



FuelCell Energy

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

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Project ID #
PD048

Overview

Timeline: Phase II

- Start: August 2008
- End: August 2010
- 85% complete

Budget

- Total project funding
 - DOE share \$750k
 - Contractor share \$218k
- Funding for FY09: \$375k
- Funding for FY10: ~\$330k

Barriers

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

Partners

- Sustainable Innovations, LLC
- University of Connecticut



Relevance

Objectives:

- **Pressure Capability:** Develop designs and materials to increase EHC pressure capability from 2,000 to 6,000 psi
- **Operating Cost:** Improve the cell performance to reduce power consumption (compression efficiency)
- **Capital Cost:** Reduce the EHC cell cost by increasing operating current density
- **Life:** Study thermal and water management options to increase system reliability and life



Relevance

Impact of EHC:

- **Increases reliability/availability over current mechanical compressors**
- **Ensures “no possibility of lubricant contamination” (No moving parts) → Fuel Cell Quality H₂**
- **Increases Compression Efficiency to 95% (DOE 2015 Target)**
- **Potentially reduces cost of H₂ delivery to <\$1/gge (DOE Long Term Target)**



Approach

- **Use high-pressure electrolyzer experience for mechanically robust cell design**
- **Higher current density operation to minimize capital and operating costs**
- **Improved flow field design to increase H₂ recovery efficiency**
- **Simple system: Reduce capital cost by reducing catalyst loading and humidification requirements**



