Update on SOFC Test Vehicle Development and Implementation

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Presentation Outline

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- Background
- Objectives
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- 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):
  - 800ºC 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 cells/stacks
  - Challenge:
    - Multiple components & phenomena, so results more difficult to interpret

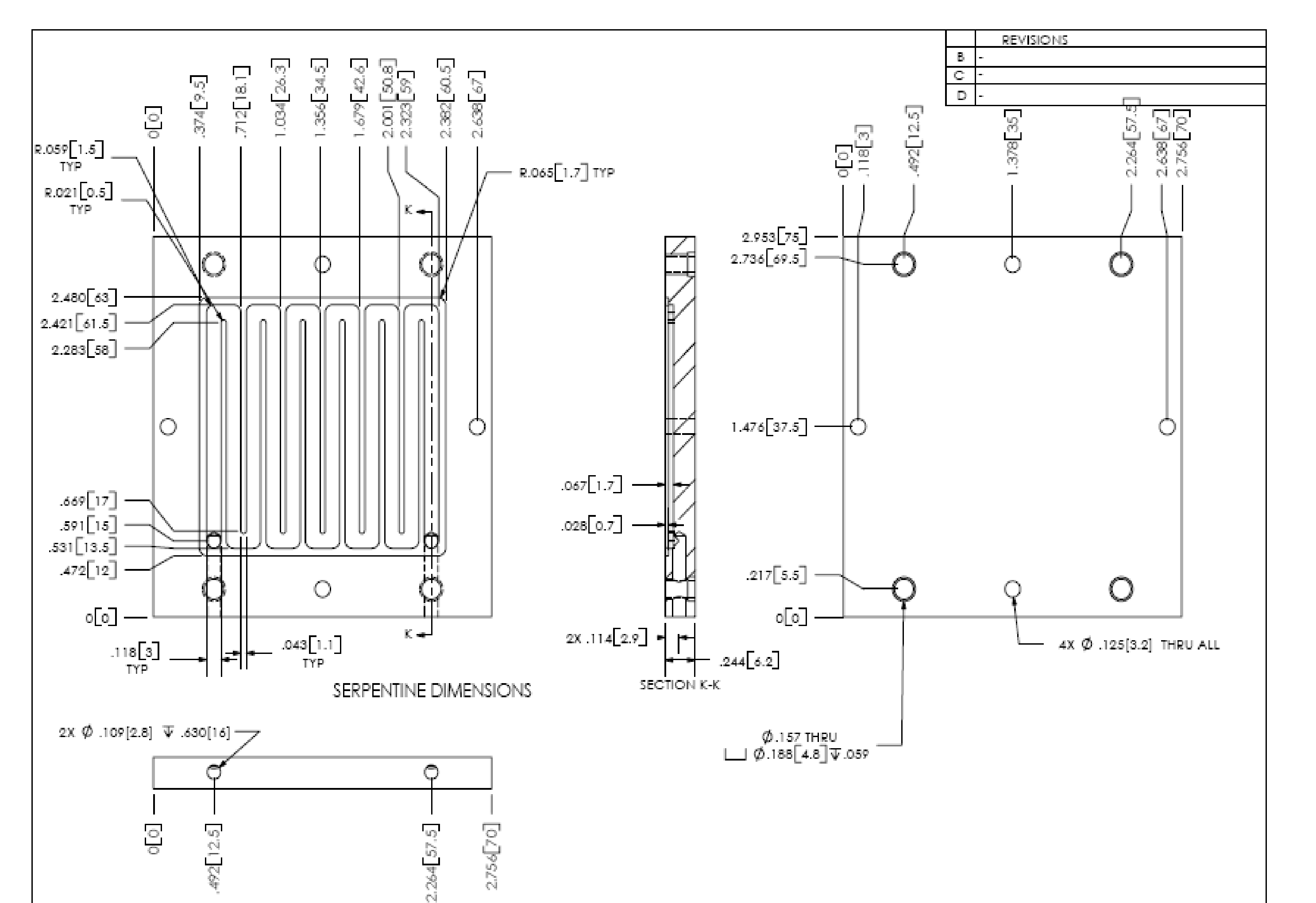
Objectives

- 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 (≥50mm x ≥50mm)
  - 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

