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

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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 $H_2$ recovery efficiency

• Simple system: Reduce capital cost by reducing catalyst loading and humidification requirements
# Milestones

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

- All FY08 Milestones Exceeded
- Three FY09 Milestones Met already, on Track to Meet all FY09 Goals
Enabler for Hydrogen Infrastructure

The EHC Technology has Unique Synergy to the Hydrogen Energy Stations

DFC Power Plant (Electricity + Hydrogen) → Electrochemical Hydrogen Separator → Electrochemical Hydrogen Compressor → H₂

FC Car
FC Bus

FuelCell Energy
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
Significant Reduction in EHC Specific Energy Consumption Achieved
Pressure Cycling

$\text{H}_2$ Product Pressure, (psi)

Number of Cycles

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

Prime

  - 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

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