CIRRUS

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

James C. Cross III
Nuvera Fuel Cells, Inc.
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Project ID # FC32

This presentation does not contain any proprietary, confidential, or otherwise restricted information
Overview

Timeline
• 3 year program
• Actual start: 7/1/2007
• Planned end: 6/30/2010

Barriers
• Barriers addressed
  – (D) Water Transport within the Stack
  – (G) Start-up and Shut-down Time and Energy/Transient Operation

Budget
• Total project funding
  – $4.970 Million (DOE)
  – $2.160 Million (Nuvera)
• FY07 funding = $619K
• FY08 funding = $1,881K

Partners
• W. L. Gore & Associates
• SGL Technologies
• University of Delaware
• Los Alamos National Lab
Objectives

The **objective** of the CIRRUS Program is to demonstrate a PEM fuel cell stack meeting DOE 2010 cold start targets:

Table 3.4.3 Technical Targets: 80-kW, (net) Transportation Fuel Cell Stacks Operating on Direct Hydrogen

<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>seconds</td>
<td>2</td>
<td>20</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>@ −20°C ambient temperature</td>
<td>seconds</td>
<td>&lt;1</td>
<td>&lt;10</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>@ +20°C ambient temperature</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start up and shut down energy †</td>
<td>MJ</td>
<td>N/A</td>
<td>7.5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>from −20°C ambient temp</td>
<td>MJ</td>
<td>N/A</td>
<td>N/A</td>
<td>1</td>
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<tr>
<td>from +20°C ambient temp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unassisted start from low temperature †</td>
<td>ºC</td>
<td>N/A</td>
<td>-20</td>
<td>-40</td>
<td>-40</td>
</tr>
</tbody>
</table>

Specific **FY08 goals** include:

• Achieving -20°C cold start target respecting the energy budget
• Identifying electrochemical material freeze cycle aging modes
FY08 Milestones

• **Achievement of -20C startup goal**
  – Reference Stack Technology
  – Conditioned gas temperatures (environmental chamber)
  – Optimized procedure using dynamic model
  – System-compatible strategy
  – >50% rated power in 30 seconds
  – Auxiliary energy use < 5 MJ

• **Identification of freeze/thaw decay/failure modes**
  – Detailed post-test analyses of freeze cycled MEAs and GDM
  – MEA stress evaluation from -40C to 65C at variable RH

• **Articulation of 2010 Technology**
  – Performance specifications & design attributes
  – Freeze start performance forecast
Approach

Program allows for one iteration:

Progress in stack thermal mass reduction is essential for meeting freeze start targets.
Open flowfield is hypothesized as favored for meeting PEMFC freeze start requirements.
Laboratory Setup

- Reference technology
- 32 cells, 360 cm² AA/cell
- Commercial freezer

- 30 kWe Greenlight station
- Fully automated
- Adding env'l chamber Q3 08

Primary testing infrastructure has been fully commissioned, with 36 freeze tests to date
Dynamic modeling offers important guidance for selection of operating protocols
Stack Testing

Startup target of 50% rated power in 30 seconds has been achieved using Reference Technology.

Reference Technology
32 cell stack
360 cm² active area
Cell stability through -20C start was acceptable -- depression of end cell voltages is evident.
Energy Accounting

\[ W_{\text{Tot}}(t) = W_{\text{AirCompressor}}(t) + W_{\text{H2Pump}}(t) \]

\[ E_{\text{Tot}} = \int_{t_0}^{t} W_{\text{Tot}}(t)[\text{MJ}] \]

Estimated energy use over complete start/shutdown cycle = 5.6 MJ approaching DOE target (previously 26 MJ)
Materials Development

Program targeting higher durability MEAs & thinner diffusion layers

Reference MEA

Polarization Curve
Reference Technology

Cell Potential (mV)

Current Density (A/cm²)

Resistance (mOhm·cm²)

SGL Gas Diffusion Material

Material

10BB
25BC
100BC

10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0

430 μm
220 μm
150 μm

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Temperature dependence of Reference MEA conductivity under various shutdown approaches has been measured.
Key target for 2010 stack technology will be a Rating Current Density (RCD) of 2.0 A/cm²
Future Work

- Install and commission environmental chamber
- Develop 2d model to afford startup procedure optimization
- Analyze post-test material sets to understand decay modes
- Improve material sets (MEA durability, GDM thickness)
- Measure MEA stresses and refine process constraints
- Develop & validate 2010 Stack Technology
Summary

• 2010 startup goal of 50% rated power in 30 seconds has been achieved (32 cell, full format Reference Technology stack)
• Energy budget target of 5 MJ currently exceeded by 12%, will be met with further optimization
• Next generation 2010 material sets are in active development, to be informed by forthcoming post-test analyses
• 2010 Technology, on account of higher performance and reduced thermal mass, will meet targets from start temperatures < -20C

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