Electrochemical Hydrogen Compressor

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Project ID
#PD048

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Overview

Timeline
• Project start date: 7/15/10
• Project end date: 7/14/13
• Percent complete: 27%

Budget
• Total project funding
  – DOE share: $1993k
  – Contractor share: $629k
• Funding received in FY10: $200k
• Funding for FY11: $500k

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

Partners
• Collaborations: Sustainable Innovations, LLC
• Project lead: FuelCell Energy
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)
Leader in Stationary Fuel Cell Power Plants

Leading fuel cell developer for over 40 years

- MCFC, SOFC, PAFC and PEM (up to 2.8 MW size products)

- Over 700 million kWh of clean power produced world-wide (>50 installations)

- Renewable fuels: over two dozen power plants operating with ADG fuel

- Ultra-clean technology: CARB-2007 certified: Facilitates clean air permitting in California

- Internal reforming technology – enables H₂ co-production
Fuel Flexibility Experience

DFC Products are uniquely capable of operating on many fuels

Westin at SFO Airport
Nat Gas CHP

29 Palms Marine Corp Base
Nat Gas Secure CHP

Santa Rita Jail, CA
Nat Gas Fuel Cell and Solar Power

California WWT Plant
BioGas CHP

Sierra Nevada Brewery
Nat Gas and BioGas CHP

Ford Paint Shop
Paint Solvent Fume Power

Pacific Missile Range
Propane Secure CHP
Co-Production of Renewable Hydrogen at OCSD, CA

Orange County Sanitation District (OCSD)

Renewable H₂ Filling Station

ADG fueled DFC-H₂® Production Unit

Energy Efficiency & Renewable Energy

Southern California Gas Company

Air Resources Board

California Environmental Protection Agency

University of California - Irvine

FuelCell Energy
OCSD Site Demonstration

- October 2010 – DFC-H₂ Start-up on Natural Gas
  - Co-production Efficiency (H₂ + Power) 54.2%
- November 2010 – Mechanical Completion of Hydrogen Fueling Station
- February 2011 – First Delivery of H₂ to Fueling Station
- March 2011 – Initial Test Fills of Fuel Cell Vehicles

Hydrogen Energy Station

Hydrogen Fueling Station
Enabling Technology for Hydrogen Co-production

DFC Power Plant
(Electricity + Hydrogen)

→

Electrochemical Hydrogen Separator

→

Electrochemical Hydrogen Compressor

→

FC Car

→

FC Bus

Technologies for Hydrogen Infrastructure and Smart Grid
DFC-H2® Applications for the Smart Grid

Hydrogen as Energy Storage can Support Intermittent Wind Energy
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 $\text{H}_2$ recovery efficiency

• Simple system: Reduce capital cost by reducing catalyst loading and humidification requirements
Principle of Electrochemical Hydrogen Compressor

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

Electrochemical compression is by far the most efficient way to compress hydrogen.
Approach to Achieving 12,000 psi Pressure Capability

- Design and Demonstrate Common Building Block (2,000 - 3,000 psi) for dual-use applications (industrial + fuel cell vehicles)
- Improve Performance of the building block (seals, creep, etc.) and implement lower cost fabrication processes
- Develop a Cascade System for 6,000 – 12,000 psi Capability
Technical Accomplishments and Progress – Previous Work

Excellent Progress Made in EHC Cell Technology (DOE – Phase II – SBIR)
## Achievements in EHC Technology Development

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Phase II Goals</th>
<th>Current Status</th>
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<tbody>
<tr>
<td>No. of Cells in Stack</td>
<td>10</td>
<td>10 ✓</td>
</tr>
<tr>
<td>Durability (single cell)</td>
<td>2,000 hrs</td>
<td>3,000 hrs ✓</td>
</tr>
<tr>
<td>Hydrogen Recovery Efficiency</td>
<td>95%</td>
<td>&gt;95% ✓</td>
</tr>
<tr>
<td>Hydrogen Product Pressure</td>
<td>6,000 psi</td>
<td>6,000 psi ✓ single stage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6,000 psi ✓ 2-stage</td>
</tr>
<tr>
<td>Compression Ratio</td>
<td>300:1</td>
<td>300:1 ✓</td>
</tr>
<tr>
<td>Minimize Hydrogen Inlet Pressure</td>
<td>5 psig</td>
<td>&lt;5 psig ✓</td>
</tr>
<tr>
<td>Pressure Cycling</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>Hydrogen Flux</td>
<td>500 mA/cm²</td>
<td>1,000 mA/cm²</td>
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Reduction in the Energy Consumption of EHC

Over 80% reduction in energy consumption
2-Stage EHC System Concept

- Low Pressure H₂: 0-50psi
- Inter-Stage H₂: 2,000psi
- Product H₂: 6,000psi

High level control strategy developed
Stage I: 2-Cell EHC Stack

- Stack runs very stable at 1,500 psi
- Flat resistance curve
Stage II: 6,000 psi EHC Cell

Cell runs better at higher pressure
Collaborations

Prime

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

Subcontractor

• Sustainable Innovations, LLC* (Industry):
  – Cell and stack design and fabrication
  – Scale-up design and fabrication
  – EHC stack cost estimates

* Within DOE H₂ Program
Proposed Future Work

- Fabricate and test four baseline cells – screen 17 improvement ideas
- Validate baseline stack design (up to 5 cells) - demonstrate 500 hr life at 2,000 - 3,000 psi
- Select promising advanced EHC cell design options
- Complete advanced EHC cell design review
- Fabricate cell hardware for advanced design (200 cm² active area)
- Design test facility for two-stage compression up to 12,000 psi
## Scale-Up Plan to Reach 8 lb/day

### Activity Covered
- **Single Cell**
  - 200 cm² Active Area
  - 500 – 1000 mA/cm²
  - Up to 0.4 lb/dy

### Activity Not Covered
- **20 - Cell**
  - 200 cm² Active Area
  - 500 – 1000 mA/cm²
  - Up to 8 lb/dy

- **10 - Cell**
  - 200 cm² Active Area
  - 500 – 1000 mA/cm²
  - Up to 4 lb/dy

- **3 - Cell**
  - 200 cm² Active Area
  - 500 – 1000 mA/cm²
  - Up to 1.2 lb/dy
Project Summary

**Relevance:** Provide highly efficient, reliable and cost-effective hydrogen compression (up to 6,000/12,000 psi)

**Approach:** Develop electrochemical compressor – solid state device

**Technical Accomplishments:**
- Reduced Capital Cost by 50% (H₂ flux increased to 1,000 mA/cm²)
- Developed 2-stage EHC system concept
- Validated 2-stage EHC hardware feasibility at 2,000/6,000 psi level

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

**Proposed Future Work:** Scale-up cell design to 200 cm² active area to increase throughput and lower the cost
Acknowledgement

- FCE: Pinakin Patel, Ray Kopp, Jonathan Malwitz
- Sustainable Innovations, LLC: Trent Molter and team
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