

SECA Program Review

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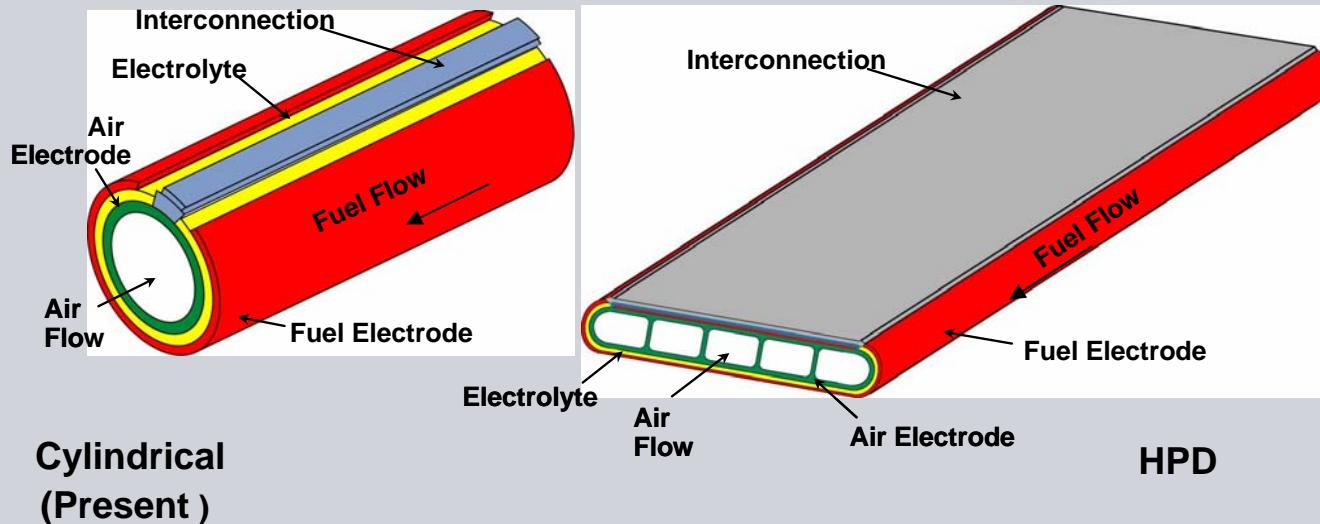
**Presented at the 8th Annual SECA Workshop
San Antonio, TX
August 7-9, 2007**

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Siemens PG SFC**

Significant Results

- Demonstrated significantly higher power density relative to tubular cells through materials and cell design improvements
- Demonstrated excellent voltage stability of Phase 1 system over 6300 hours of operation
- Met or exceeded all phase 1 requirements
- Fabricated and tested next generation high power density cells - Delta design
- Developed concepts for stack design with Delta cells

High Power Density (HPD) Cell Concept



Cylindrical
(Present)

HPD

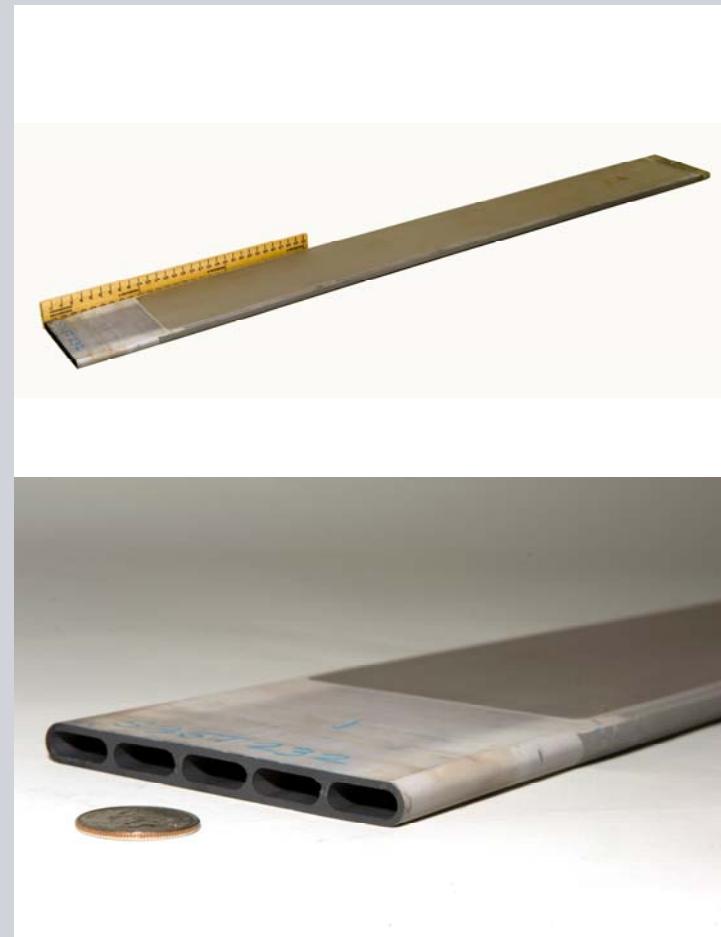
- Maintains seal-less design
- Potential to eliminate air feed tubes
- Reduction in ohmic resistance
- Increase in cell power density
- More compact stack

