III.9 Electrochemical Hydrogen Compressor

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Fiscal Year (FY) 2012 Objectives

- Develop a solid-state electrochemical hydrogen compressor (EHC) building block capable of compressing hydrogen from near-atmospheric pressure to 2,000-3,000 psi.
- Study feasibility of an EHC multi-stage system capable of compressing hydrogen from near-atmospheric pressure to 6,000-12,000 psi.
- Increase compression efficiency to 95% (DOE 2015 target).

Technical Barriers

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

(B) Reliability and Cost of Hydrogen Compression

Technical Targets

This project is directed at developing a solid-state EHC. The EHC is an enabling device for low-cost hydrogen delivery. Goals include the following:

- Single-stage compression of hydrogen from near-atmospheric pressure to 2,000-3,000 psi.
- Multi-stage compression of hydrogen from near-atmospheric pressure to 6,000-12,000 psi.
- Ensure no possibility of lubricant contamination of the hydrogen from compression (DOE 2015 target).
- Reduce EHC specific energy consumption.
- Scale up EHC to a capacity of 2-4 lb/day H_2.

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

FY 2012 Accomplishments

- Hydrogen pressure: Reached 12,800 psi hydrogen pressure in a single-stage EHC cell (Figure 1).
- Hydrogen recovery: Achieved 98% hydrogen recovery in a single cell.

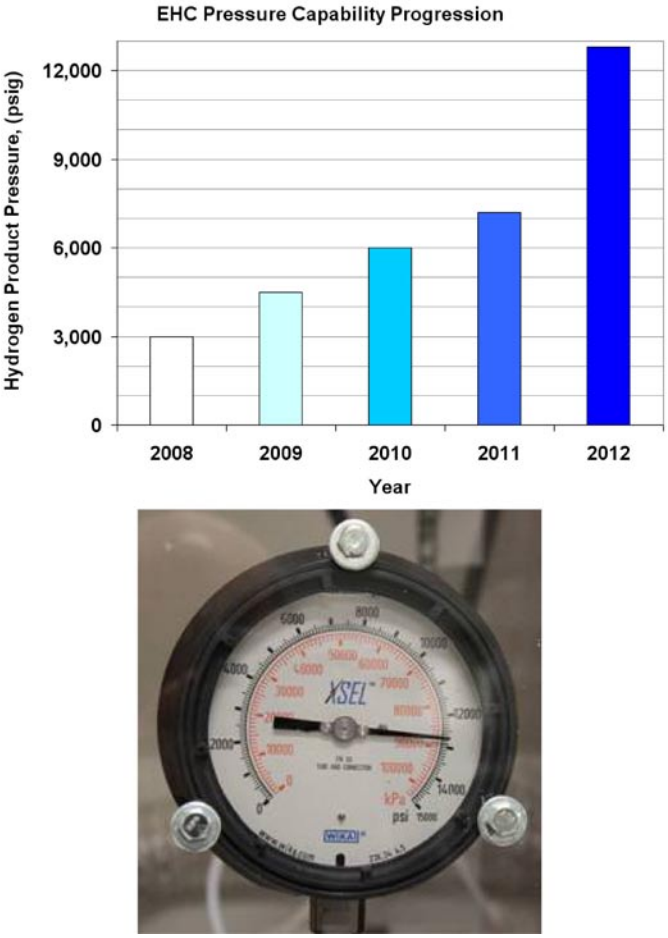

FIGURE 1. Met DOE 2015 Pressure Target for Forecourt Compressors

- Capital cost: Increased hydrogen flux up to 1,200 mA/cm^2 and reduced EHC cell part count by 20% (Figures 2 and 3).
- Durability: Demonstrated 6,000 hour life at elevated current density (750 mA/cm^2 – Figure 4).

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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 onboard 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.

