



FuelCell Energy



DOE Hydrogen Program

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

Ludwig Lipp

FuelCell Energy, Inc.

May 19, 2009

Project ID #
pdp_22_lipp

Overview

Timeline: Phase II

- Start: August 2008
- End: August 2010
- 38% complete

Budget

- Total project funding
 - DOE share \$750k
 - Contractor share \$218k
- Funding received in FY08: \$8.1k
- Funding for FY09: \$375k

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

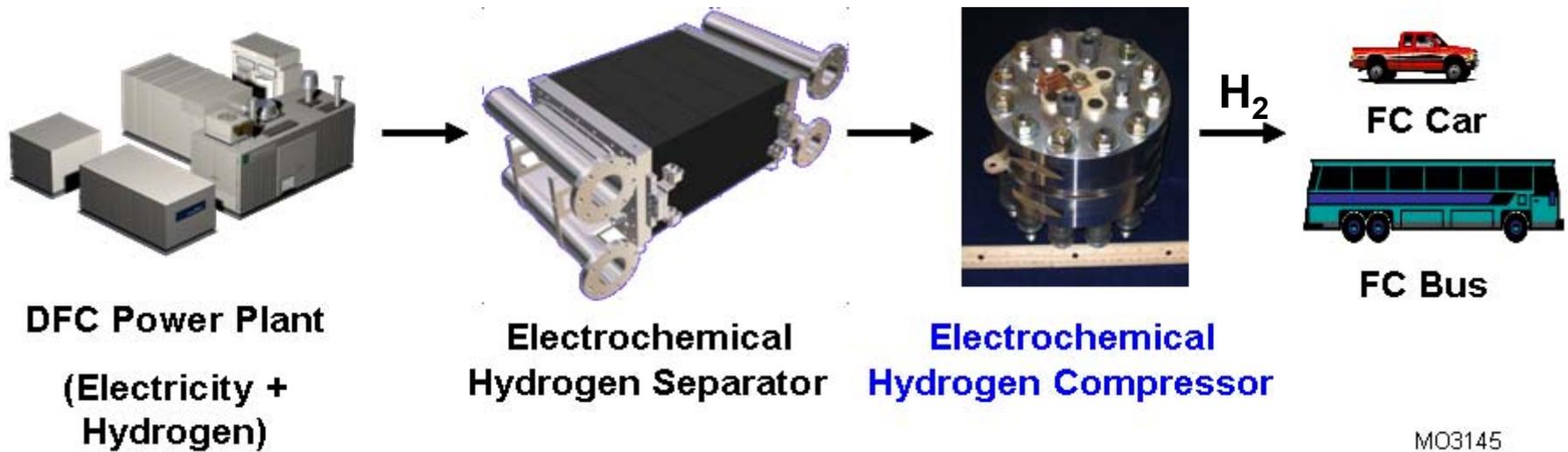
Parameter	FY08 Goals	FY09 Goals	Current Status
Hydrogen Product Pressure	2,000 psi	Up to 6,000 psi	4,500 psi
Minimize Hydrogen Inlet Pressure	30 psig	5 psig	< 5 psig ✓
Compression Ratio	40:1	Up to 300:1	300:1 ✓
Hydrogen Recovery Efficiency	90%	96%	Up to 95%
Pressure Cycling	10 cycles to 2,000 psi	50 cycles to 4,500 psi	>1,000 cycles to 3,000 psi
Life Testing	50 hrs at 2,000 psi	500 hrs at 4,500 psi	~3,000 hrs at 3,000 psi
No. of Cells in Stack	1	3	3 ✓

