

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

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Project ID #
PDP29

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**

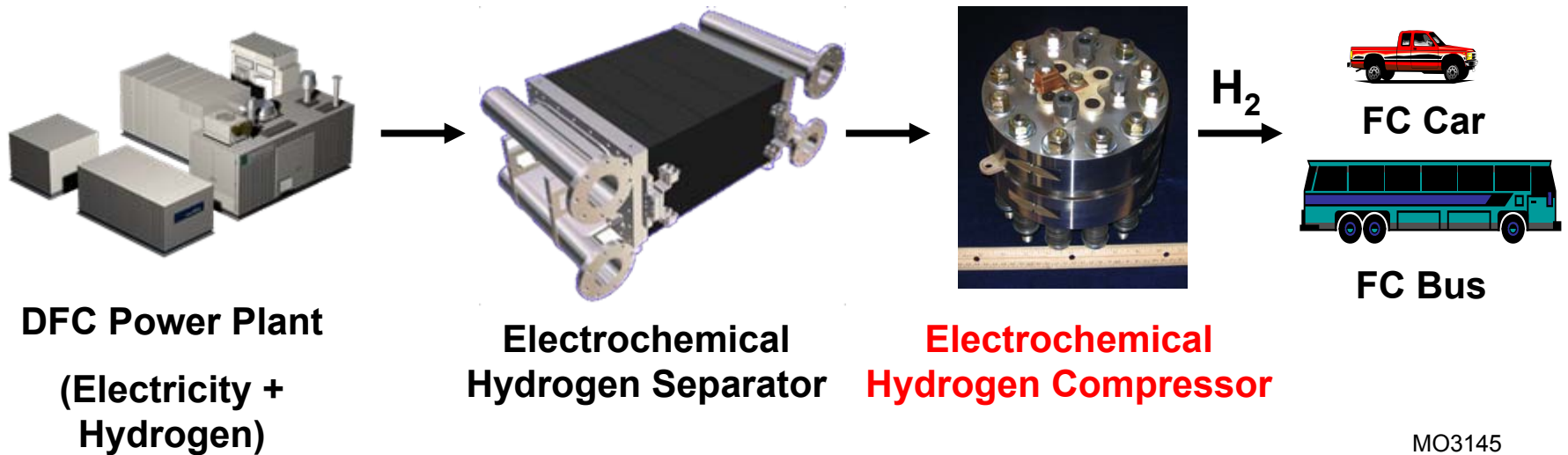
Milestones

- **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 H₂ back diffusion (reduce ohmic resistance)**
- **Flow field design to increase H₂ recovery efficiency**
- **Reduce capital cost by reducing Pt loading, cell footprint and humidification requirements (simple system)**