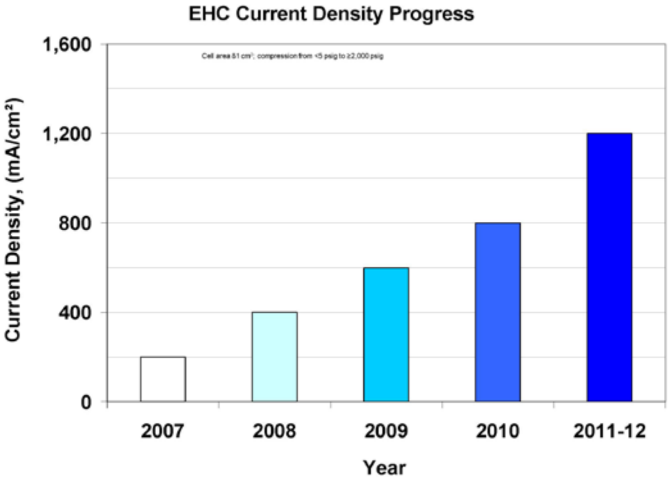

FIGURE 2. Six-Fold Increase in Current Density Leads to Significant Cost Reduction

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 a solid-state EHC.

Approach

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

- Increase hydrogen recovery efficiency by improving flow field design.
- Reduce capital cost by increasing the hydrogen flux.
- Reduce operating cost by improving membrane and electrode design.
- Develop a multi-stage system concept for compression to 6,000-12,000 psi.

To this end, the approach includes the design, fabrication and evaluation of improved cell architecture, and the development and demonstration of critical sealing technology to contain the high-pressure hydrogen within the EHC.

Results

A major focus of this year's efforts was to increase the pressure capability of the EHC cell beyond the previously demonstrated 6,000 psi. The design, fabrication and testing