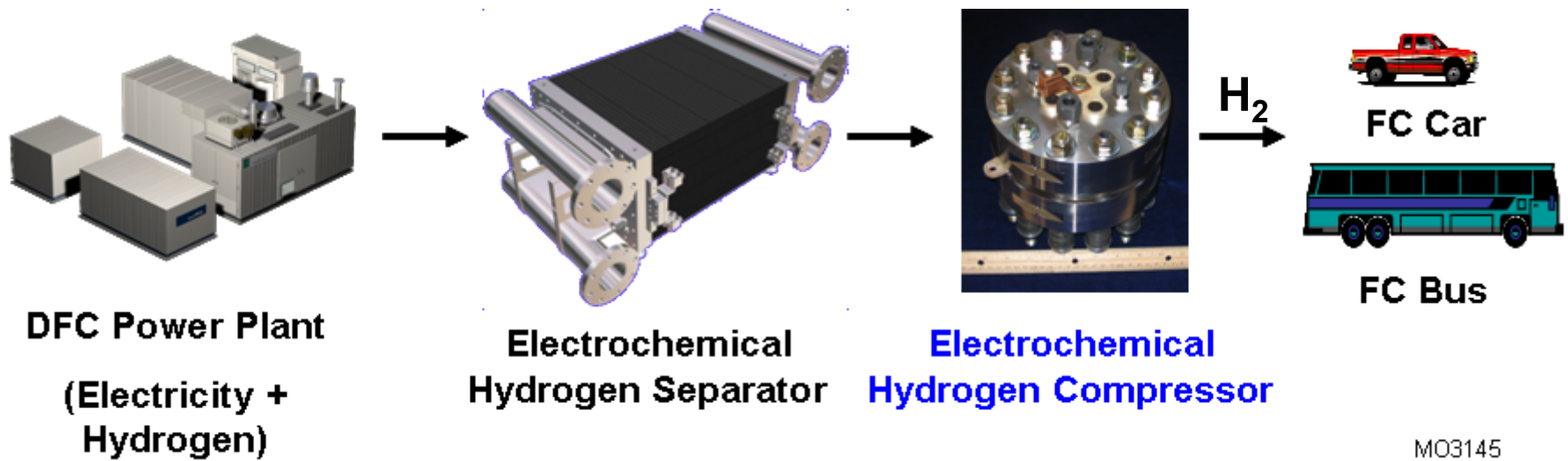
Milestones

Parameter	FY09 Goals	FY10 Goals	Current Status
Hydrogen Product Pressure	4,500 psi in 3-cell stack	6,000 psi in single cell	Up to 5,600 psi in single cell
Minimize Hydrogen Inlet Pressure	5 psig	5 psig	< 5 psig ✓
Compression Ratio	Up to 300:1	300:1	300:1 ✓
Hydrogen Recovery Efficiency	96% in single cell	95% in 10-cell stack	Up to 90% in 10-cell stack
Pressure Cycling	50 cycles to 4,500 psi in single cell	≥20 cycles to 3,000 psi in 10-cell stack	20 cycles to 3,000 psi in 10-cell stack ✓
Life Testing	500 hrs at 4,500 psi in 3-cell stack	≥500 hrs at 3,000 psi in 10-cell stack	~100 hrs at 3,000 psi in 10-cell stack
No. of Cells in Stack	3	10	10 ✓

- **All FY09 Milestones Met**
- **Making Progress Towards FY10 Milestones**



Enabler for Hydrogen Infrastructure

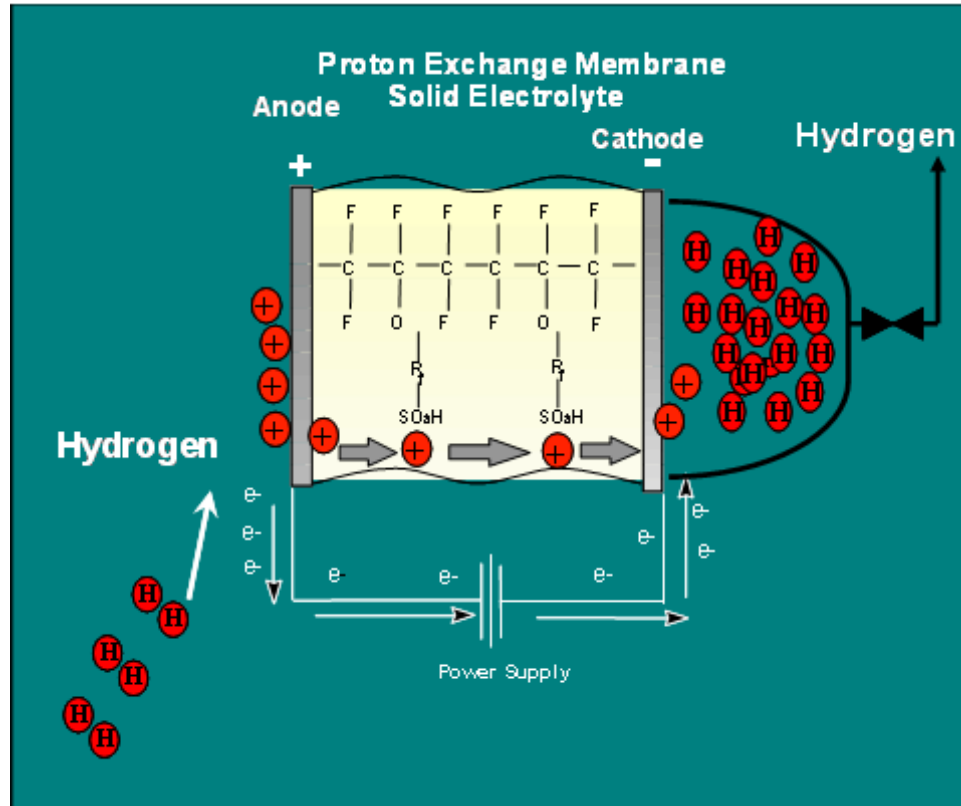


MO3145

The EHC Technology has Unique Synergy to the Hydrogen Energy Stations



Principle of an Electrochemical Hydrogen Compressor



- Simple Operating Principle with No Moving Parts – **Solid State !**
- Use of Hydrogen Electrode for High Compression Efficiency