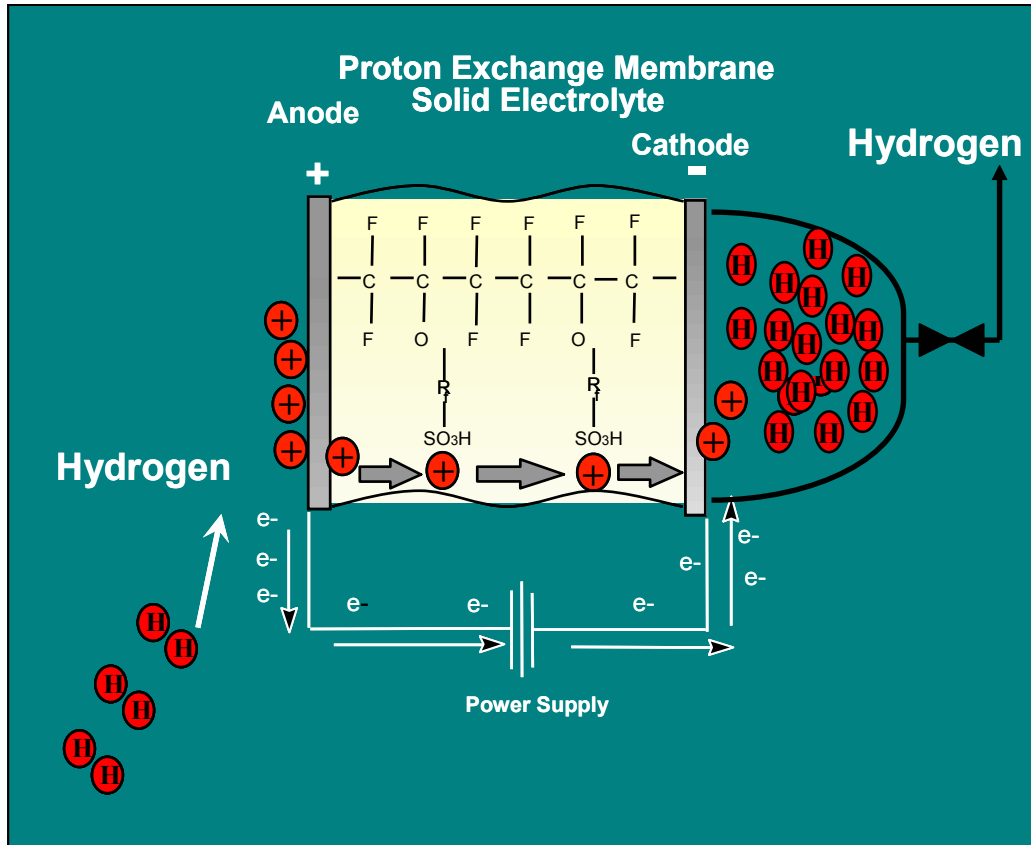
Enabler for Hydrogen Infrastructure



MO3145

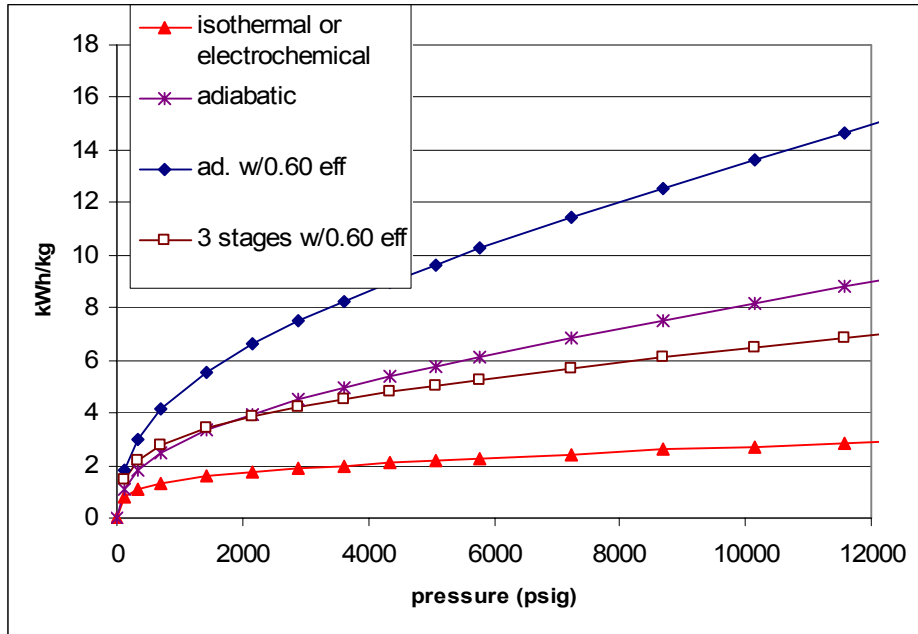
The EHC technology has unique synergy to the Hydrogen Energy Stations

