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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 H_2
- Increases Compression Efficiency to 95% (DOE 2015 Target)
- Potentially reduces cost of H_2 delivery to <$1/gge (DOE Long Term Target)

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Approach

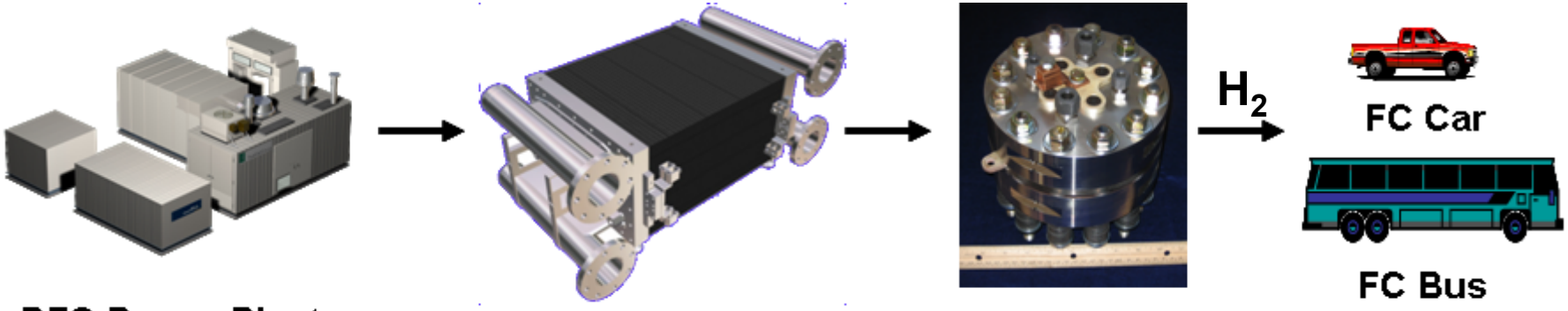
- Use high-pressure electrolyzer experience for mechanically robust cell design
- Higher current density operation to minimize capital and operating costs
- Improved flow field design to increase H_2 recovery efficiency
- Simple system: Reduce capital cost by reducing catalyst loading and humidification 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** ✓

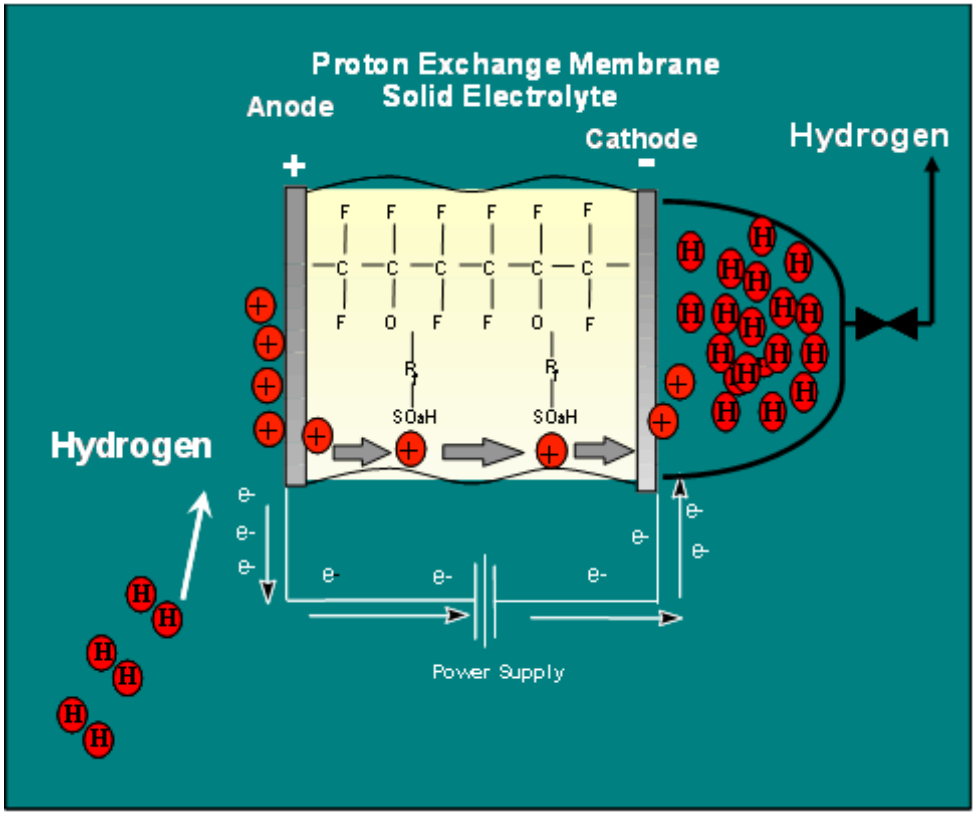
- **All FY09 Milestones Met**
- **Making Progress Towards FY10 Milestones**

