Validation milestone of the Co-Production of Hydrogen and Electricity at Energy Stations section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- **Milestone 37: Validate prototype energy station for 12 months; projected durability >40,000 hours; electrical efficiency >40%; availability >0.90.** We will demonstrate the operation of our solid oxide fuel cell at a customer site for 1 year. We will optimize the performance to achieve >40% electrical efficiency and >90% availability.

Approach

- Test a vendor provided hydrogen pump prototype in stand-alone mode.
- Analyze the volume and purity of hydrogen produced by the prototype unit.
- Design the integration of the vendor-provided hydrogen pump production unit with our fuel cell.
- In our lab, test the hydrogen pump integrated with our fuel cell.
- Analyze the volume and purity of hydrogen produced.
- Analyze the efficiency and availability of the fuel cell; project in-field availability and durability.
- Operate the system in the field for 12 months.
- Analyze the results of fuel cell electricity and hydrogen production.

Accomplishments

- Completed site selection for demonstration. The system will be installed at the Ted Stevens Anchorage International Airport. There are several participants, including a commercial customer, local authorities and contractors, and the university-affiliated project monitoring partner.
- Performed initial modeling of the combined electricity + hydrogen generating system in ASPEN Plus for purposes of design and integration.
- Down-selected the hydrogen production sub-system technology. The selected vendor is H2 Pump, LLC of Latham, NY, who manufactures an electrochemical hydrogen pump suitable for the gas

compositions produced by the planar solid oxide fuel cell (PSOFC) electricity generator.

- Completed the first set of tests on a prototype hydrogen pump. The tests were performed directly on PSOFC anode tail gas.
- Completed the hydrogen safety plan for the project.

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Introduction

Bloom Energy's (BE's) systems, when manufactured in high volume, can produce low-cost hydrogen by co-producing hydrogen and electricity simultaneously with one common set of low-cost equipment. The main objectives of this project are to 1) deliver and field test a pilot plant producing high purity hydrogen and electricity in Alaska; 2) show the feasibility of a delivered cost of hydrogen below $2.50 per gge; 3) demonstrate that our systems can run on liquid fuels, such as ethanol; and 4) create learning opportunities regarding commercial customer needs so that the DOE and BE can use this demonstration project to gain critical insights necessary to build, deliver and install a commercially viable stationary fuel cell system.

Approach

The project is divided into two phases. In Phase 1 we will design, test, and build an electricity generator and a hydrogen purifier. To the extent technically feasible, as we build these systems, we will pull standard parts and subassemblies from inventory, adding custom components to satisfy the project requirements. In Phase 2, we will demonstrate those technologies in the field. We will operate the system with the cooperation of our testing partner in Alaska. We will work closely with the selected commercial partner, with the goal of understanding how this technology can solve real problems for commercial customers.

Results

The project is presently in Phase 1. Principal tasks at this stage are site selection, system design, and hardware build.

Site Selection

A relationship was formed with a commercial customer operating at the Ted Stevens Anchorage International Airport. A site survey was completed on February 15, 2007 in Alaska, which included participation from Bloom Energy; the commercial customer; Chugach Electric Association; the project monitoring partner from University of Alaska, Fairbanks; an Anchorage Airport Environmental Specialist; a hydrogen safety consultant; and a potential construction manager. A photograph of the proposed site is shown in Figure 1.

Environmental impacts to the operation and maintenance of the PSOFC electricity generator were exposed as the significant factor in site design. The proposed installation will mitigate sub-freezing temperatures, water glaciation, and high winds; worst case low temperatures have been measured at –35°C. Additionally, site design criteria includes requirements for a Class 5 earthquake zone and natural gas delivered to the site known to be occasionally "dirty" – sometimes containing liquid and/or sediment.