Principle of an Electrochemical Hydrogen Compressor

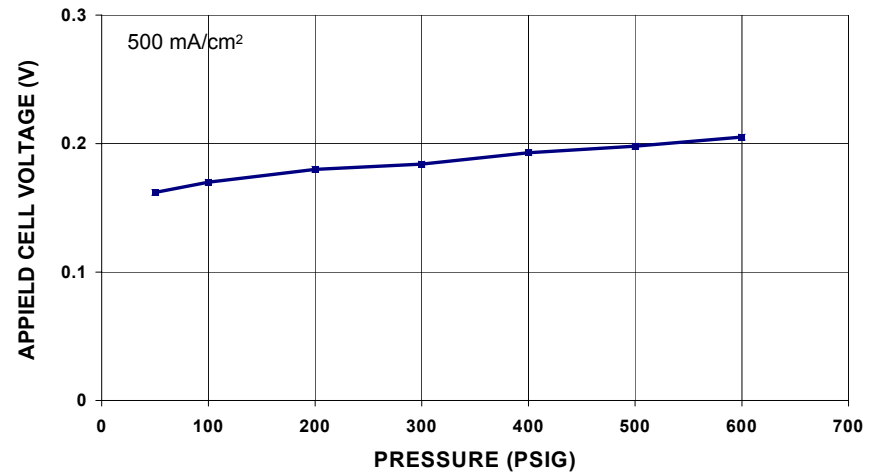


- Simple operating principle with no moving parts
- Use of hydrogen electrode for high compression efficiency

Compressor Efficiency Comparison

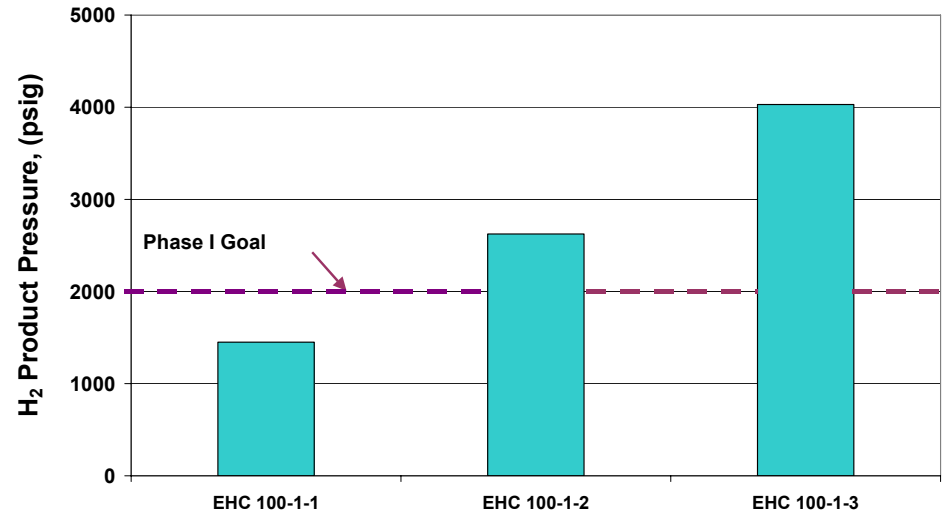
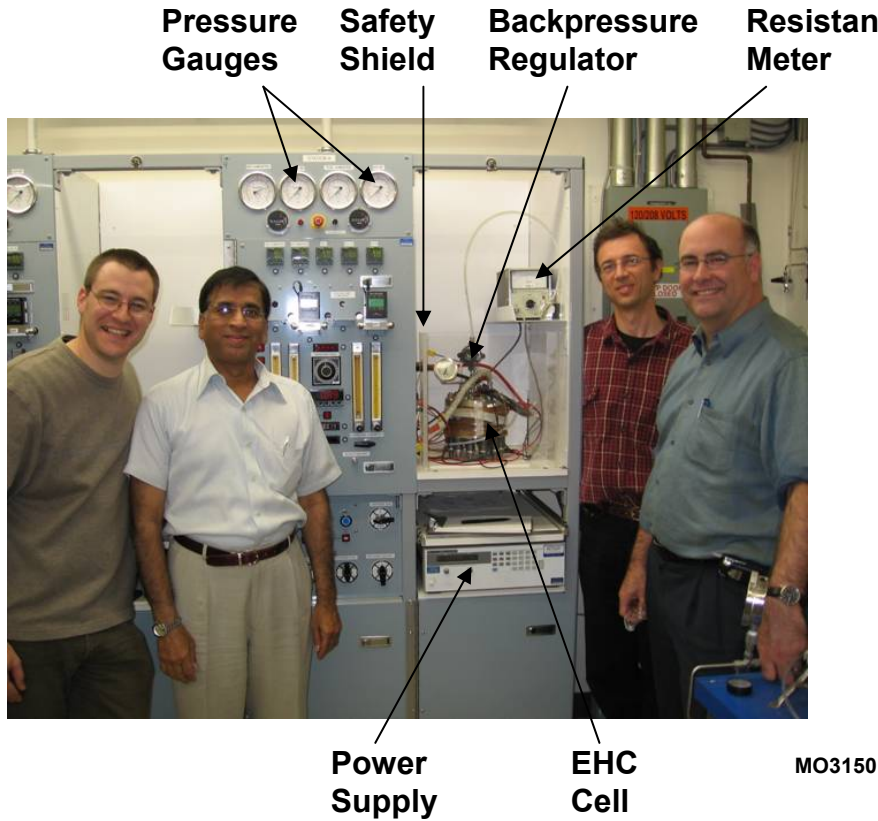