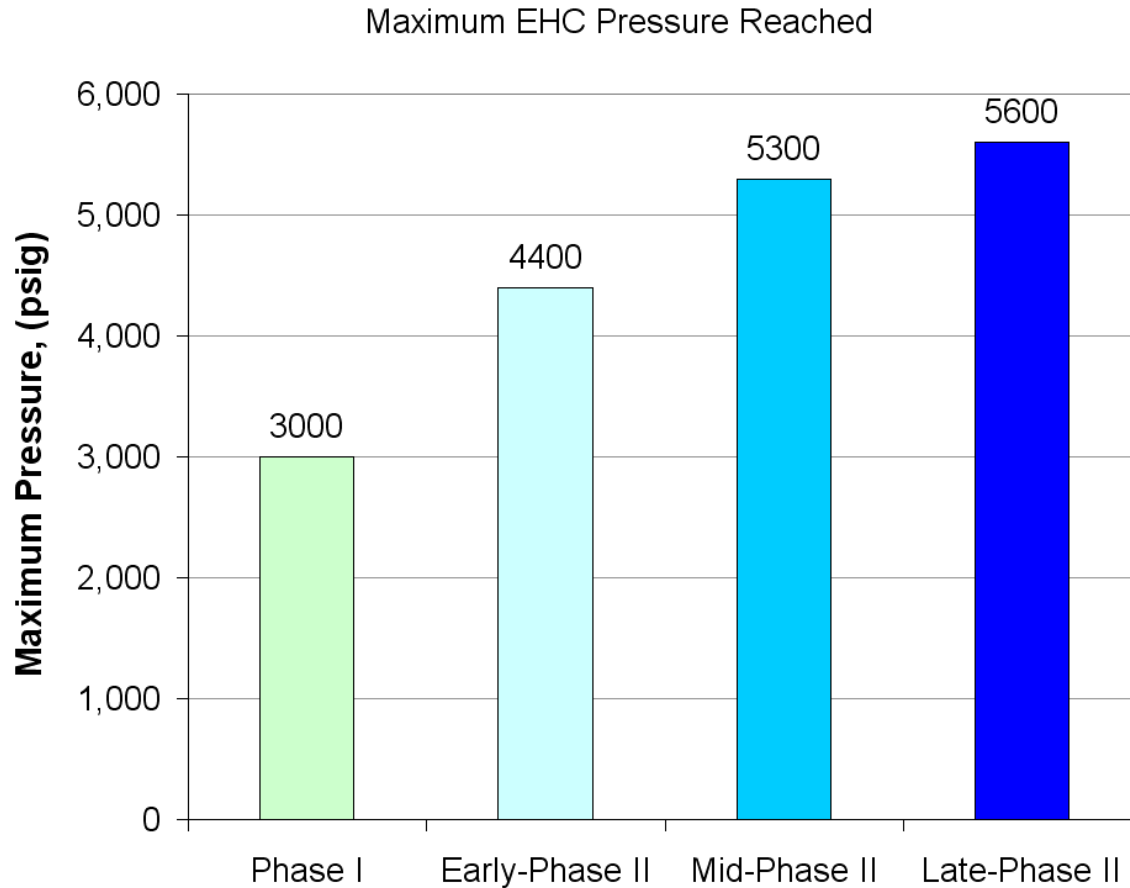
Technical Accomplishments

EHC 10-cell stack operation demonstrated

- **Compression Mode Operation:** Increased capability from 4,500 psi to 5,600 psi in a single stage EHC cell (360:1 compression ratio)
- **Compression Efficiency:** Further reduced cell resistance → energy consumption comparable to mechanical compressors
- **Pressure Cycling:** Completed 20 pressure cycles from 100 to 3,000 psi in 10-cell stack
- **Stack:** Scaled-up EHC technology from 3-cell to 10-cell stack (up to 3,000 psi)



