Update on SOFC Test Vehicle Development and Implementation


Pacific Northwest National Laboratory
Richland, WA 99352

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Presentation Outline

- Conclusions
- Background
- Objectives
- Approach
- Test Vehicle Design
- Implementation: Vehicle Assembly & Test Results
- Future Work
- Conclusions
- Acknowledgements
Conclusions

- A stack test vehicle based on 50mm x 50mm cells (40mm x 40mm cathode) has been developed for use by PNNL and other SECA participants.

- Details of test vehicle components, including CAD files of the metal components, will be made available to interested SECA participants.

- First test is in progress (initiated 7/30/07):
  - 800°C with InDEC anode-supported cell, refractory glass seal, and Mn-Co spinel-coated SS441 stainless steel “interconnects”
  - High OCV indicates effectiveness of seals
  - Degradation observed during isothermal testing at 0.7V at ~800°C
Background

SECA Core Program Testing at Sub-stack Level

- Materials Characterization
  - XRD, SEM, EDS, TEM, XPS, TGA, DSC, PSA, dilatometry, electrical conductivity, single & dual atmosphere oxidation
- Multiple Component Tests
  - Button cell testing
  - ASR testing of interconnect/cathode contact/cathode structures
  - Electrical testing and leak testing of seal/interconnect and cell/seal/interconnect structures

Next Step: “Stack” Testing

- Advantage: Higher degree of relevance to SECA Industry Team cellsstacks
- Challenge:
  - Multiple components & phenomena, so results more difficult to interpret
Objectives

- Develop SOFC stack test fixture on behalf of SECA Core Technology Program (CTP)
- Evaluate/validate new materials, fabrication processes, and design concepts under realistic stack conditions
  - Larger cell size ($\geq 50\text{mm} \times \geq 50\text{mm}$)
  - Complete stack functionality (cell, seals, interconnects)
  - Validate materials/concepts developed by PNNL and other SECA CTP participants
- Make fixture design available to other SECA participants for implementation at their facilities
- Facilitate technology transfer from SECA CTP to SECA Industry Teams
  - Bridge the gap between small-scale CTP tests (e.g., button cells) and SECA industry team stacks
Approach

Design
- Initial fixture design provided by LBNL, McCallister Technical Services, and Lane Wilson
- Design modified by PNNL to incorporate glass seals, cell-in-frame design concepts

Implementation
- Parts
  - Cells purchased from H.C. Starck (InDEC)
    - 50 mm x 50 mm ASC3 anode-supported cells; LSM/YSZ cathode; ~$190 each
  - Other components (interconnects, cell frame, seals) fabricated at PNNL
    - 441 steel provided by Allegheny Technologies, Inc.
- Assembly and testing at PNNL
  - Electrochemical performance evaluation via I-V and EIS analysis
  - Post-test analysis via optical microscopy, XRD, SEM, EDS, TEM, XPS, etc
  - Compare stack results with results from tests on individual materials and sub-stack structures, as well as modeled results
Initial Design
Thermal-Fluid-Electrochemical modeling analysis was performed for the 50 mm x 50 mm cell. Both serpentine and parallel rib configurations were evaluated. No pressure drop issues in either case (at 50 mm x 50 mm scale). The analyses indicated that, in either case, stack would operate “isothermally” (<5 °C maximum temperature difference).
Modified Design of Steel Components

CAD files will be fine-tuned and then made available to interested CTP participants.
## H.C.Starck “InDEC” Cells

Anode-supported Cells, “Type 3”

<table>
<thead>
<tr>
<th>Component</th>
<th>Material Details</th>
<th>Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anode support</td>
<td>Porous NiO/YSZ</td>
<td>520-600 μm</td>
</tr>
<tr>
<td>Anode</td>
<td>Porous NiO/YSZ</td>
<td>5-10 μm</td>
</tr>
<tr>
<td>Electrolyte</td>
<td>Dense 8YSZ</td>
<td>4-6 μm</td>
</tr>
<tr>
<td>Cathode</td>
<td>Porous 8YSZ/LSM – LSM Double Layer</td>
<td>30-40 μm</td>
</tr>
<tr>
<td>Cell Dimensions</td>
<td>50 mm x 50 mm x 525-625 μm</td>
<td>(+/- 0.2 mm)</td>
</tr>
<tr>
<td>Cathode Dimensions</td>
<td>40 mm x 40 mm</td>
<td></td>
</tr>
</tbody>
</table>
At 750°C, 0.85 V * 325 mA/cm² ≈ 275 mW/cm²
Cell-in-Frame

1.5 mm thick, 441 steel
Cathode side is coated w/ Mn-Co Spinel
**Cathode Plate**

4.5 mm thick 441 steel (coated with Mn-Co spinel)

Anode plate is similar, except has recess for Ni mesh
Heat Exchangers

- Air & fuel heat exchangers fabricated from Inconel 600
- Cathode heat exchanger aluminized to minimize Cr volatility
Stack Test Assembly

Air heat exchanger
Cell-in-frame
Fuel heat exchanger
Cathode plate
Anode plate

4 Furnace T/C; 2 Stack T/C (fuel outlet; air outlet)
Components of Initial Test

Stack Test Cross-Section: Not to Scale

- Perimeter Seals: Mica/Ag Hybrid
- Cell-to-Frame Seal: Refractory Glass
- Cathode plate: 441 Steel w/ Mn-Co Spinel Coating
- Frame
- Anode plate: 441 Steel
- Nickel Mesh
- Nickel Oxide Contact Paste
- LSM-20 Contact Paste
Results from Initial Test

- Cell-to-frame seal: Refractory glass, 950°C
- Stack fabrication: 900°C, 2 hours
- Stack operating temperature: ~800°C
- High OCV indicates effective sealing
Results from Initial Test: Power Density at 0.7 V

Power Density (W/cm²) vs. Time (h)

- SS441; YSO77x1; spinel; H-micax4
- 97%H₂ 450 sccm; air 900 sccm
- 809°C
Future work

Complete first stack test; perform post-test analysis

Variables to be evaluated in future experiments:
- Seals: Refractory glass seals, “Soft” glass seals, composite glass seals, reactive air brazes
- Coatings: Mn-Co spinel, aluminization of interconnect/frame seal areas; NETL-Albany Ce treatment
- Alloys: Alternative stainless steels, e.g., surface/bulk modified 441
- New cathodes & cathode contact Materials
- Thermal Conditions: Isothermal, thermal cycling, imposed thermal gradients

Compare experimental results with sub-stack tests and modeled results

Expand test capability (multiple test stands)

Pursue development of multiple cell/larger cell stack test fixtures
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Acknowledgements

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Initial fixture design provided by LBNL, Lane Wilson, and McCallister Technical Services

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Additional PNNL contributors: Gary Maupin, Jared Templeton, Joshua Templeton, Kerry Meinhardt, Kevin Simmons
Results from Initial Test: Fuel Utilization

![Graph showing fuel utilization and power density]