Electrochemical H₂ compression is the most efficient



Low power consumption for hydrogen compression

Increase in EHC Pressure Capability

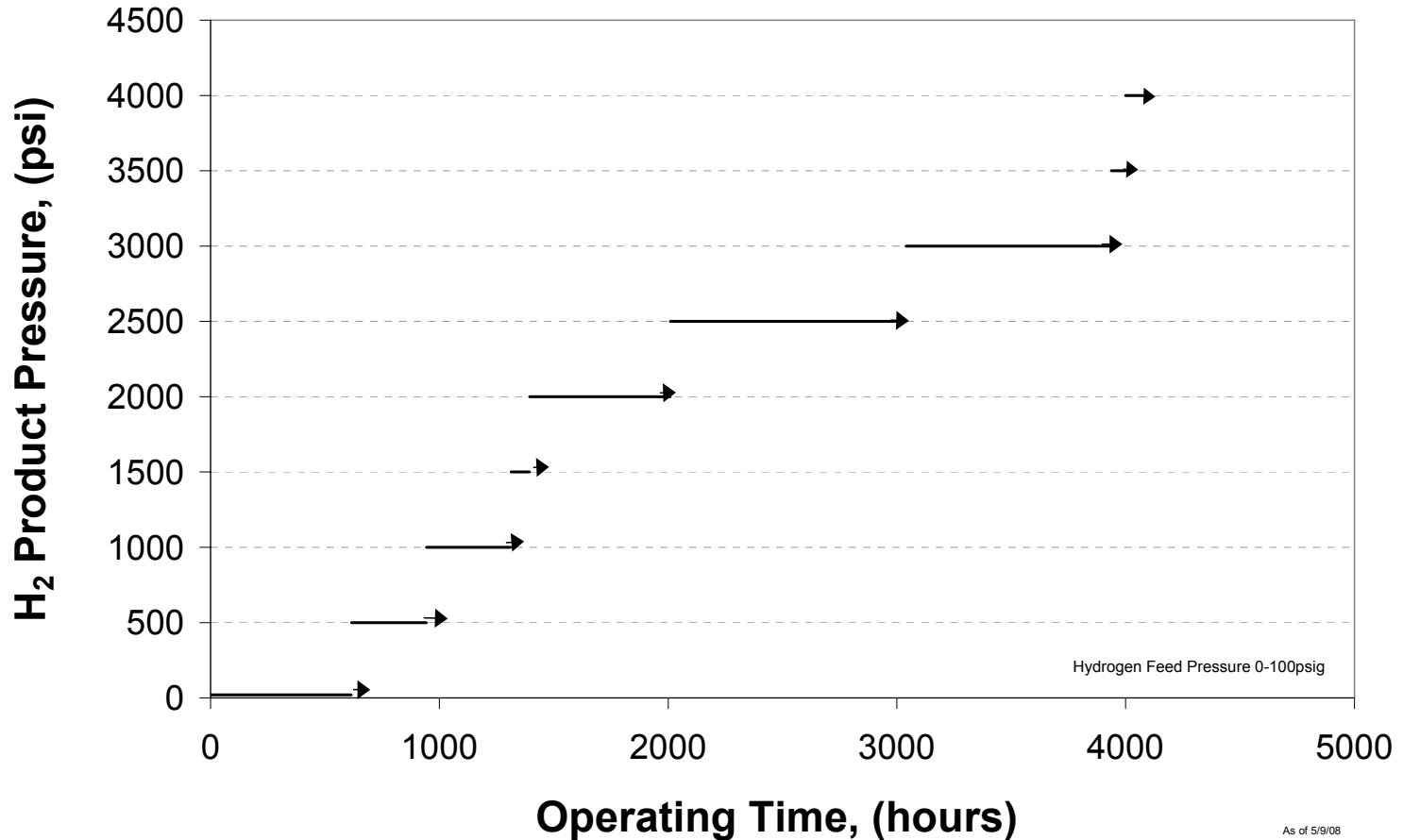


EHC Cell Temp 50°C, Active Area: 100cm², Anode: 20-30psi

