III.7 Development of Highly Efficient Solid-State Electrochemical Hydrogen Compressor

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Objectives

- Demonstrate feasibility of a solid-state electrochemical hydrogen compressor (EHC) cell capable of compressing hydrogen from near-atmospheric pressure to up to 6,000 psi.
- Increase the cell performance (reduce power consumption, improve compression efficiency) while lowering the cost compared to previous designs.
- Study thermal and water management to increase system reliability and life.
- Scale up EHC to a short stack.

Technical Barriers

This project addresses the following technical barrier from the Hydrogen Delivery section (3.2) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(B) Reliability and Costs of Hydrogen Compression

Technical Targets

This project is directed at demonstrating the feasibility of solid-state electrochemical hydrogen compression. The EHC is an enabling device for low-cost hydrogen delivery. Phase II goals include the following:

- Compress hydrogen from 300 psi to up to 6,000 psi.
- Develop multi-cell stack design and validate in a short stack.
- Demonstrate compression ratio up to 300:1.
- Achieve stack performance stability at 3,000 psi for 500 hours.
- Increase hydrogen recovery efficiency to 98%.

The ultimate goal of the project is to meet the DOE targets for forecourt compressors [1].

Accomplishments

- Compression Efficiency: Reduced specific energy consumption by 70% compared to the best Phase I result (Figure 1).
- EHC Scale Up: Cell technology scaled up from single cell to 3-cell stack.
- Compression Mode Operation: Demonstrated compression ratio of 300:1 in a single step.
- Operation Hours: >6,000-hour cumulative EHC operation at different conditions.
- Hydrogen Recovery: Achieved 95% hydrogen recovery rate in the 3-cell stack.

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Introduction

With the depletion of fossil fuel reserves and a global requirement for the development of a sustainable economy, hydrogen-based energy is becoming increasingly important. Production, purification and compression of hydrogen represent key technical challenges for the implementation of a hydrogen economy, especially in the transportation sector where on-board storage of pure hydrogen may be required at pressures up to 10,000 psi and compression of the hydrogen fuel up to 12,000 psi.

The level of maturity of current hydrogen compressor technology is not adequate to meet projected infrastructure demands. Existing compressors are inefficient and have many moving parts, resulting in significant component wear and therefore excessive maintenance. New technologies that achieve higher operational efficiencies, are low in cost, safe and easy to operate are therefore required. This project addresses high-pressure hydrogen needs by developing an efficient, low-cost, solid-state EHC.

Approach

The approach to address the Phase II goals consists of the following major elements:

- Build on Phase I experience to develop high-pressure stack design.
- Flow field design to increase hydrogen recovery efficiency.
- Reduce capital cost by reducing catalyst loading and simplifying system design.
- Reduce operating cost by improving membrane and electrode design.

To this end, the approach includes the construction and evaluation of advanced stack architecture, and the development and demonstration of critical sealing technology to contain the high-pressure hydrogen within the cathode compartment of the stack.

Results

The EHC cell architecture has been improved to reduce energy consumption. A 70% reduction in specific energy consumption compared to Phase I has been achieved, as shown in Figure 1. The goal of demonstrating a compression ratio of 300:1 has been met. Moreover, the EHC has been scaled up from a single cell to a 3-cell stack. It was designed, fabricated and tested for ~1,000 hours, reaching pressures up to 3,000 psi. A hydrogen recovery rate of 95% has been demonstrated in the 3-cell stack.

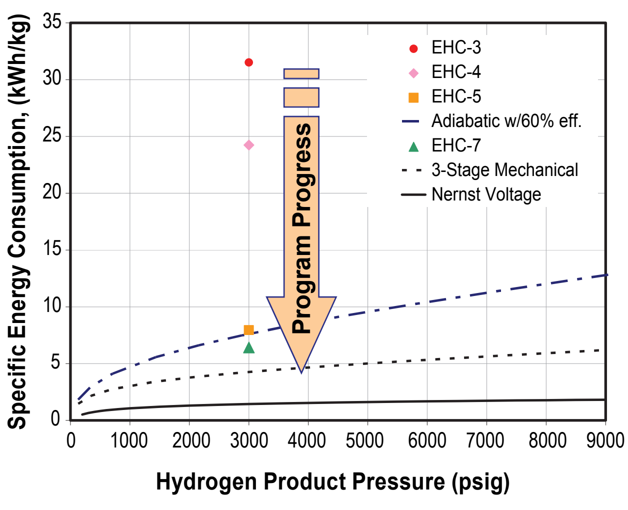

FIGURE 1. Significant Reduction in EHC Specific Energy Consumption Achieved

Conclusions and Future Direction

We have reduced the specific power consumption of the EHC by 70% and successfully demonstrated the feasibility of a multi-cell solid-state EHC. For the remainder of the Phase II effort, further work is suggested as follows:

- Increase pressure capability of EHC cell from 3,000 to 6,000 psi.
- Validate multi-cell stack design in a 10-cell stack.
- Further reduce power consumption to 70% of current design.
- Increase hydrogen recovery to 98%.
- Estimate capital and operating cost benefits.

Special Recognitions & Awards

This work was awarded the 2009 DOE Hydrogen Program R&D Award during the DOE Hydrogen Program Merit Review and Peer Evaluation Meeting in Washington, D.C.

FY 2009 Publications/Presentations

1. L. Lipp, "Development of Highly Efficient Solid State Electrochemical Hydrogen Compressor (EHC)", 2009 DOE Hydrogen Program Merit Review and Peer Evaluation Meeting, Washington, D.C., May 19, 2009.

References

1. HFCIT MYRDD Plan, Table 3.2.2 "Technical Targets for Hydrogen Delivery", section on Forecourt Compressors, page 3.2-14.