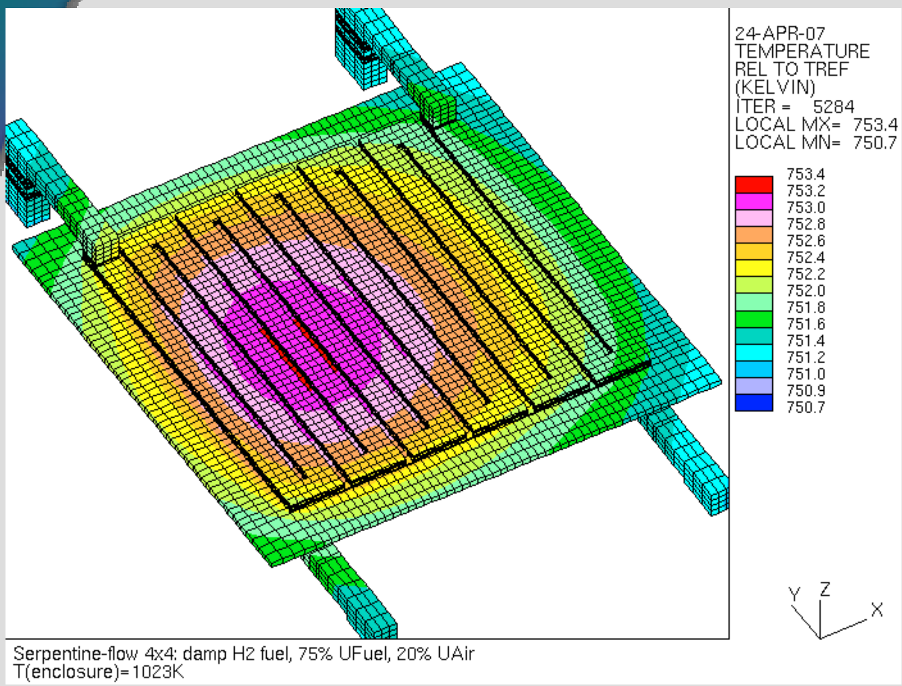
Approach

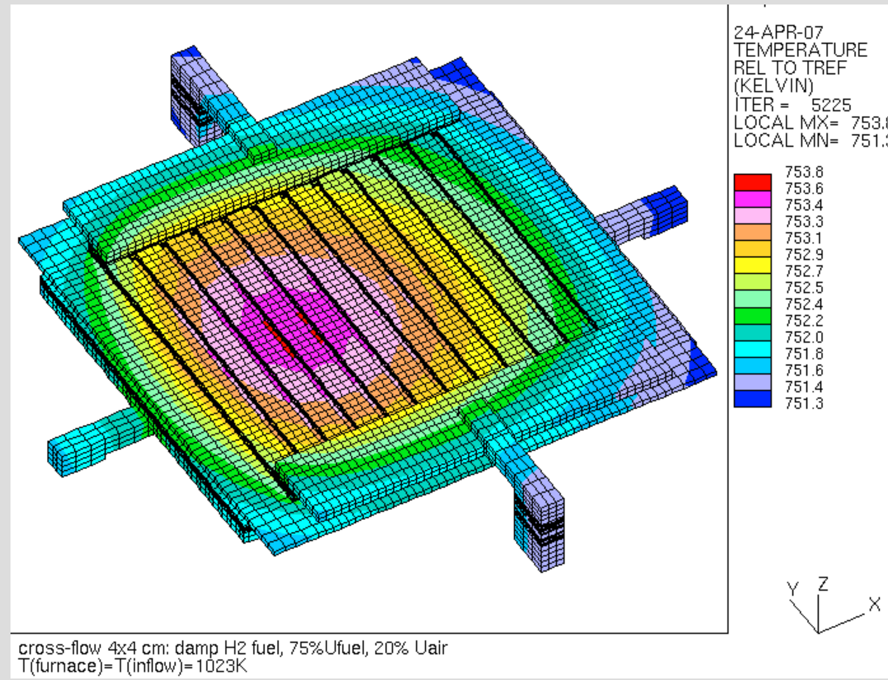
- Design
  - Initial fixture design provided by LBNL, McCallister Technical Services, and Lane Wilson
  - Design modified by PNNL to incorporate glass seals, cell-in-frame design concepts
- Implementation
  - Parts
    - Cells purchased from H.C. Starck (InDEC)
      - 50 mm x 50 mm ASC3 anode-supported 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