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

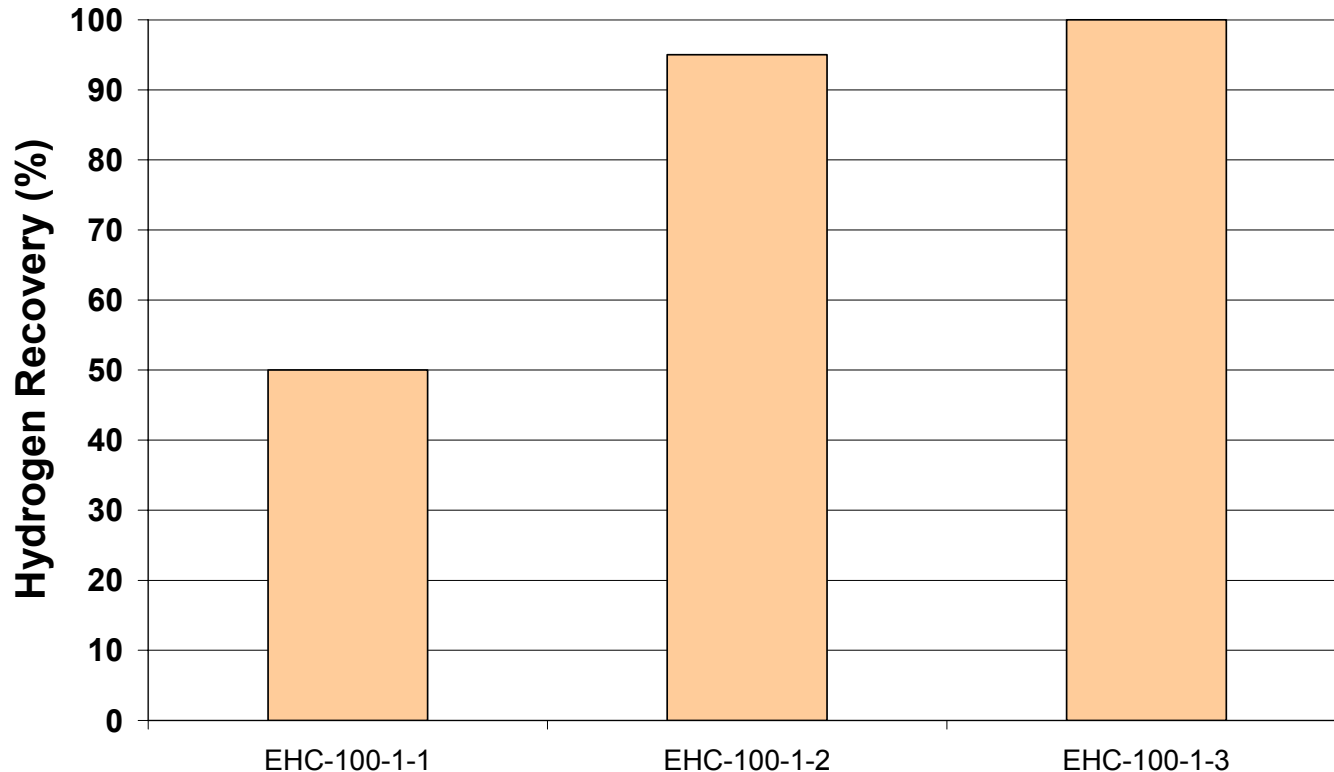
Significant increase in Product Hydrogen pressure achieved with each cell iteration, exceeding the project goal by 100%