System Design

A process flow diagram (PFD) of the proposed design has been developed. Figure 2 shows how a

FIGURE 1. Proposed Installation Site (Ted Stevens Anchorage International Airport) for Demonstrating Co-Production of Hydrogen and Electricity

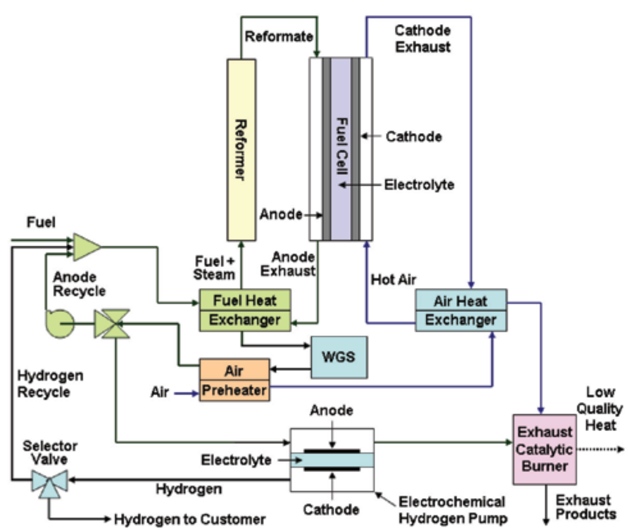

FIGURE 2. Process Flow Diagram for the Combined PSOFC and Hydrogen Separation System

PSOFC and an electrochemical hydrogen pump can be integrated to co-produce hydrogen and electricity. The fuel exhaust from the natural gas-fueled PSOFC could be processed in a hydrogen separation subsystem to provide proton exchange membrane fuel cell-grade hydrogen fuel to an external user. Alternatively, the hydrogen separation subsystem could raise the overall electric generating efficiency of the PSOFC by 3% to 4% in the electric-only mode by circulating recovered anode exhaust hydrogen back to the inlet of the PSOFC. Initial laboratory integration testing of this concept was demonstrated at BE prior to this DOE project.

ASPEN Plus was used to model the process in both configurations as shown in Figure 3. The data from the modeling are being used to define the test protocols for the hydrogen separation subsystem.

A safety review was completed for the system, and is being used in the site design.

Hardware Build

This project proposed two different technologies for performing the required hydrogen separation: one based on partial pressure swing adsorption and another based on an electrochemical pump. We have down-selected the latter primarily on the basis of design maturity of components from H2 Pump LLC, Latham, NY.

The electrochemical pump is designed to perform at the elevated CO levels characteristic of the PSOFC anode tail gas without degrading. The hydrogen produced by the pump is expected to meet the purity requirements without further processing.

A subscale prototype pump has been received from the vendor (Figure 4) and has been integrated with operating PSOFC stacks. Initial testing was successful but is preliminary, and testing and design work is continuing.

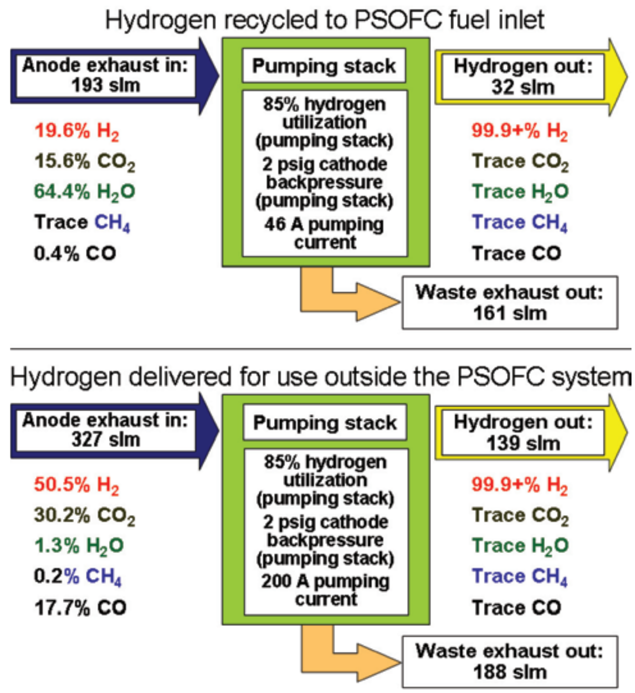

FIGURE 3. ASPEN Plus Results Summary for Gas Compositions at Two Operating Points, using the PFD shown in Figure 2

FIGURE 4. Prototype Electrochemical Hydrogen Pump from H2 Pump LLC (Latham, NY)

Conclusions and Future Directions

Next steps in this project include the following:

- Continued testing of the prototype.
- Economic analysis based on the selected technology.
- Design and construction of the full-size electrochemical pump.
- Integration with a SOFC electricity generator.

FY 2007 Publications/Presentations

1. Quarterly reports for this project were provided to the DOE, and a presentation was made at the DOE Hydrogen Program Annual Merit Review held in Arlington, Virginia on May, 2007.