Development of Highly Efficient Solid State Electrochemical Hydrogen Compressor (EHC)

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Project ID # PDP29

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Overview

Timeline: Phase I

- Start: June 2007
- End: March 2008
- 100% complete

Budget

- Total project funding
  - $100K

Barriers

- Barriers addressed for gaseous hydrogen compression:
  - Improve reliability
  - Eliminate contamination
  - Reduce cost
  - Improve energy efficiency

Partners

- Sustainable Innovations, LLC

Objectives

- **Demonstrate feasibility of a solid-state hydrogen compressor cell capable of compressing hydrogen to 2,000 psi**
- **Increase the cell performance (power consumption, compression efficiency) while lowering the cost compared to previous designs**
- **Study thermal and water management to increase system reliability and life**

Milestones

- Compress hydrogen from near-atmospheric pressure to 2,000 psi
- Demonstrate performance stability at 2,000 psi for 50 hours
- Demonstrate hydrogen recovery efficiency of 95%
- Demonstrate 10 pressure cycles to 2,000 psi

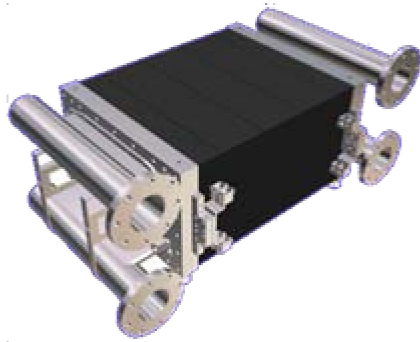
Approach

- **Use high-pressure electrolyzer experience for mechanically robust cell design**
- **High current density operation to minimize the effect of H_2 back diffusion (reduce ohmic resistance)**
- **Flow field design to increase H_2 recovery efficiency**
- **Reduce capital cost by reducing Pt loading, cell footprint and humidification requirements (simple system)**

Enabler for Hydrogen Infrastructure

DFC Power Plant

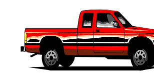
(Electricity + Hydrogen)