Feasibility Demonstration of EHC Technology



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

Hydrogen Recovery Efficiency



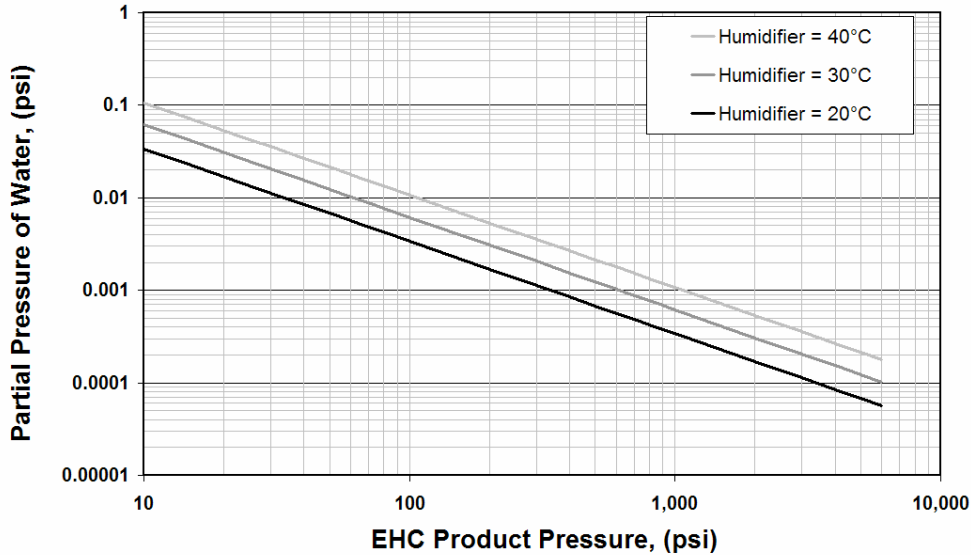
EHC Cell Temp 50°C, Active Area = 100cm², Anode Pressure 20-30psig

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

(DOE Target: 98%)

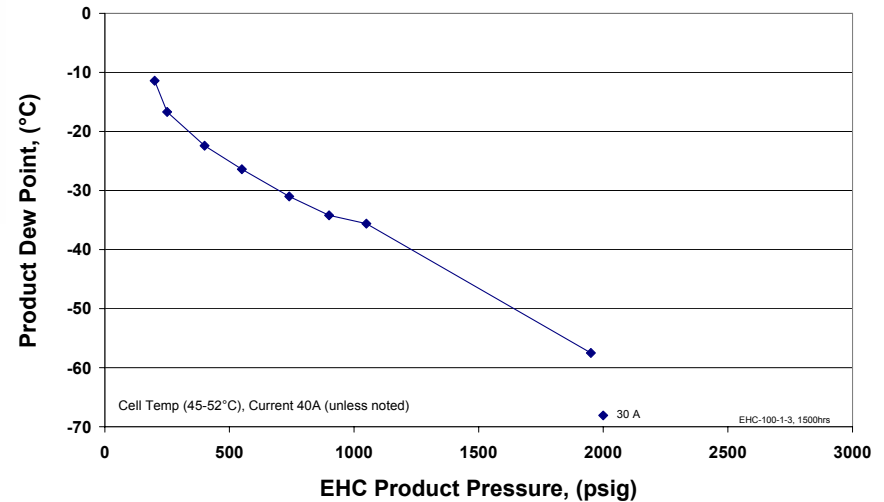
Hydrogen Product Purity

Partial Pressure of Water vs. EHC Product Pressure



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

EHC Product Hydrogen Dew Point vs. Product Pressure



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/cm² 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/cm²**
- **Demonstrate 2 lb/day H₂ at 3,000 psi**
- **Reduce power consumption to 50% of current design**
- **Maintain hydrogen recovery >98%**
- **Estimate capital and operating cost benefits**