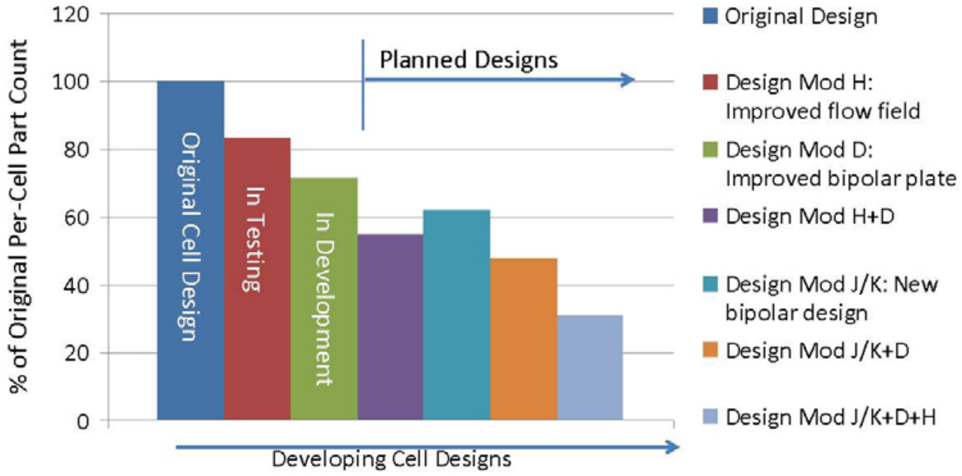

FIGURE 3. Reducing Cell Part Count for EHC Cost Reduction

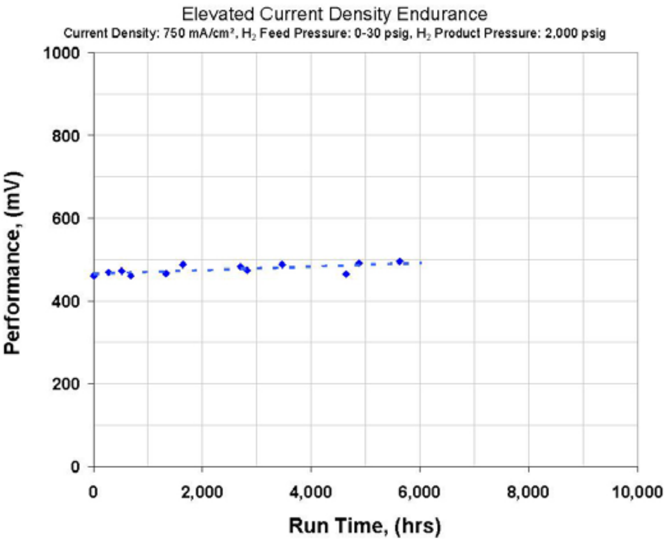

FIGURE 4. 6,000 Hour Endurance Demonstrated at Elevated Current Density

efforts resulted in an increase in pressure capability to 7,500 psi. The lessons learned from this cell were implemented in a subsequent design, which reached a maximum pressure of 12,800 psi, as shown in Figure 1. The hydrogen was being fed at near-atmospheric pressure. Improvements that enabled these results include seals with higher pressure capability and an improved MEA support structure. The new pressure record meets the DOE 2015 compression target for forecourt compressors (12,000 psi) [1]. This design, when scaled up and implemented in a stack, is expected to bring significant savings in capital and operating costs compared to a multi-stage system. The high-pressure single-stage design comes with a higher technology risk and will require significant additional development (beyond the current project).

Efforts to improve the internal fluids management resulted in a cell that was capable of operating continuously at a hydrogen recovery rate of 98%. It was compressing hydrogen from near-atmospheric pressure to 3,000 psi and has been operated for >1,000 hours. This is an important step towards meeting the DOE 2015 target of 95% compression efficiency. These features will be incorporated into a planned larger-area cell design.

Capital cost was reduced in two different ways. First, the operating current density of the EHC cell was increased from a previous maximum of 800 mA/cm^2 to a peak current density of 1,200 mA/cm^2, as shown in Figure 2. This was possible due to a higher performance MEA and a lower cell resistance at high pressure. The 50% increase in current density translates to a 50% higher hydrogen flux from the same size hardware, therefore significantly reducing the equipment cost. The second way cost reduction was achieved was by lowering the EHC cell part count by 20% in a new cell design that incorporates an improved flow field. Further reductions in part count are underway, as shown in Figure 3. They are focused on improved bipolar plate designs and its combination with the improved flow field. Mass manufacturability is an important criterion that is being taken into account in the selection of the improved component designs.

Durability is a critical parameter in the life-cycle cost. Therefore, a cell running at an elevated current density of 750 mA/cm^2 was endurance tested for 6,000 hours. As can be seen in Figure 4, cell performance was essentially stable throughout the test. This suggests that the current cell hardware is capable of long-term operation at 2,000 psid. This is providing valuable design input for the planned EHC scale up.

Conclusions and Future Directions

The feasibility of reaching DOE's pressure target of 12,000 psi has been demonstrated in a single-stage EHC cell. The hydrogen flux through the EHC was increased by up to 50%, which translates to a lower capital cost. A 20% reduction in EHC cell part count also contributes to reduced cost. Durability of the EHC cell architecture has been demonstrated in a 6,000 hour test, confirming its robustness. The following summarizes critical performance parameters that were advanced during this reporting period:

Parameter	2011 Value	2012 Value
Output Pressure	7,000 psi	12,800 psi
Current Density	800 mA/cm^2	1,200 mA/cm^2
Endurance	3,000 hours	6,000 hours
% of Original Part Count	100%	80%

Future efforts will include further improvements in cell architecture for a lower cost design, which will then be incorporated into an advanced, 200-cm^2 EHC cell and short stack. The scaled up short stack will be designed for a capacity of 2-4 lb/day H_2 to meet the objective of the project.

FY 2012 Publications/Presentations

1. L. Lipp, "Electrochemical Hydrogen Compressor", 2012 DOE Hydrogen Program Merit Review and Peer Evaluation Meeting, Arlington, VA, May 14–18, 2012.

References

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