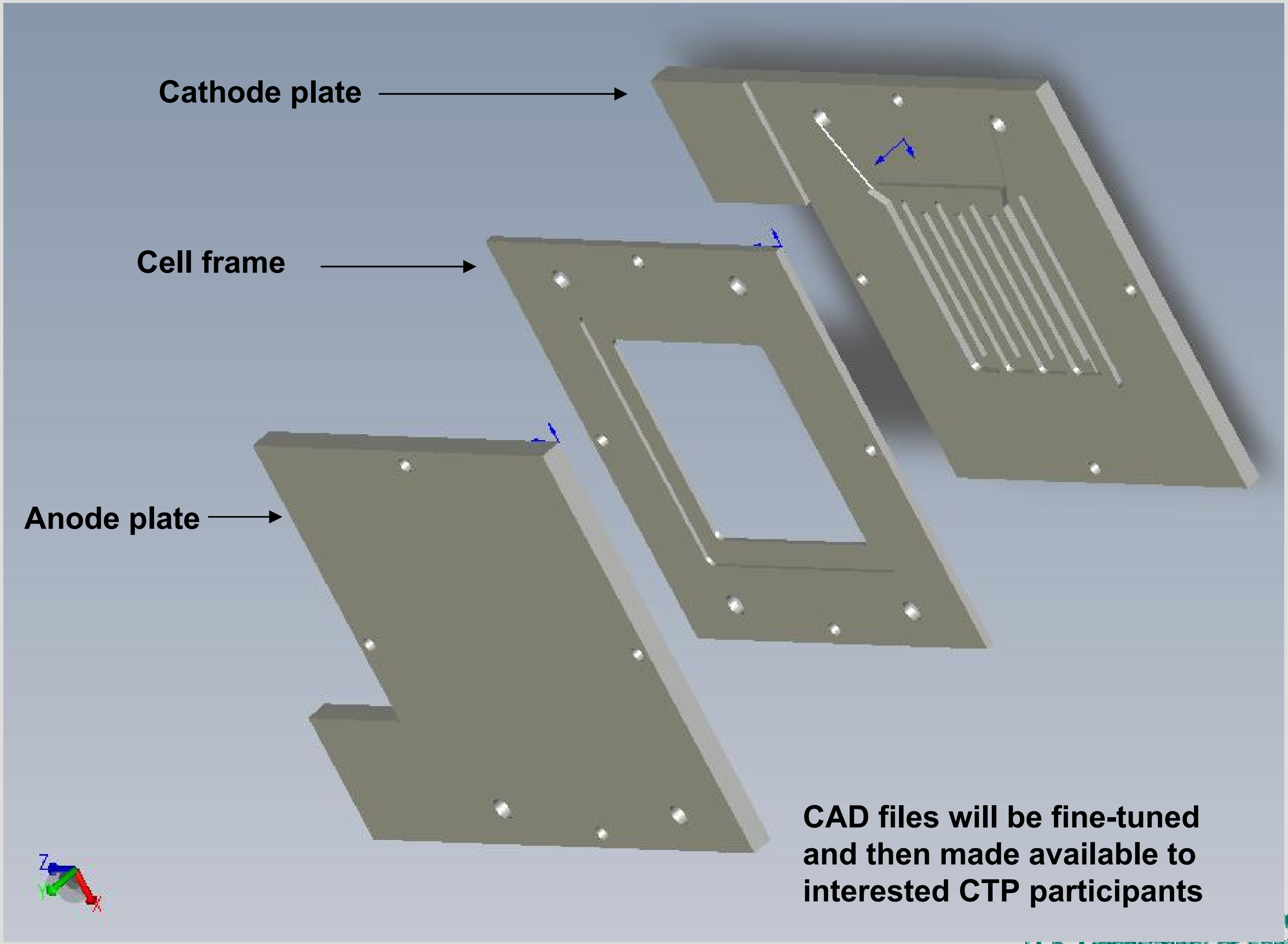
Modeling of stack test fixture





- **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

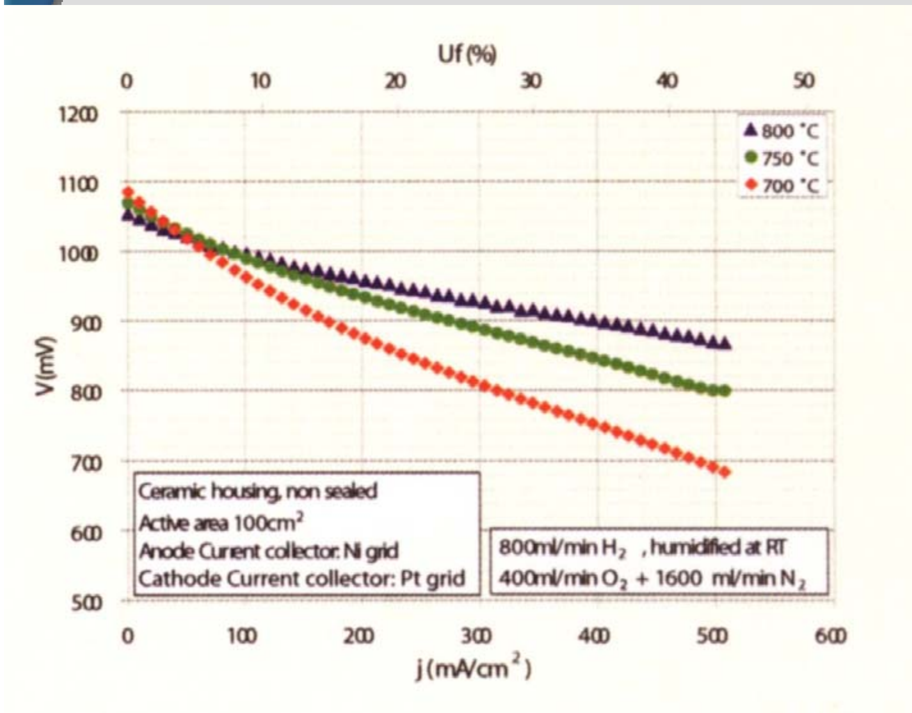


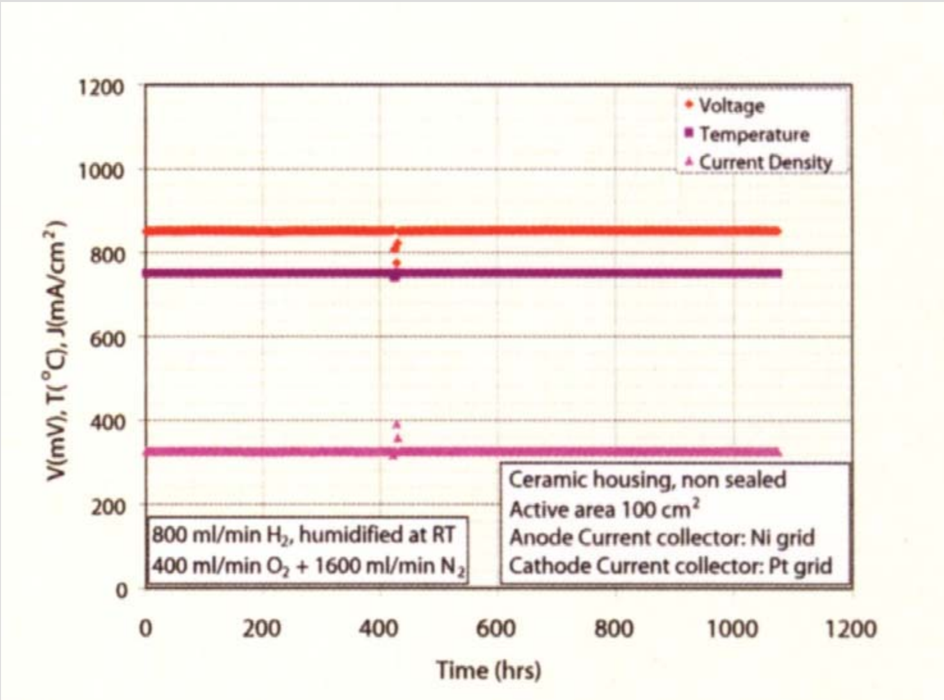
CAD files will be fine-tuned and then made available to interested CTP participants