Enabler for Hydrogen Infrastructure



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

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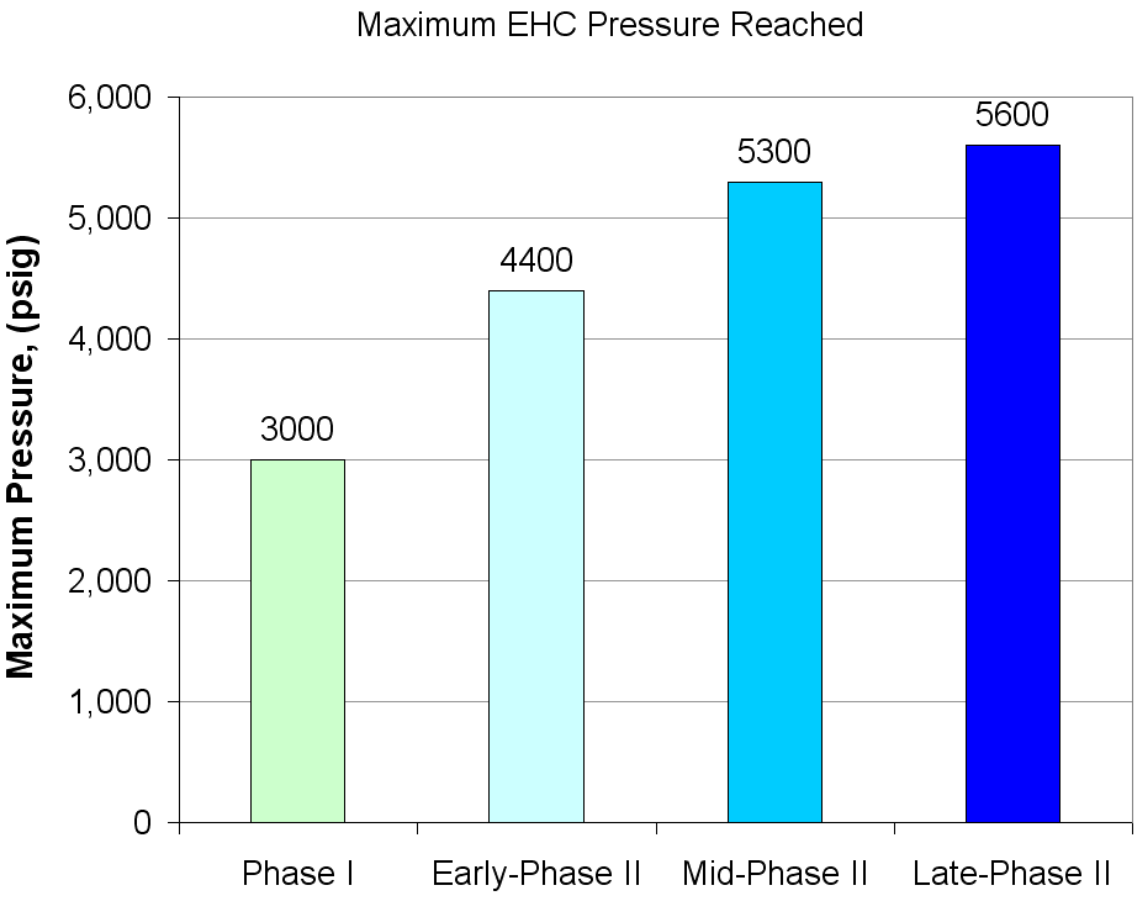
Technical Accomplishments