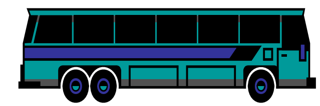
Electrochemical Hydrogen Separator

Electrochemical Hydrogen Compressor

H_2



FC Car

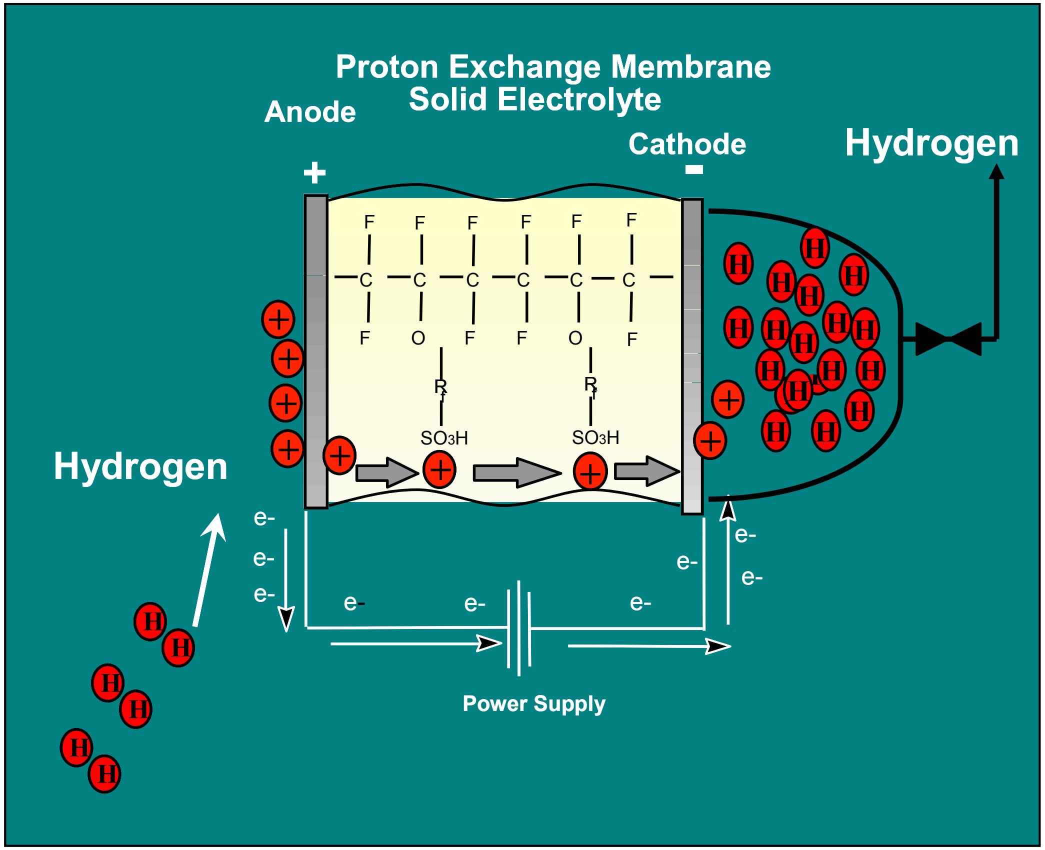


FC Bus

MO3145

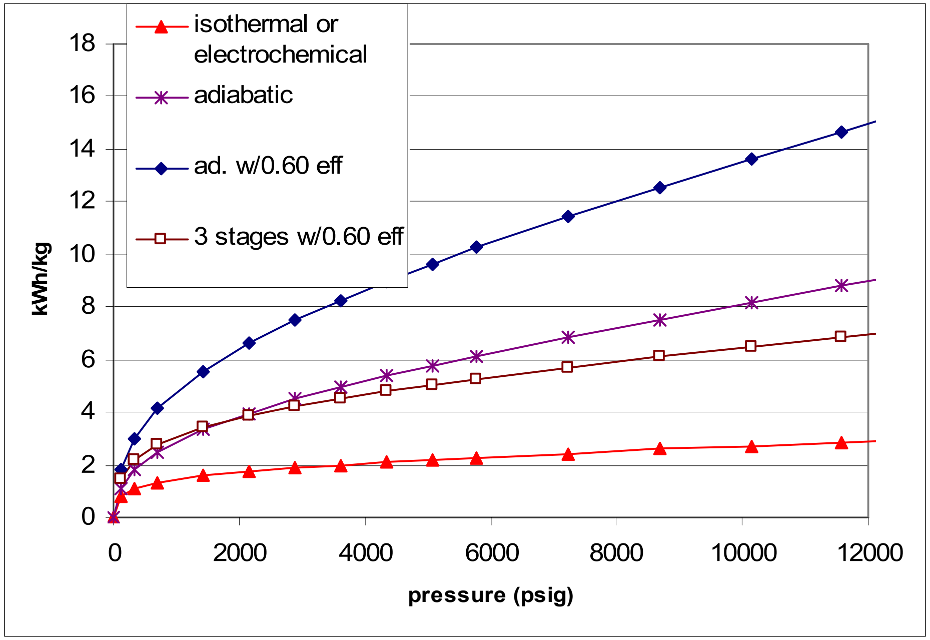
The EHC technology has unique synergy to the Hydrogen Energy Stations

Principle of an Electrochemical Hydrogen Compressor

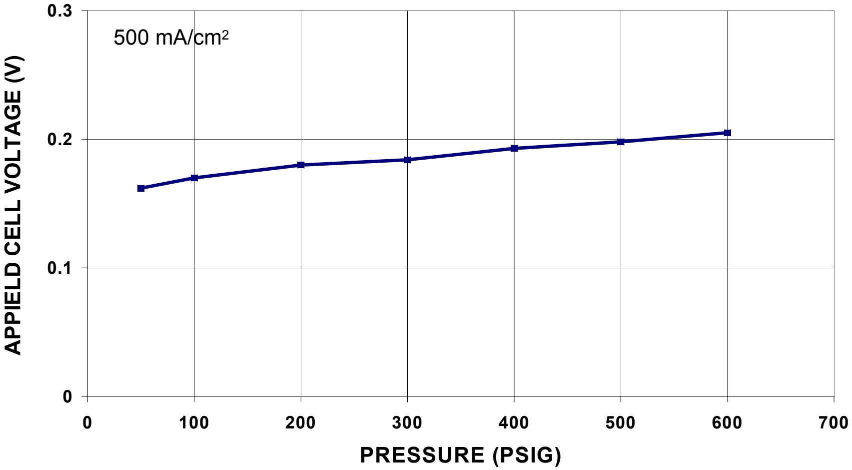


- Simple operating principle with no moving parts
- Use of hydrogen electrode for high compression efficiency