H.C.Starck "InDEC" Cells

Anode-supported Cells, "Type 3"		
Anode support	Porous NiO/YSZ	520-600 μm
Anode	Porous NiO/YSZ	5-10 μm
Electrolyte	Dense 8YSZ	4-6 μm
Cathode	Porous 8YSZ/LSM – LSM Double Layer	30-40 μm
Cell Dimensions	50 mm x 50 mm x 525-625 μm	(+/- 0.2 mm)
Cathode Dimensions	40 mm x 40 mm	

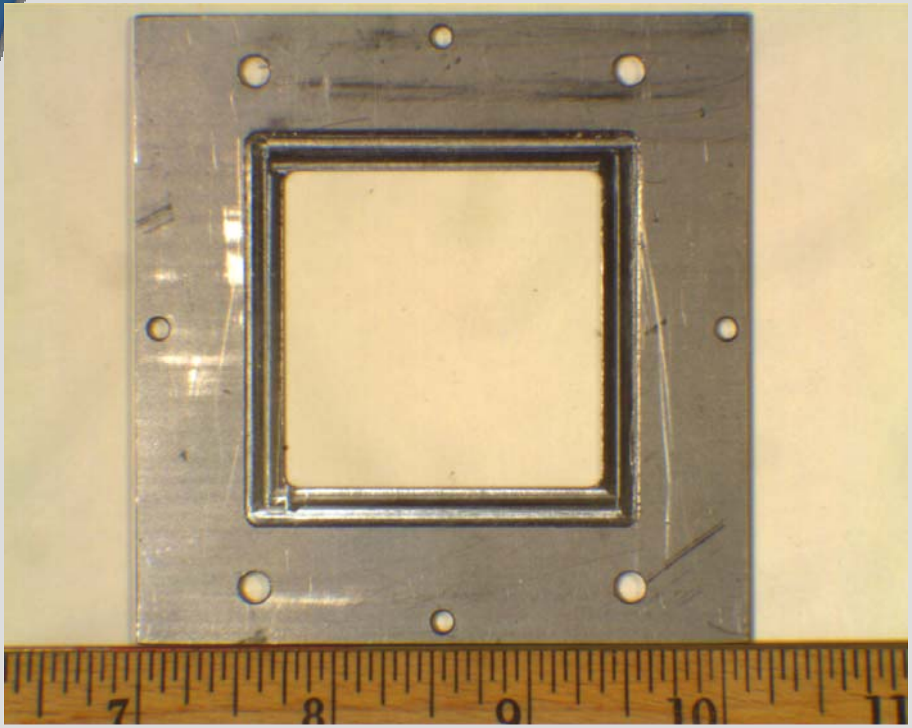
H.C.Starck "InDEC" Cells

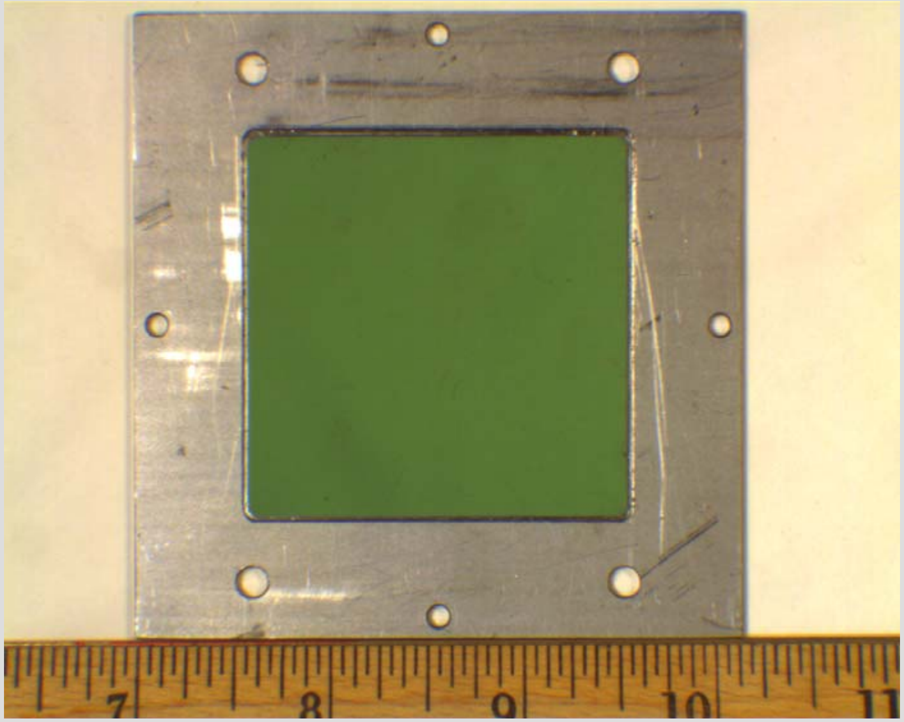




At 750ºC, 0.85 V * 325 mA/cm² ≈ 275 mW/cm²

Cell-in-Frame

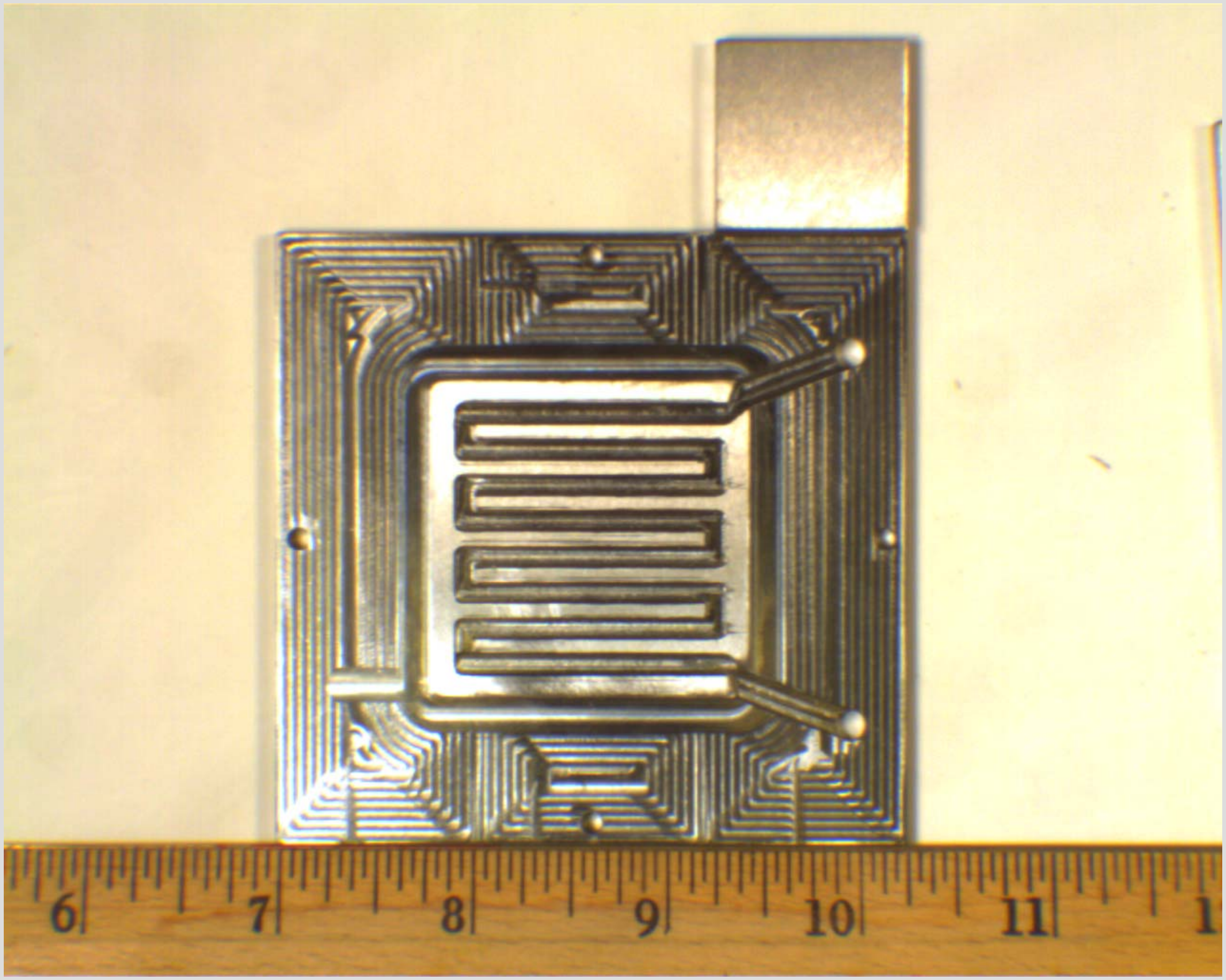