EHC 10-cell stack operation demonstrated

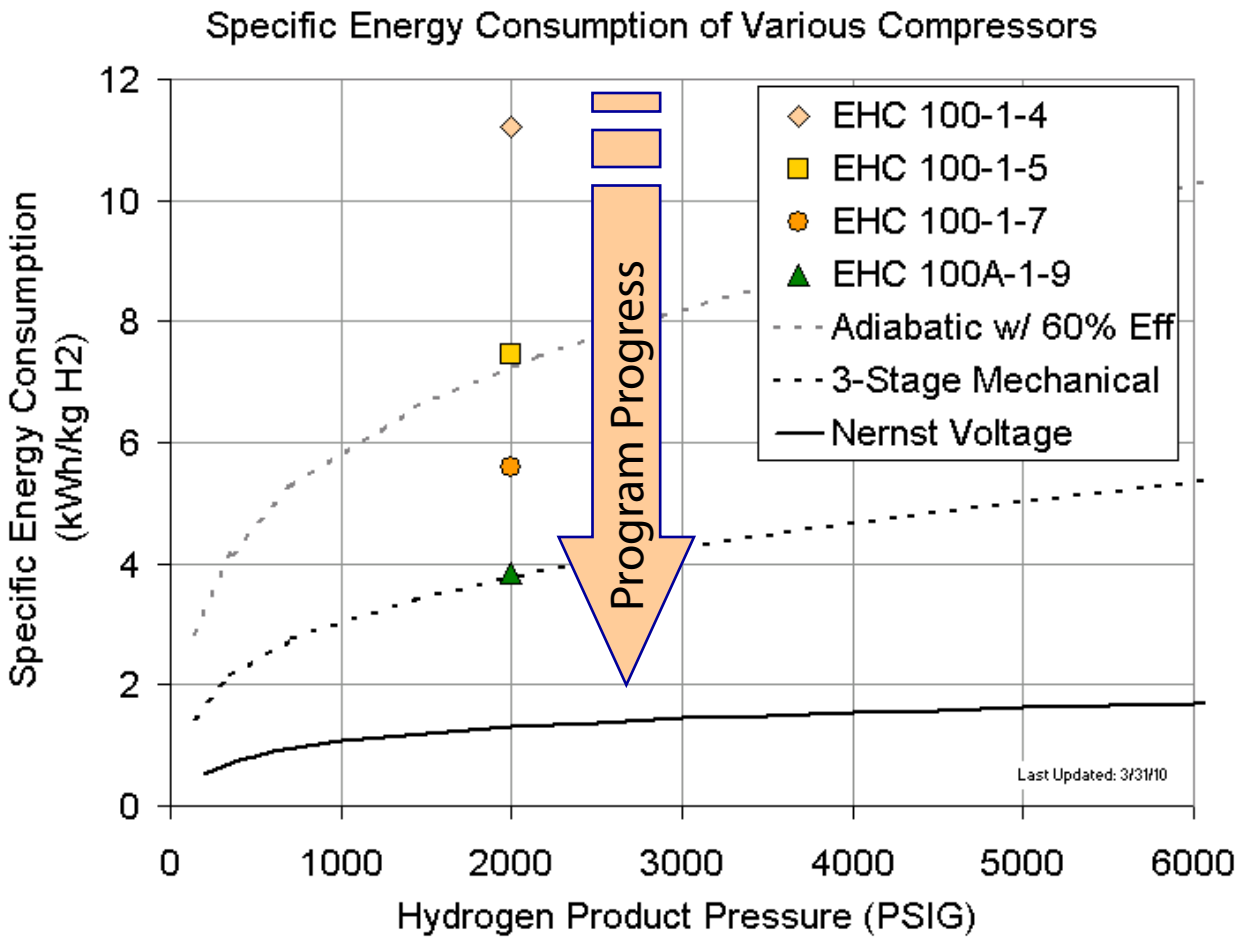
- **Compression Mode Operation:** Increased capability from 4,500 psi to 5,600 psi in a single stage EHC cell (360:1 compression ratio)
- **Compression Efficiency:** Further reduced cell resistance → energy consumption comparable to mechanical compressors
- **Pressure Cycling:** Completed 20 pressure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



