Electrochemical Hydrogen Compression (EHC)

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• Experience with all fuel cells – MCFC, SOFC, PEM, PAFC, etc.

• Excellent progress in commercialization of MCFC technology
  (>300 MW installed + backlog, >50 MW per year production rate, 11 MW single site unit in Korea, >1.5 billion kWh produced)

• Unique internal reforming technology for high efficiency fuel cells
Advanced Hydrogen Co-production Technology

DFC® Power Plant
(Electricity + Hydrogen)

Solid State Hydrogen Separator (EHS)

Solid State Hydrogen Compressor (EHC)

Fuel Cell Cars

Materials Handling Equipment

Liquid Biofuels

Peak and Back-up Power

1 yr Factory Test at FCE
>2.5 yr Site Demo at OCSD (DFC-H2-PSA)

100-cell baseline stack tested
Advanced CO-tolerant stack tested for 1 year

1 year operation at 3,000 psi
Feasibility of 12,000 psi demonstrated

Strategic Alliance with Hydrogen Users
## EHC Technology Status

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Program Goals</th>
<th>Current Status</th>
<th>DOE Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Product Pressure</td>
<td>Up to 3,000 psi building block, 6-12 kpsi</td>
<td>12,800 psi single stage 6,000 psi 2-stage</td>
<td>12,500 psi</td>
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<tr>
<td>Hydrogen Inlet Pressure</td>
<td>5 - 300 psi</td>
<td>0 – 2,000 psi</td>
<td>300 psi</td>
</tr>
<tr>
<td>Compression Ratio</td>
<td>Up to 300:1</td>
<td>300:1</td>
<td>43:1</td>
</tr>
<tr>
<td>Hydrogen Recovery Efficiency</td>
<td>90 - 95%</td>
<td>&gt;95%</td>
<td>99.5%</td>
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<tr>
<td>Hydrogen Flux</td>
<td>500 - 1,000 mA/cm²</td>
<td>750 mA/cm² for &gt;6,000 hrs</td>
<td>High</td>
</tr>
<tr>
<td>Hydrogen Capacity</td>
<td>2-4 lb/day at 3,000 psi</td>
<td>~0.8 lb/day</td>
<td>Up to 1000 kg/day</td>
</tr>
<tr>
<td>Endurance Capability</td>
<td>1,000 hrs at 3,000 psi</td>
<td>&gt;8,000 hrs at 3,000 psi</td>
<td>&gt;5 years</td>
</tr>
<tr>
<td>Compression Efficiency</td>
<td>&lt;10 kWh/kg at 3,000 psi</td>
<td>6-12 kWh/kg from &lt;30 to 3,000 psi</td>
<td>6.2 kWh/kg from 300 to 12,500 psi</td>
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</table>
Technology Challenges

• Cell Technology: Creep of cell materials (especially electrode support) increases resistance and power requirement

• Hydrogen backdiffusion through the membrane: reduces compression efficiency

• Seal degradation (time, T, compression cycling): higher operating temperature reduces cost, but limits life

• Stack Technology: Higher current density operation is limited by stack cooling strategy; >1,000 mA/cm² needed to reduce capital cost

• Scale-up: cell area, stack height for 6-12 kpsi operation

• Manufacturing: tighter tolerances reduce yields and increase cost

• H₂ embrittlement and excessive yield of compression hardware
Key R&D Activities

- Larger-area multi-cell stack technology development needed for greater capacity building block, longer-term endurance testing, innovative packaging
- Develop lower-cost protective coatings with desirable tolerances
- Develop hydrogen-resistant seal materials and designs with acceptable creep at higher operating temperatures
- Higher strength materials development needed for 6-12 kpsi operation (lower-cost support layers with higher yield strength and spring constant, engineered structure, …)
- Develop membranes with lower H\textsubscript{2} diffusion (new materials, barrier layers with low electrical resistance)
- Develop robust, low-cost thermal and water management systems