1.5 mm thick, 441 steel

Cathode side is coated w/ Mn-Co Spinel

Cathode Plate

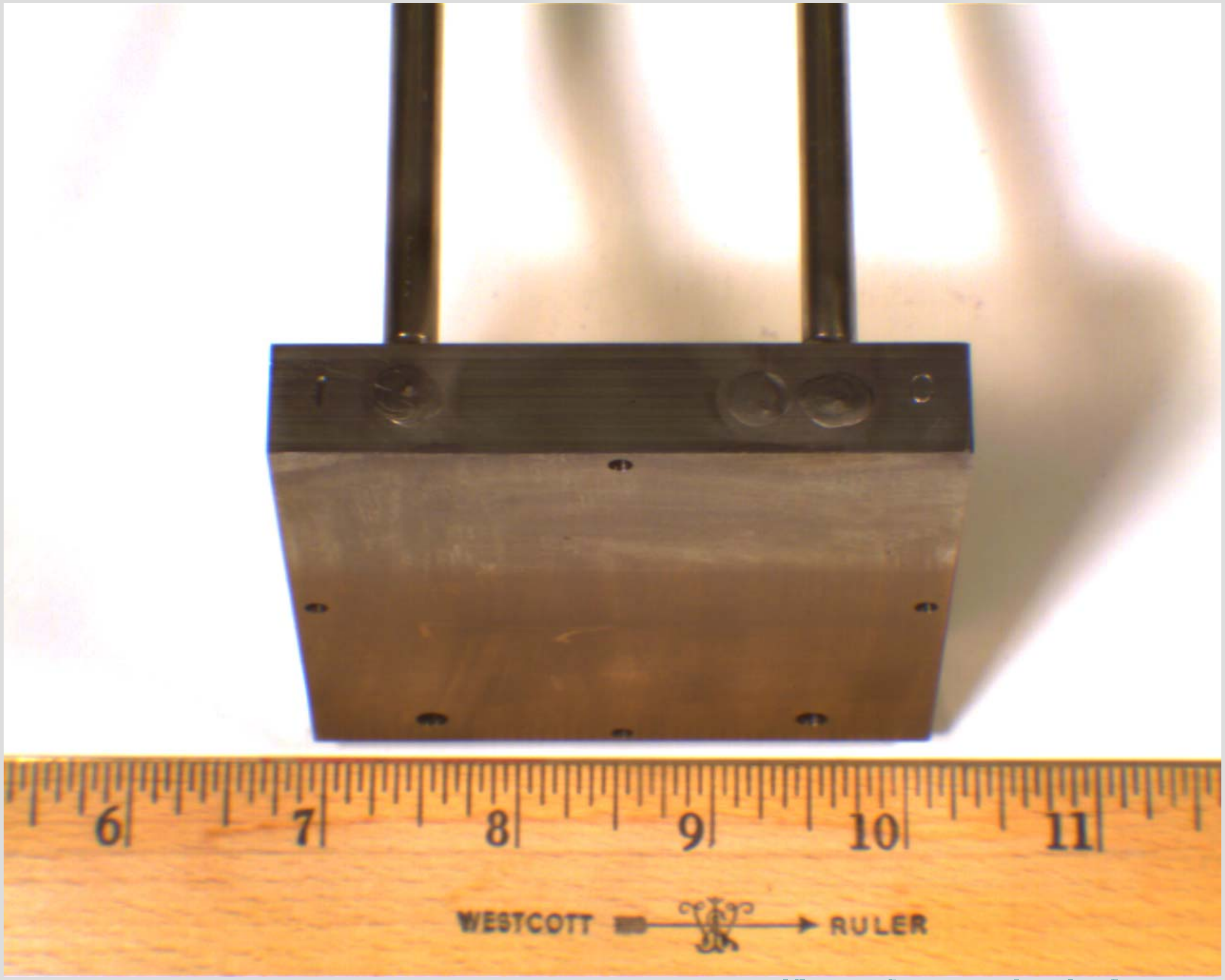


4.5 mm thick 441 steel (coated with Mn-Co spinel)

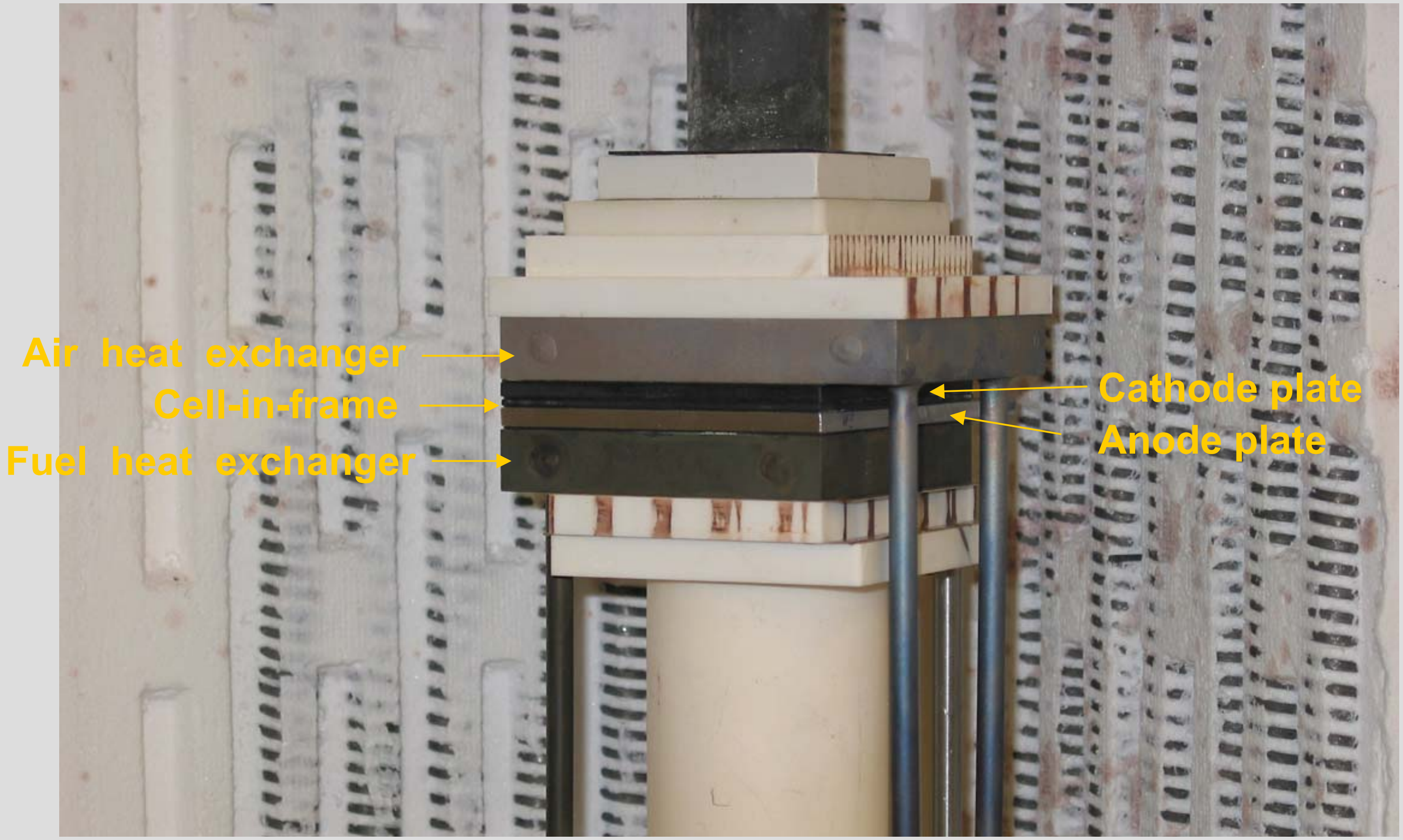
Anode plate is similar, except has recess for Ni mesh

