Subfreezing Start/Stop Protocol for an Advanced Metallic Open-Flowfield Fuel Cell Stack

Presented at: US DOE New Projects Kickoff Meeting
Washington, DC

13-14 February 2007
Objective

This project will demonstrate a PEM fuel cell stack that is able to perform and start up in subfreezing conditions, respecting allowed energy budget, and showing limited impact at extreme temperatures over multiple exposures, without irreversibly degrading its performance more than 5%.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Units</th>
<th>2003 Status</th>
<th>2005 Status</th>
<th>2010</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold start-up time to 50% of rated power</td>
<td>sec</td>
<td>120 sec</td>
<td>20 sec</td>
<td>30 sec</td>
<td>30 sec</td>
</tr>
<tr>
<td>0-20°C ambient temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0+20°C ambient temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start up and shut down energy from -20°C ambient temp</td>
<td>MJ</td>
<td>na</td>
<td>7.5 MJ</td>
<td>5 MJ</td>
<td>5 MJ</td>
</tr>
<tr>
<td>from +20°C ambient temp</td>
<td>MJ</td>
<td>na</td>
<td>na</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Durability with cycling</td>
<td>hours</td>
<td>na</td>
<td>~1,000 hours</td>
<td>5,000h</td>
<td>5,000h</td>
</tr>
<tr>
<td>Unassisted start from</td>
<td>°C</td>
<td>na</td>
<td>-20 °C</td>
<td>-40</td>
<td>-40</td>
</tr>
</tbody>
</table>
Nuvera Technology Differentiators

Flowfield
- Standard: Directed Flow
- Nuvera: Open Flow

BPA Material
- Standard: Graphite
- Nuvera: Base Metal Alloy

Humidification
- Standard: External Humidifier
- Nuvera: 100% Internal
Cold Operation Experience

Storage $T = -30^\circ C$

- $TH_2 = -18^\circ C$, Power = 50%
- $TH_2 = -21^\circ C$, Power = 40%
- $TH_2 = -23^\circ C$, Power = 30%

OCV

Time $15 \, s$

Storage $T = -20^\circ C$

Scale up

16 cells (3.4 kW power)

128 cells (27 kW power)
Approach

**DOE 2010 program target**
-20°C to 50% power in 30s
(using <5MJ energy)
Startability from -40°C

**Control strategy implementation with focus on system efficiency**

**Components limitation investigation**

Freezing reliability increased

**Nuvera Current status**
30kW stack started from -30°C to 30% power in 30s
20-30 subfreezing startups repeated (automotive)
> 500 freeze/thaw cycles (stationary and automotive)

**Progress**

Start up and Shut down cycles
Water management strategy implementation
Thermal capacity reduction

**Time**

Stack Design Stabilisation
Freeze and thaw cycling sealing verification
Operation with dry reactants
Project Overview

Baseline Study & Analysis [Nuvera]
- Task 1.1 System Constraint Analysis
- Task 1.2 Control Methods Analysis
- Task 1.3 Materials Analysis

Component Selection & Evaluation
- Task 2.1 Dynamic Thermo-electric Stack Model
- Task 2.2 Identify Optimal Operating Strategy

Control Strategy Development [Nuvera]

Optimization of Flow Field Design and Cell Functionality [Nuvera]
- Task 6.1 Ex-situ Flow Field Characterization
- Task 6.2 Optimization of Flow Field Design
- Task 6.3 In-situ evaluation of components and control strategies
- Task 6.4 Postmortem component testing

Task 7 [Nuvera] Build and evaluate short stacks with optimized materials and operating methods

Go / No Go

Go / No Go

Delivery of Stack to DOE

Task 8 [Nuvera] Program management & Co-ordination

Project Team:

Nuvera Fuel Cells
Gore
SGL Carbon Group
University of Delaware
Active project duration is 36 months.

<table>
<thead>
<tr>
<th>DOE FISCAL YEAR</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
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<td>10/1/06</td>
<td>10/1/07</td>
<td>10/1/08</td>
<td>10/1/09</td>
<td>V</td>
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<tr>
<td>Ending</td>
<td>9/30/07</td>
<td>9/30/08</td>
<td>9/30/09</td>
<td>9/30/10</td>
<td>V</td>
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<tr>
<td># Active Project Months</td>
<td>6</td>
<td>12</td>
<td>12</td>
<td>6</td>
<td>V</td>
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Summary

*Specific goals of the project*
- Start-up to 50% rated power from -20C in 30 seconds using <5 MJ of energy
- Decay <5% with 1000X exposure to -40C

*Success enablers*
- Open & low thermal mass flowfield
- Internal humidification
- State of the art material (MEA, GDL) combinations
- Proven methods and targeted controls optimization
- Project Team (Nuvera, Gore, SGL, & Univ of Delaware)