Hydrogen Product Pressure

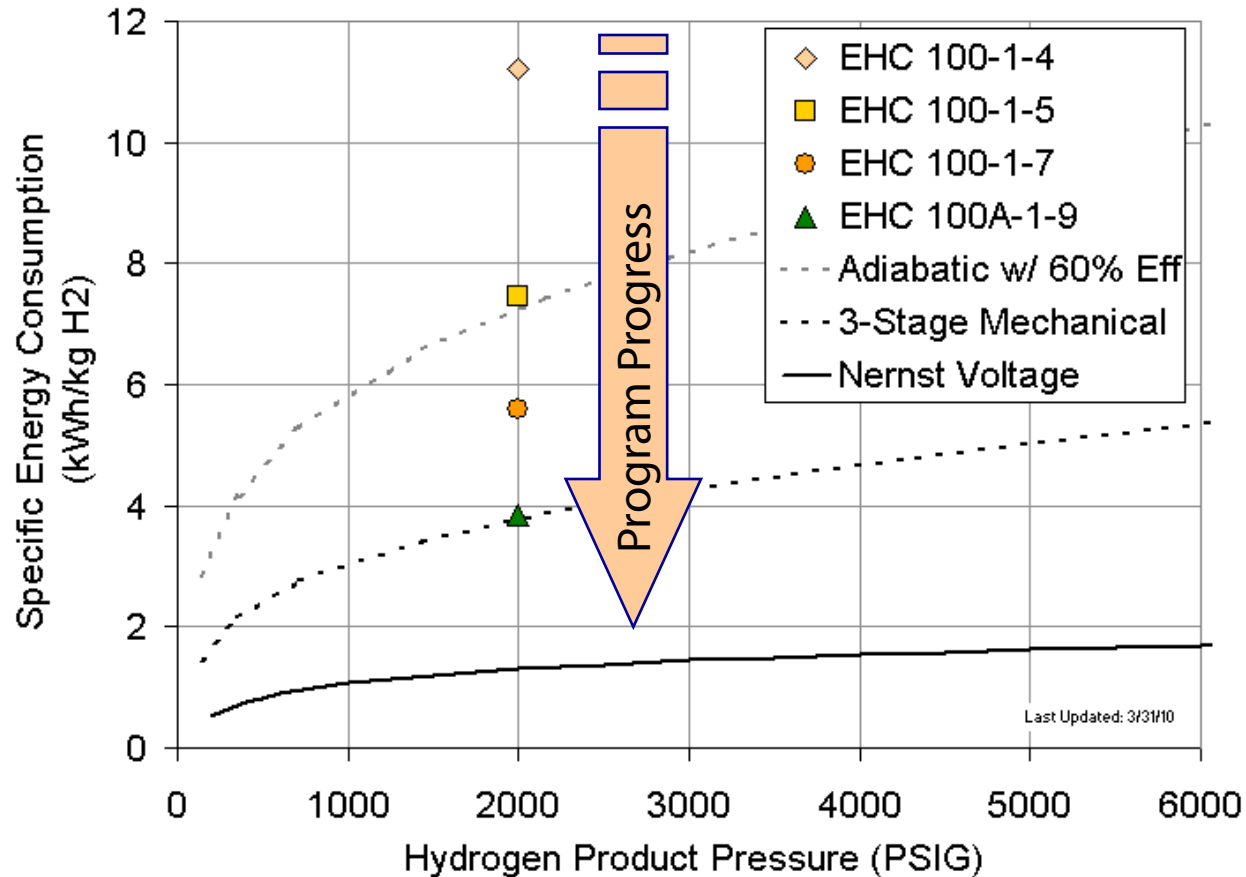


Approaching FY10 Pressure Goal of 6,000 psi (Single Cell)