Compressor Efficiency Comparison

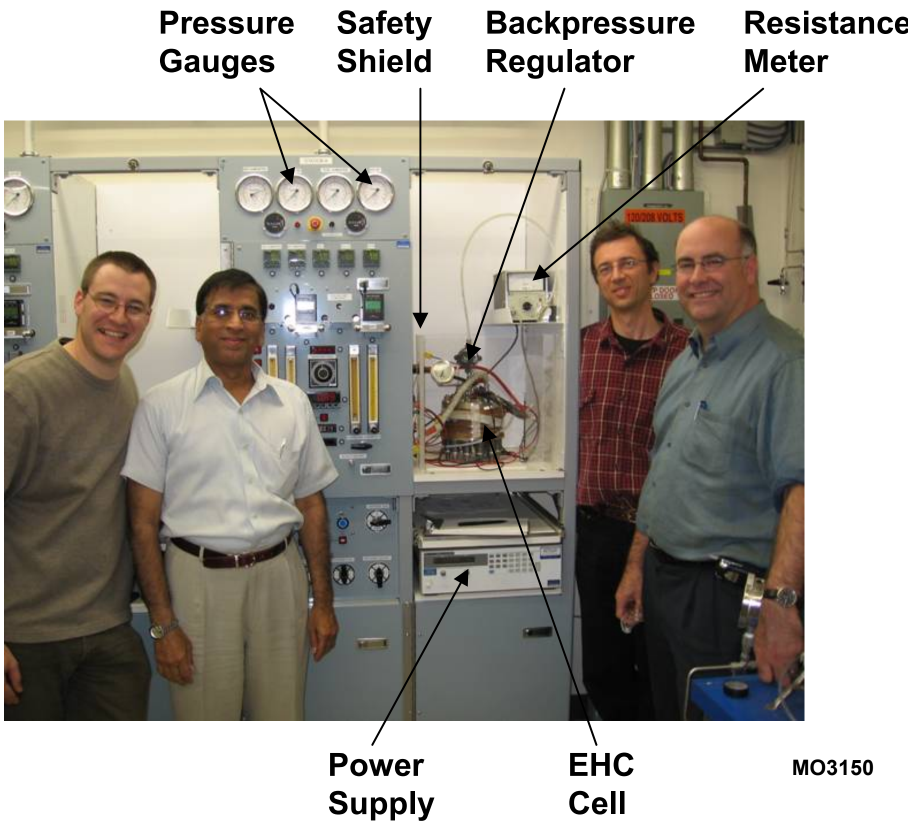


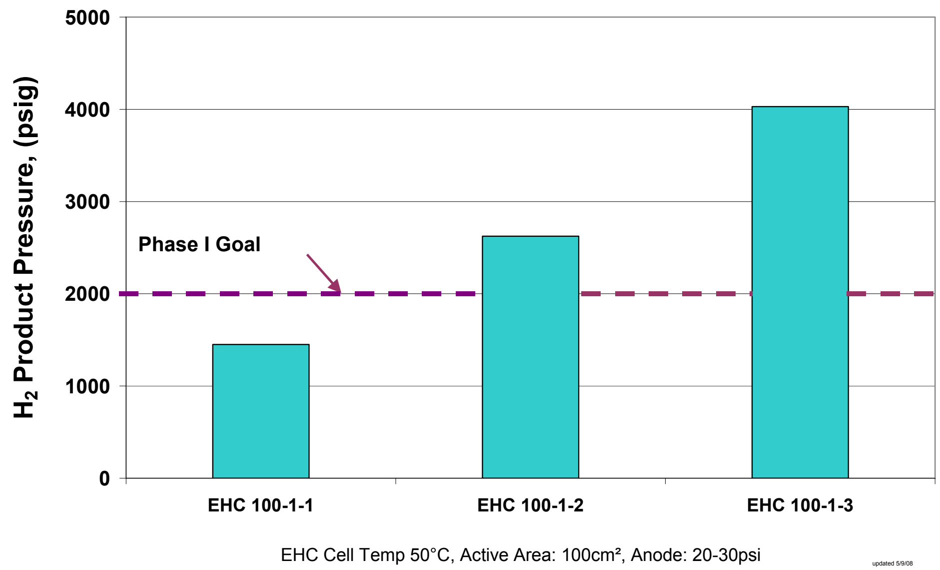
Electrochemical H_2 compression is the most efficient