Significant Reduction in EHC Specific Energy Consumption Achieved

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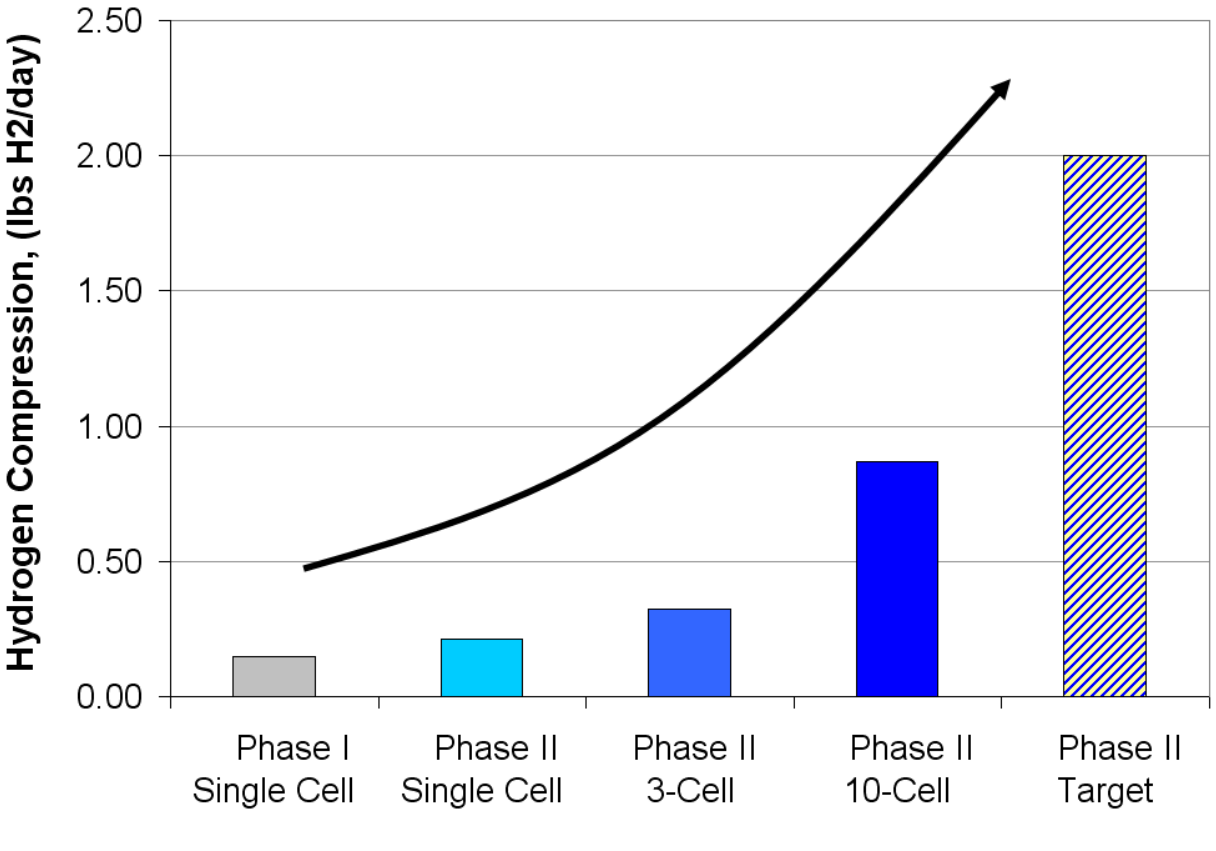
Hydrogen Compression



- **Increased EHC Capacity 5x**
- **Making Progress Towards Target Flow Rate of 2 lbs H_2/day**

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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 H_2 Program**

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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 H_2 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

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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 H_2 at 3,000 psi)

Acknowledgements

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