Energy Consumption

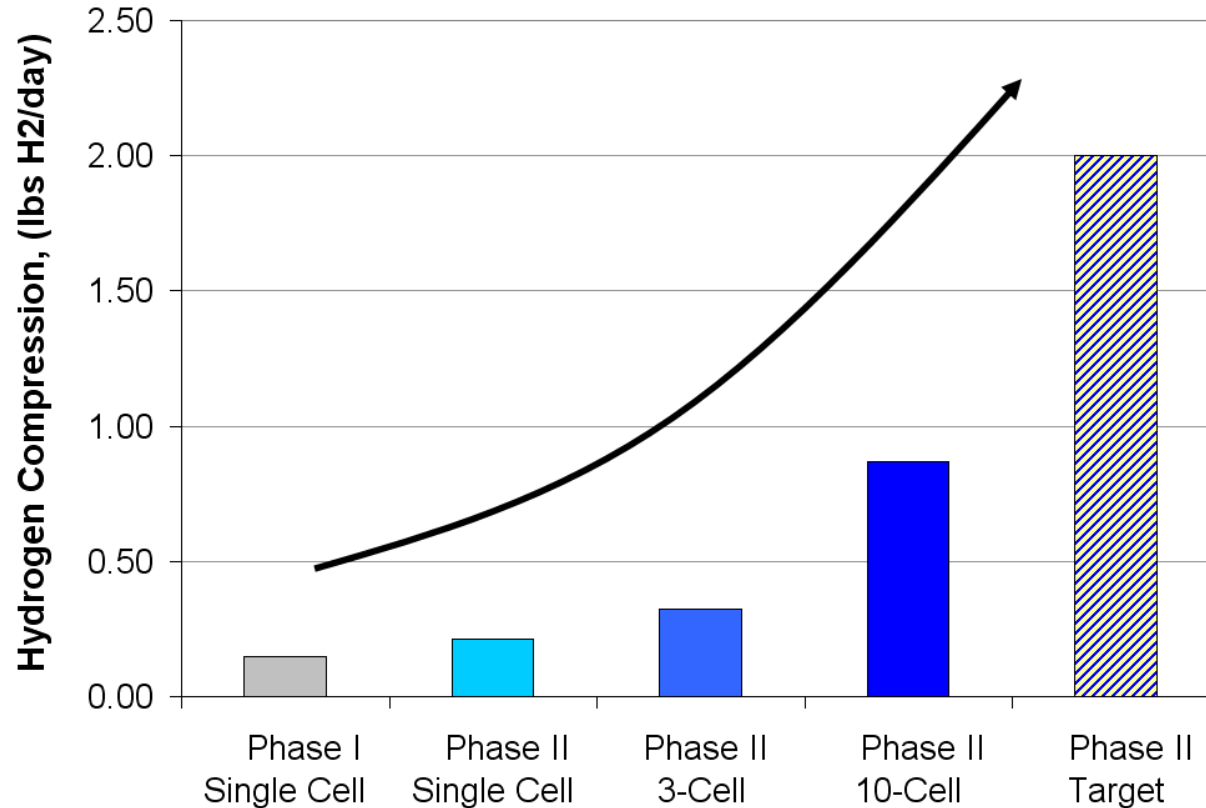
Specific Energy Consumption of Various Compressors



Significant Reduction in EHC Specific Energy Consumption Achieved



Hydrogen Compression



- **Increased EHC Capacity 5x**
- **Making Progress Towards Target Flow Rate of 2 lbs H₂/day**



Collaborations

Prime

- **FuelCell Energy, Inc.* (Industry):**
 - Leading fuel cell developer for over 40 years

Subcontractors

- **Sustainable Innovations, LLC* (Industry):**
 - Cell and stack design and fabrication
- **University of Connecticut* (Academic):**
 - Identification and evaluation of low-cost materials

* Within DOE H₂ Program



Proposed Future Work

- **Increase pressure capability of single-stage EHC cell from 5,600 to 6,000 psi**
- **Further reduce power consumption of current design**
- **Improve 10-cell stack design to achieve long-term operation**
- **Demonstrate 2 lb/day H₂ at 3,000 psi**
- **Increase hydrogen recovery to 95%**
- **Demonstrate 500 hr life at 3,000 psi in 10-cell stack**
- **Update estimates of capital and operating costs**



Project Summary

Relevance: Provide highly efficient, reliable and cost-effective hydrogen compression (up to 6,000 psi)

Approach: Develop electrochemical compressor – solid state device

Technical Accomplishments: Demonstrated single-stage compression to 5,600 psi, operated 10-cell stack

Collaborations: Active partnership with industry (Sustainable Innovations) and University (UConn) on materials, design and fabrication

Proposed Future Work: Further increase pressure, efficiency and throughput (2 lb/day H₂ at 3,000 psi)



Acknowledgements

- **DOE: Monterey Gardiner, Richard Farmer, Tim Armstrong**
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- **FCE: Jonathan Malwitz, Ray Kopp, Pinakin Patel**