Low power consumption for hydrogen compression

Increase in EHC Pressure Capability

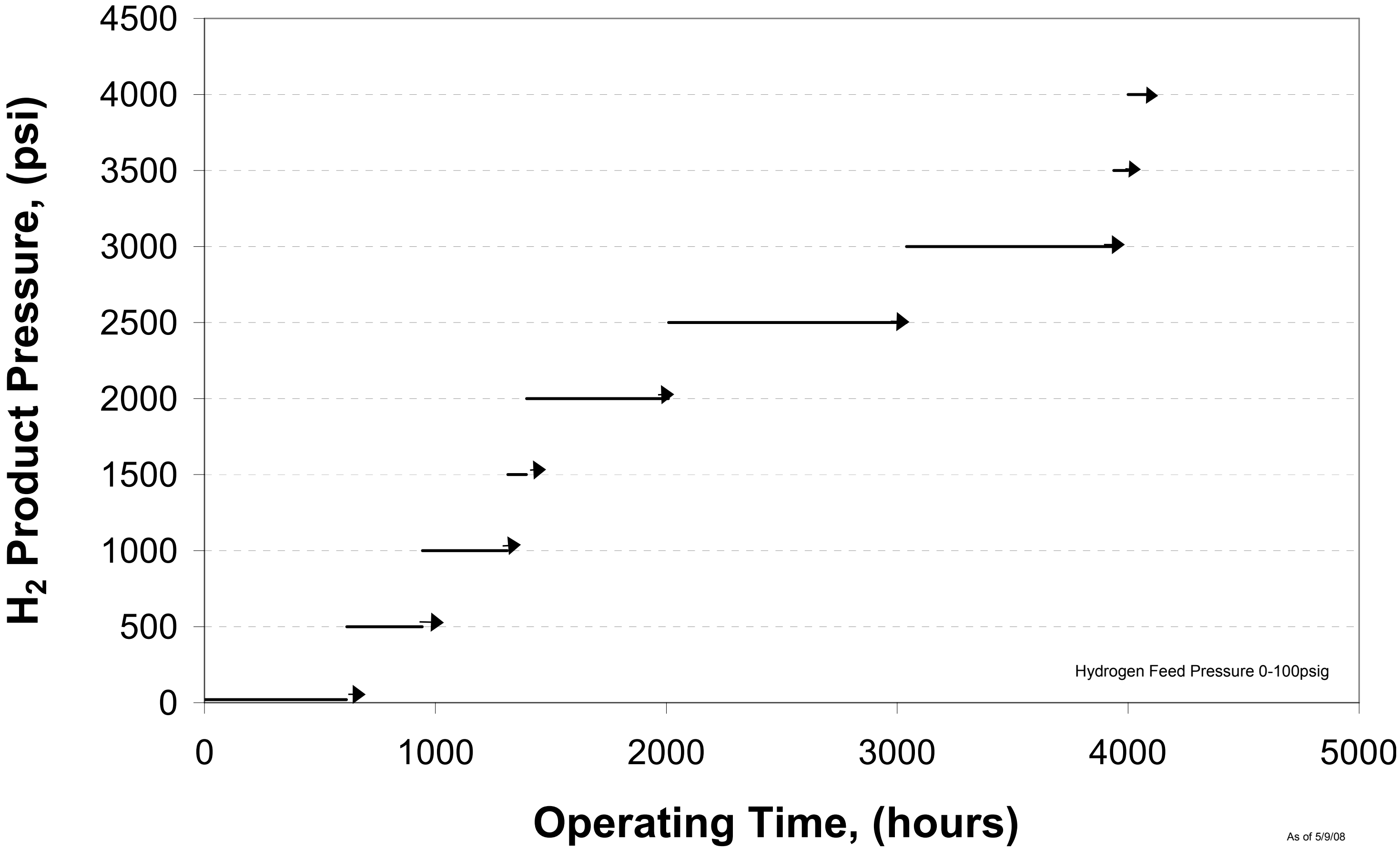




>4,000 hours of safe operation at up to 4,000 psi