- **All FY08 Milestones Exceeded**

- **Three FY09 Milestones Met already, on Track to Meet all FY09 Goals**



Enabler for Hydrogen Infrastructure

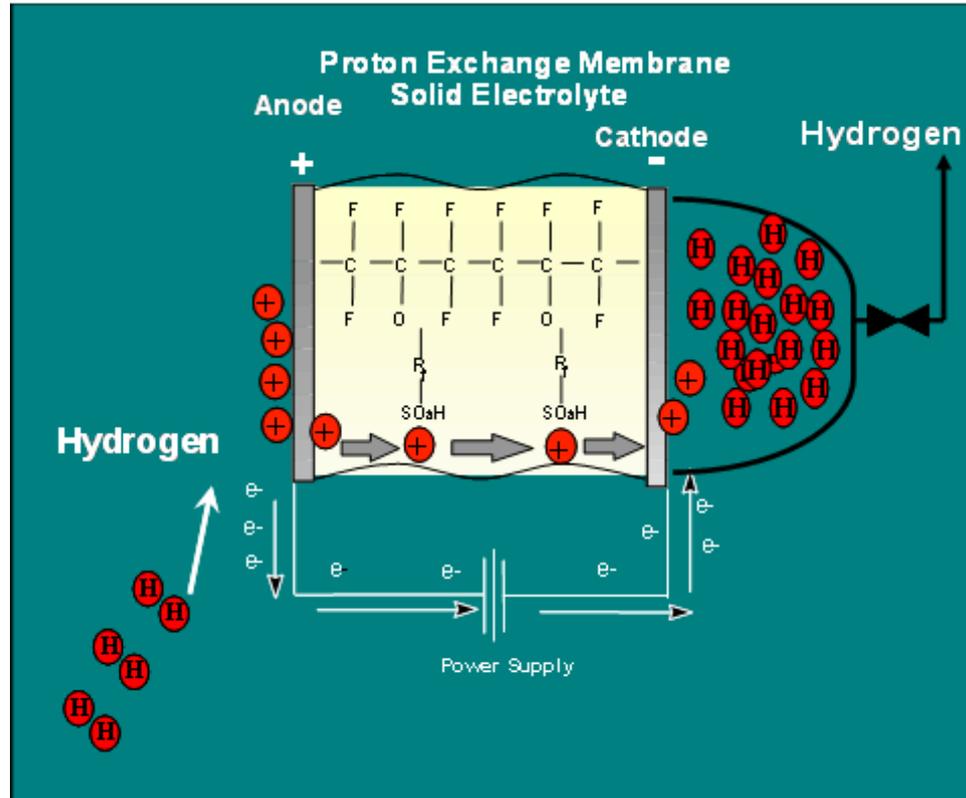


M03145

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



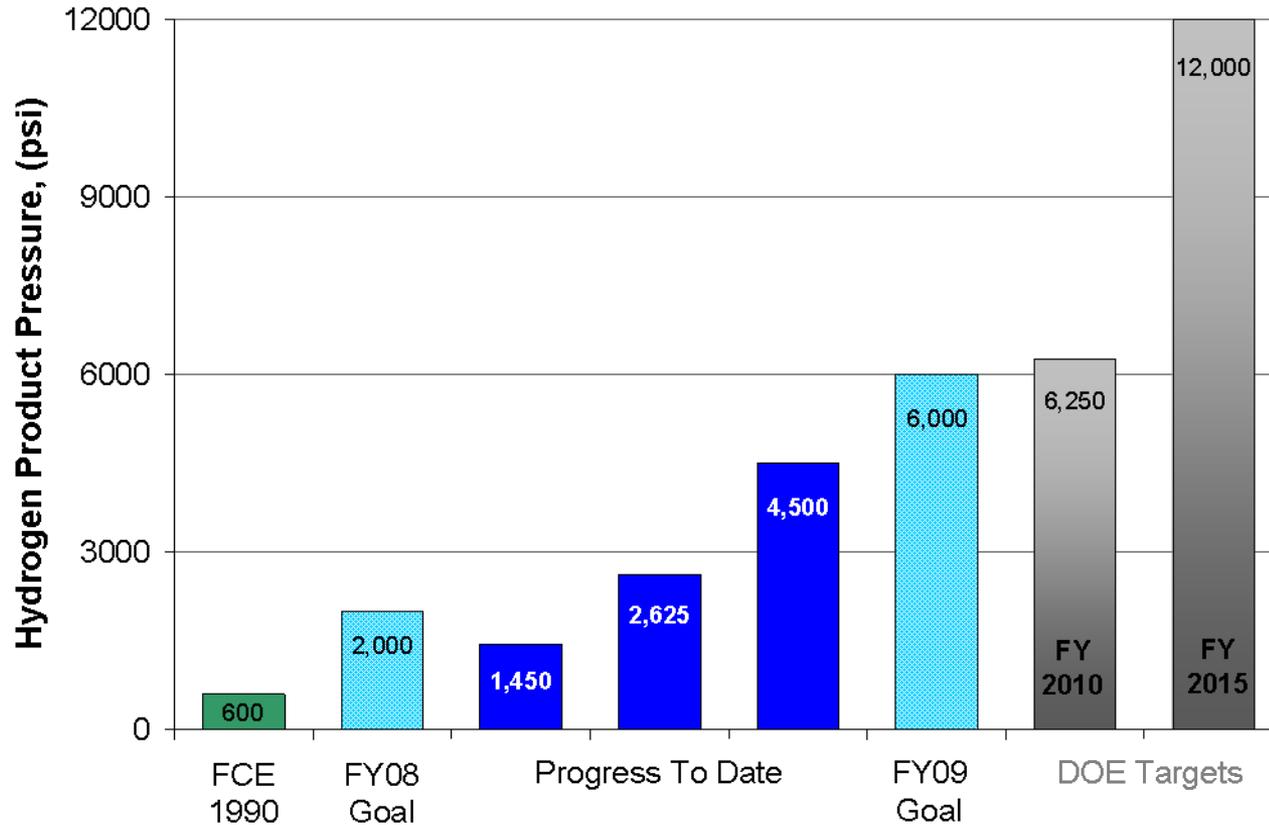
Technical Accomplishments

EHC short stack operation demonstrated

- **Compression Mode Operation:** Increased capability from 3,000 psi to 4,500 psi in a single stage EHC cell (300:1 compression ratio)
- **Compression Efficiency:** Reduced cell resistance by 70% → energy consumption comparable to mechanical compressors
- **Pressure Cycling:** Completed >1,000 pressure cycles from 100 to 3,000 psi without performance loss
- **Stack:** Scaled-up EHC technology from single cell to 3-cell stack (up to 3,000 psi)



