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

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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

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

- **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
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

- EHC 100-1-4
- EHC 100-1-5
- EHC 100-1-7
- EHC 100A-1-9

Adiabatic w/ 60% Eff
3-Stage Mechanical
Nernst Voltage

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 psi 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

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• FCE: Jonathan Malwitz, Ray Kopp, Pinakin Patel