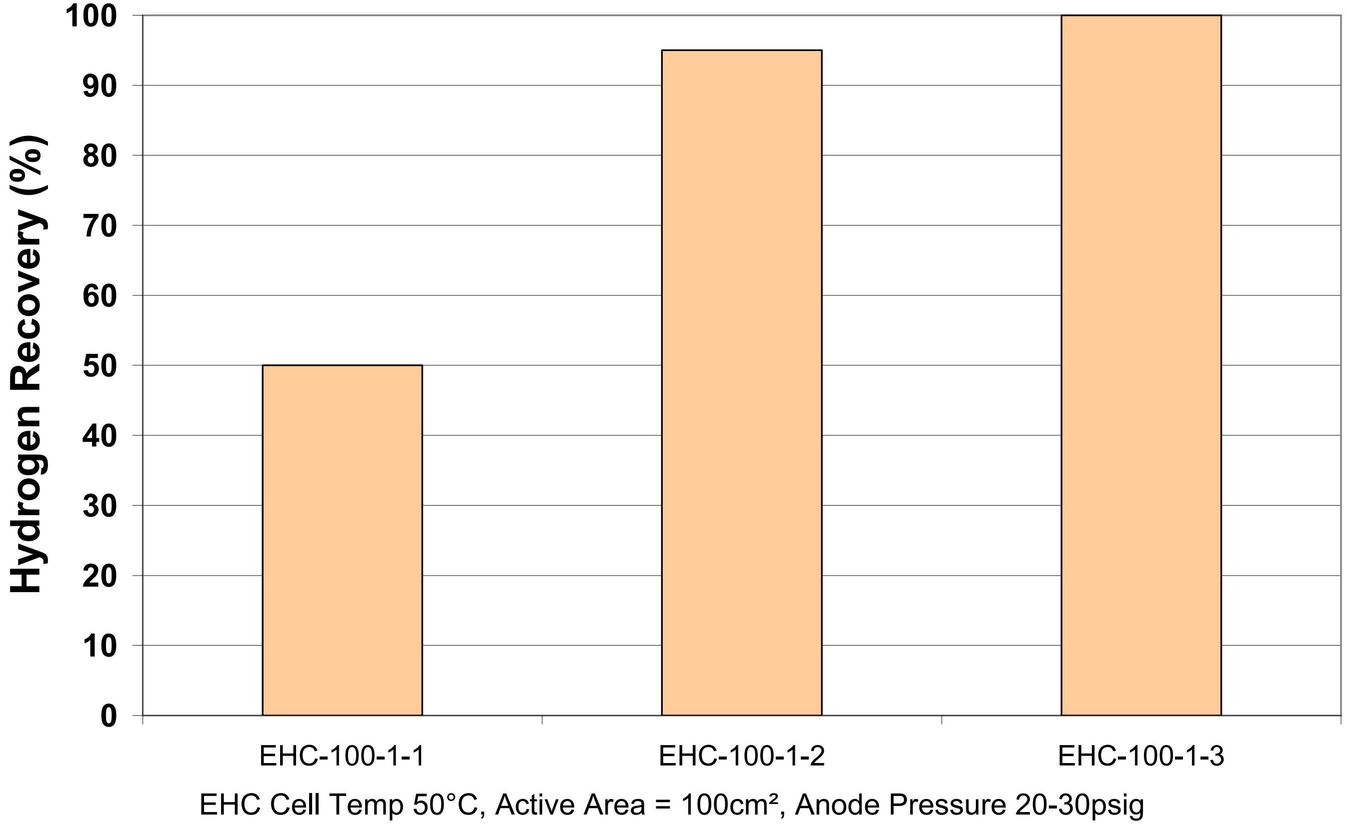
Significant increase in Product Hydrogen pressure achieved with each cell iteration, exceeding the project goal by 100%