Heat Exchangers

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



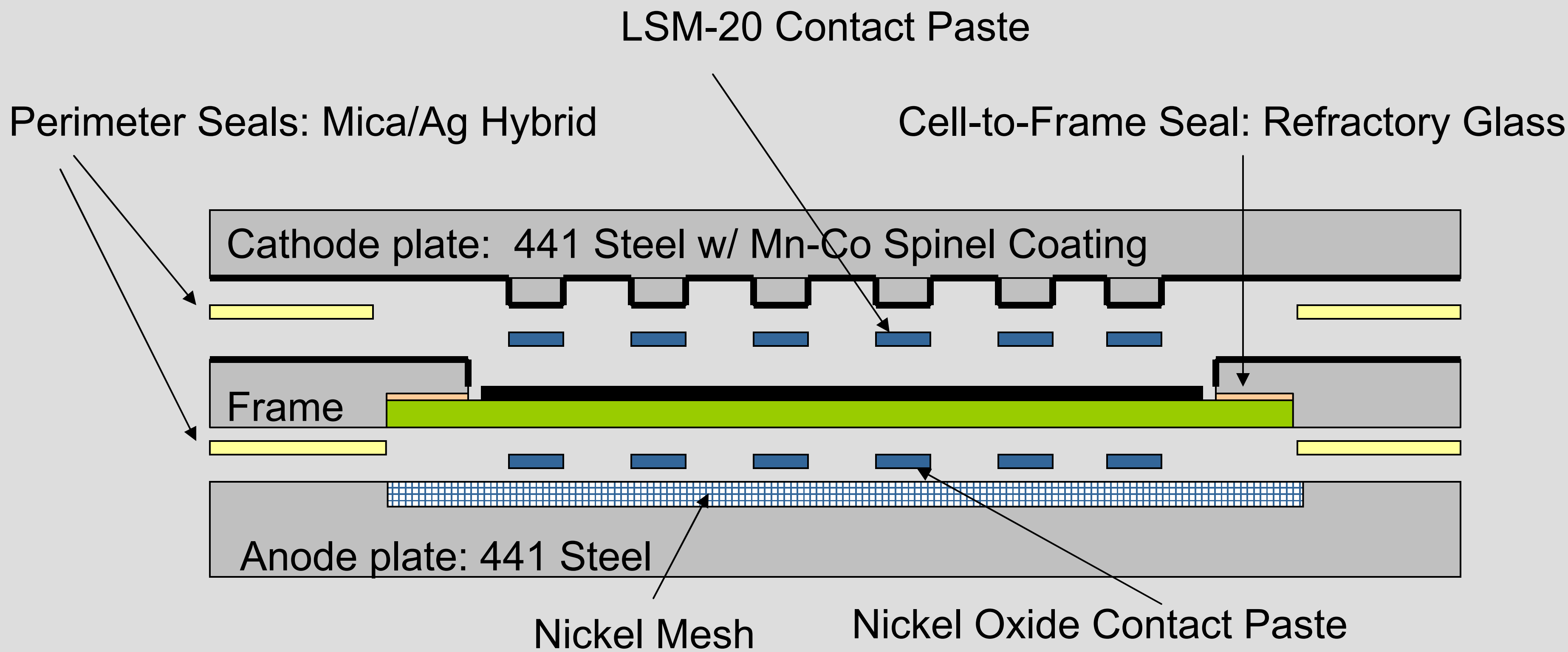
Stack Test Assembly



4 Furnace T/C; 2 Stack T/C (fuel outlet; air outlet)

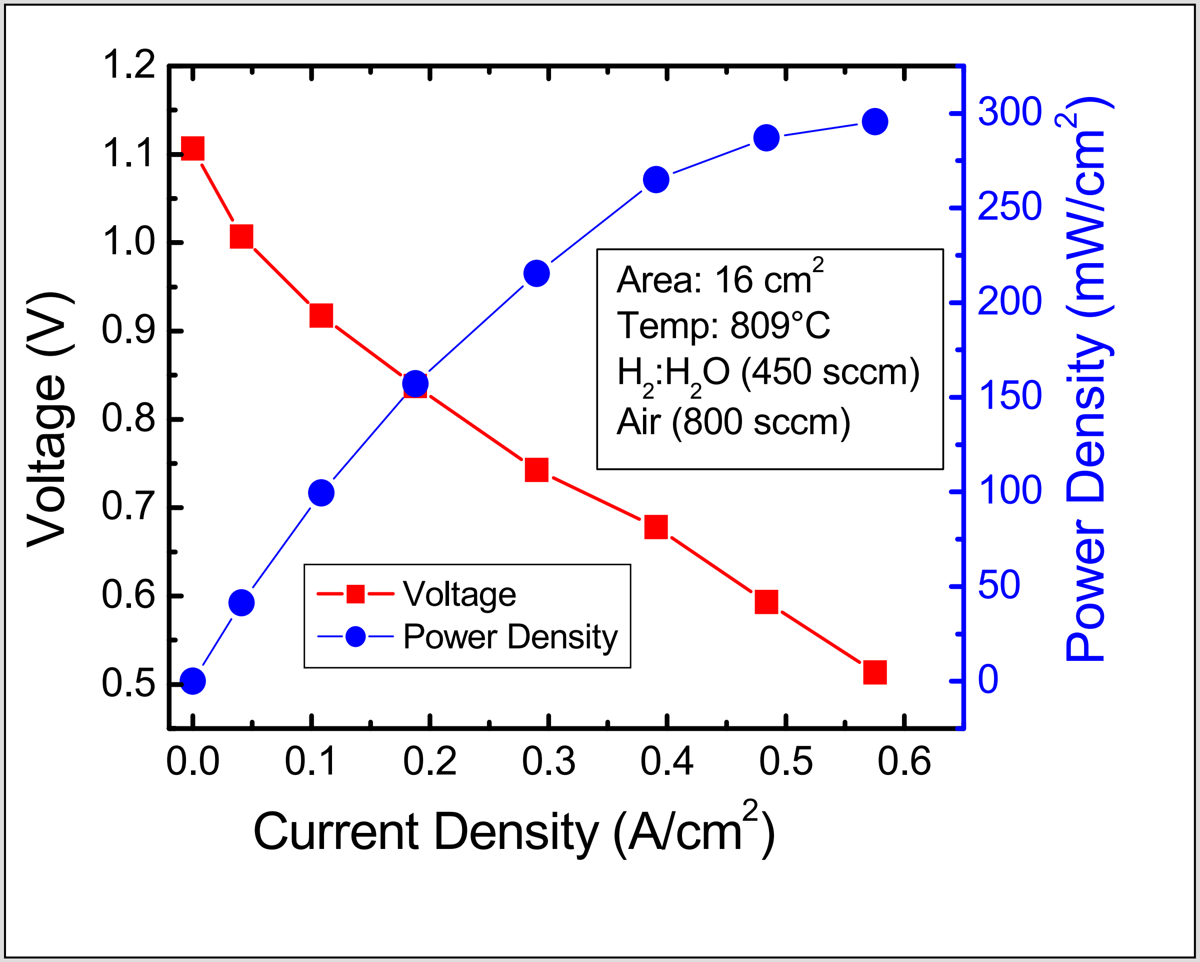
Components of Initial Test

Stack Test Cross-Section: Not to Scale

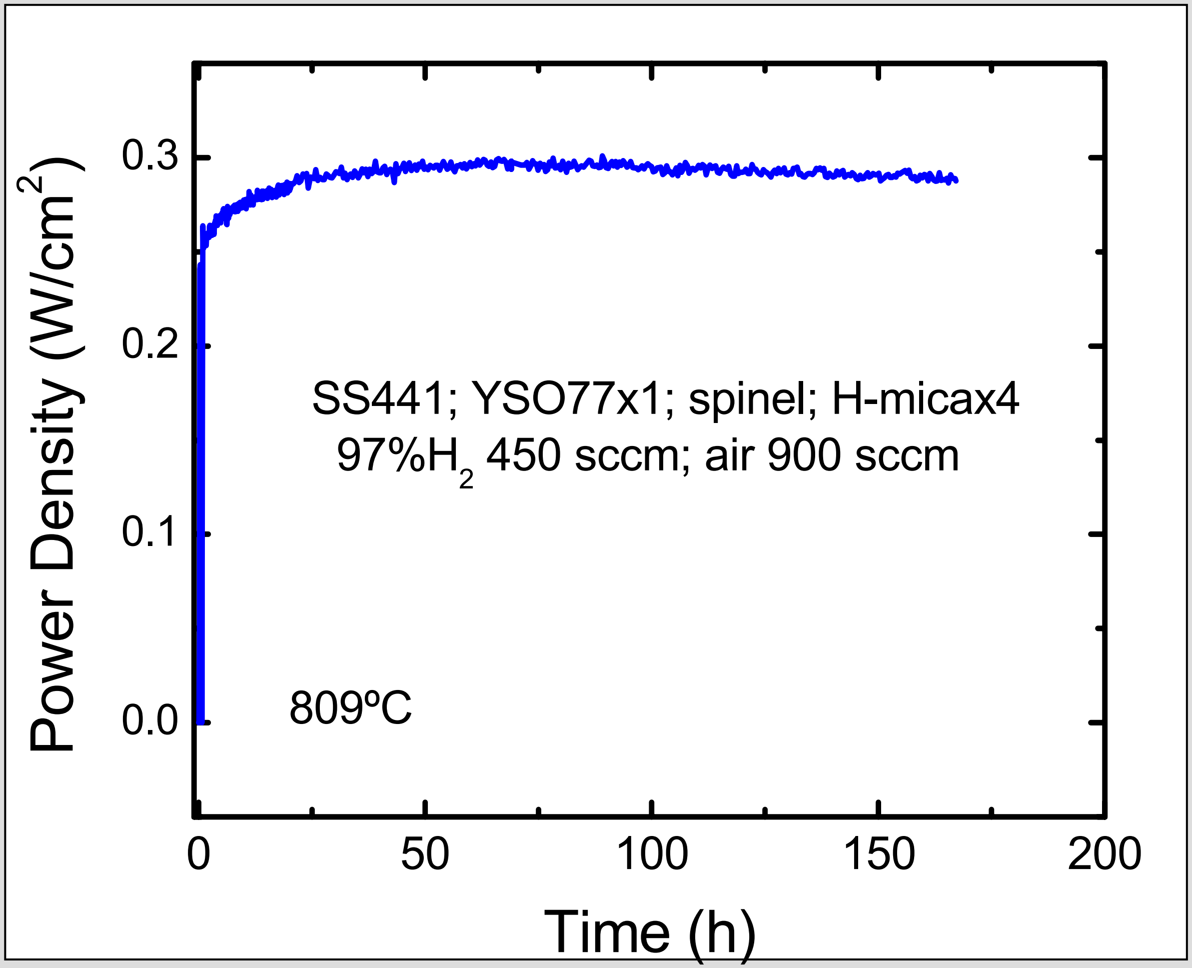


Results from Initial Test

- Cell-to-frame seal: Refractory glass, 950ºC
- Stack fabrication: 900ºC, 2 hours
- Stack operating temperature: ~800ºC
- High OCV indicates effective sealing



Results from Initial Test: Power Density at 0.7 V



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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- Jim Rakowski at Allegheny Technologies, Inc.
- Additional PNNL contributors: Gary Maupin, Jared Templeton, Joshua Templeton, Kerry Meinhardt, Kevin Simmons

Results from Initial Test: Fuel Utilization