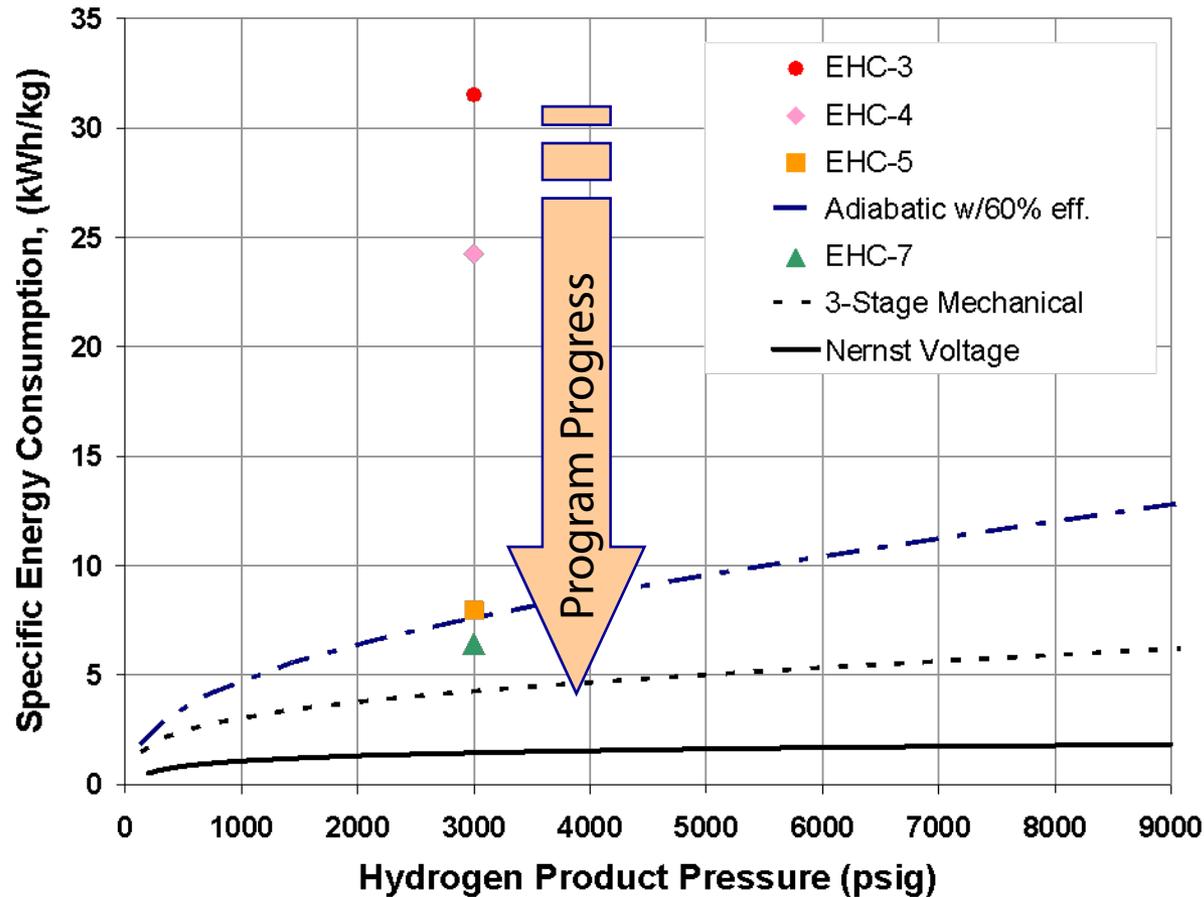
Hydrogen Product Pressure



- **Met FY08 Pressure Goal**
- **On Track to Meet FY09 Pressure Goal**



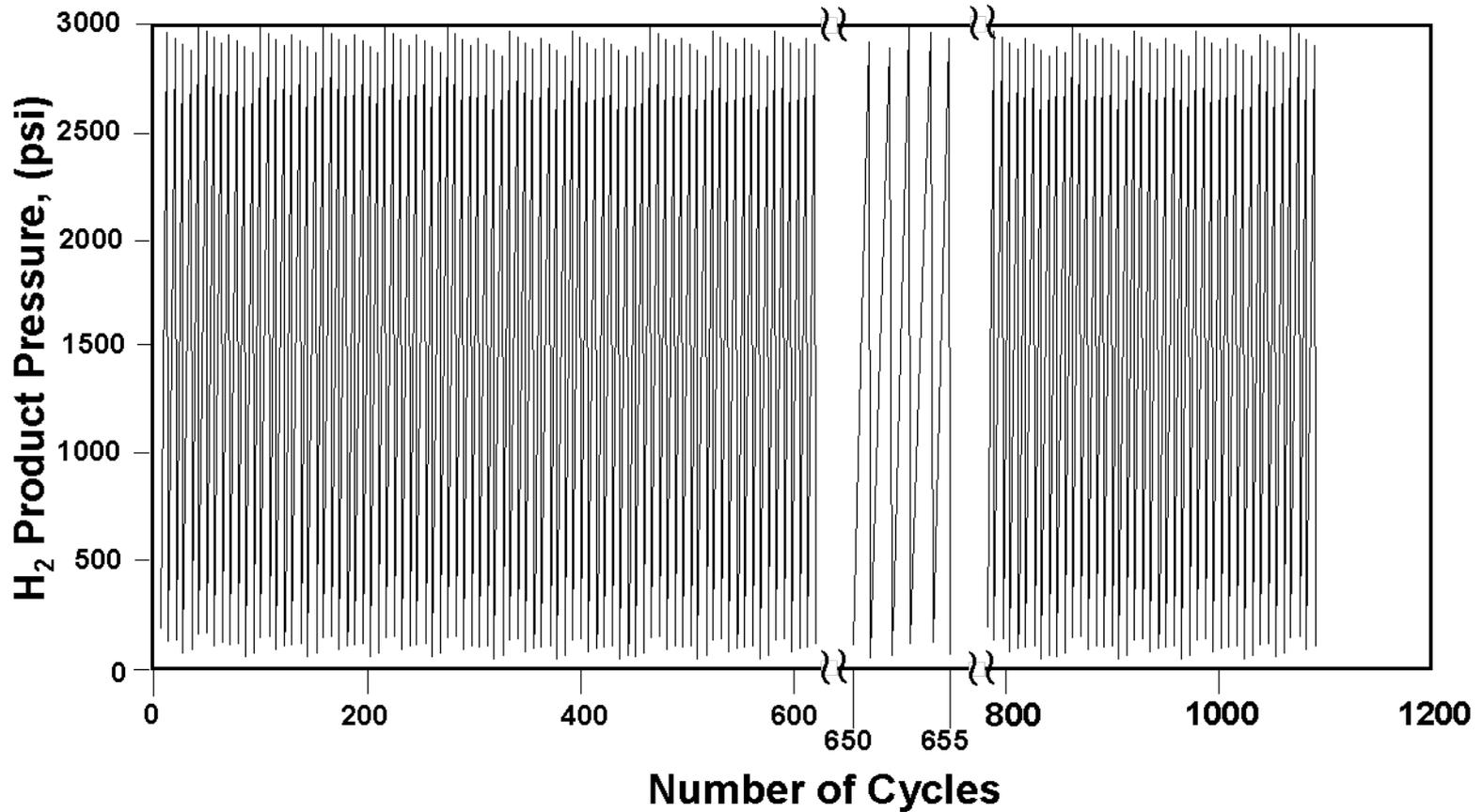
Energy Consumption



Significant Reduction in EHC Specific Energy Consumption Achieved



Pressure Cycling



> 1,000 Pressure Cycles to 3,000 psi Validates **Robust Cell Design**



Collaborations

Prime

- **FuelCell Energy, Inc.* (Industry):**
 - Leading fuel cell developer for over 30 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 4,500 to 6,000 psi**
- **Further reduce power consumption of current design**
- **Develop and validate multi-cell stack design in a 10-cell stack**
- **Demonstrate 2 lb/day H₂ at 3,000 psi**
- **Increase hydrogen recovery to 98%**
- **Demonstrate 2,000 hr life at 6,000 psi in single cell**
- **Estimate 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 4,500 psi, operated 3-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**
- **Sustainable Innovations, LLC: Trent Molter, Mark Dristy**
- **FCE: Jonathan Malwitz, Ray Kopp, Pinakin Patel**