Feasibility Demonstration of EHC Technology



Exceeded the program goal of 2,000 psi for 50 hours

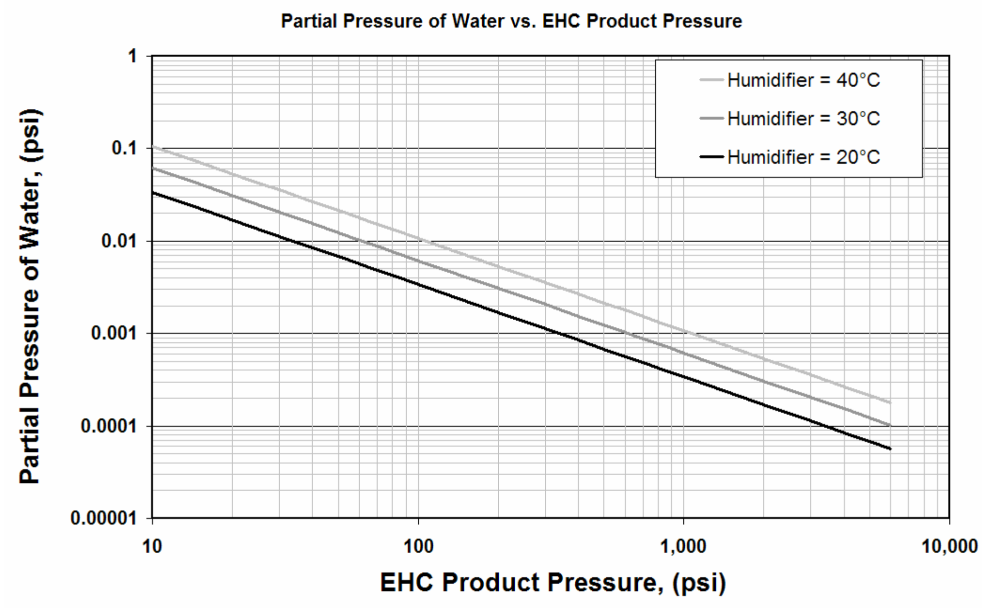
Hydrogen Recovery Efficiency



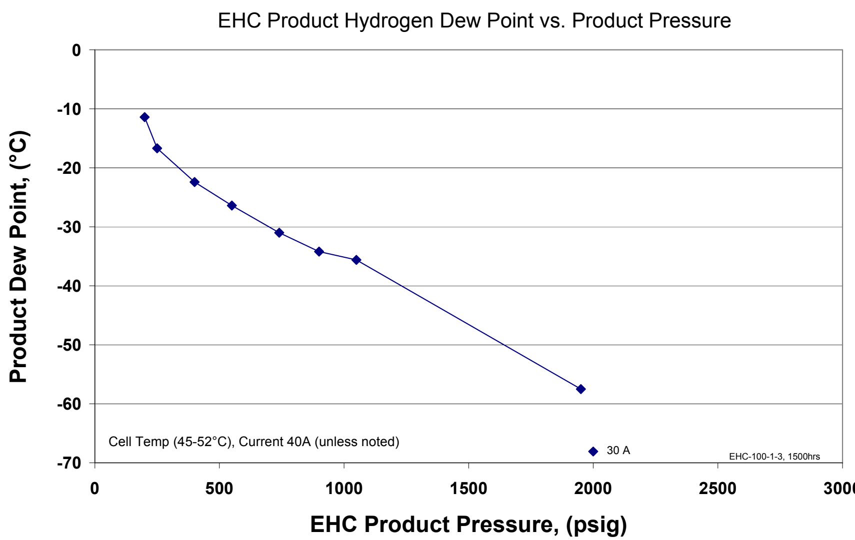
Compression of 100% of the hydrogen fed to EHC has been demonstrated

(DOE Target: 98%)

Hydrogen Product Purity



Water content can be minimized by increasing product pressure and decreasing humidifier temperature



Fuel Cell Vehicle quality hydrogen can be produced

Cost Reduction Accomplishments

- **Reduced Pt content by 90% without any performance loss**
- **Demonstrated EHC operation without external humidification for >50 hours**
- **Achieved 100% hydrogen recovery rate (DOE target: 98%)**

Summary

EHC feasibility successfully demonstrated

- **Compression Mode Operation:** Increased capability from 500 psi to 4,000 psi in a single stage EHC cell (160:1 compression ratio)
- **Pressure Cycling:** Completed >100 pressure cycles from 100 to 3,000 psi without performance loss
- **Operation Hours:** >4,000 hr total EHC operation at different conditions
- **Hydrogen Flux:** Increased operating current density from initially 50 to 700 mA/cm^2 by improving the component ohmic resistance by 75%

Suggested Future Work (Phase II)

- Increase pressure capability of single-stage EHC from 2,000 to 6,000 psi
- Develop multi-cell stack design and validate in a 10-cell stack
- Increase operating current density up to 2,000 mA/cm^2
- Demonstrate 2 lb/day H_2 at 3,000 psi
- Reduce power consumption to 50% of current design
- Maintain hydrogen recovery >98%
- Estimate capital and operating cost benefits