First Generation HPD Cells

- Selected HPD5 (five channels) as first generation HPD cell to develop cell and bundle fabrication processes and confirm benefits relative to tubular cells
- Current HPD5 cell active length is 75 cm compared to 150 cm for tubular cells (maintains similar active area)

Active Length: 75 cm

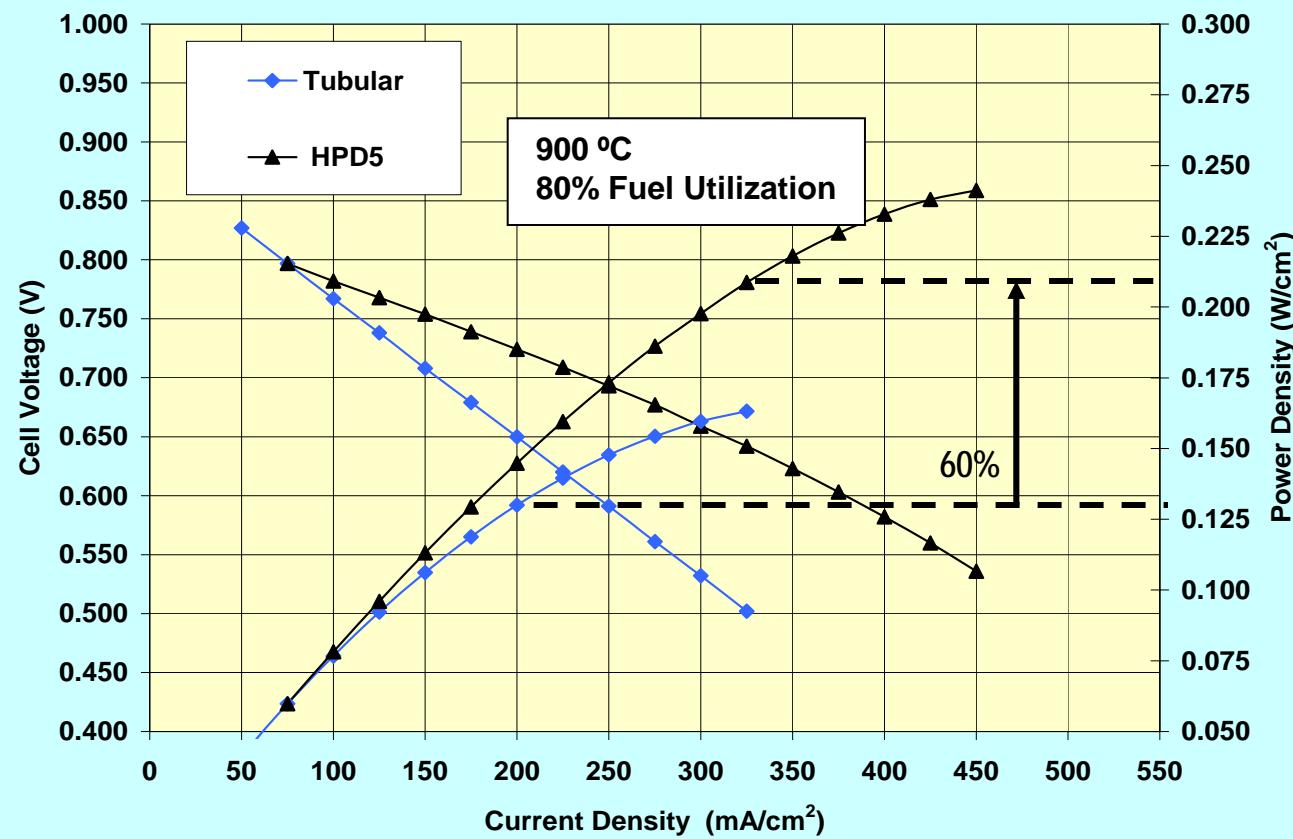
Active area: ~900 cm²



Cell Performance at 900°C – HPD5 VS. Tubular

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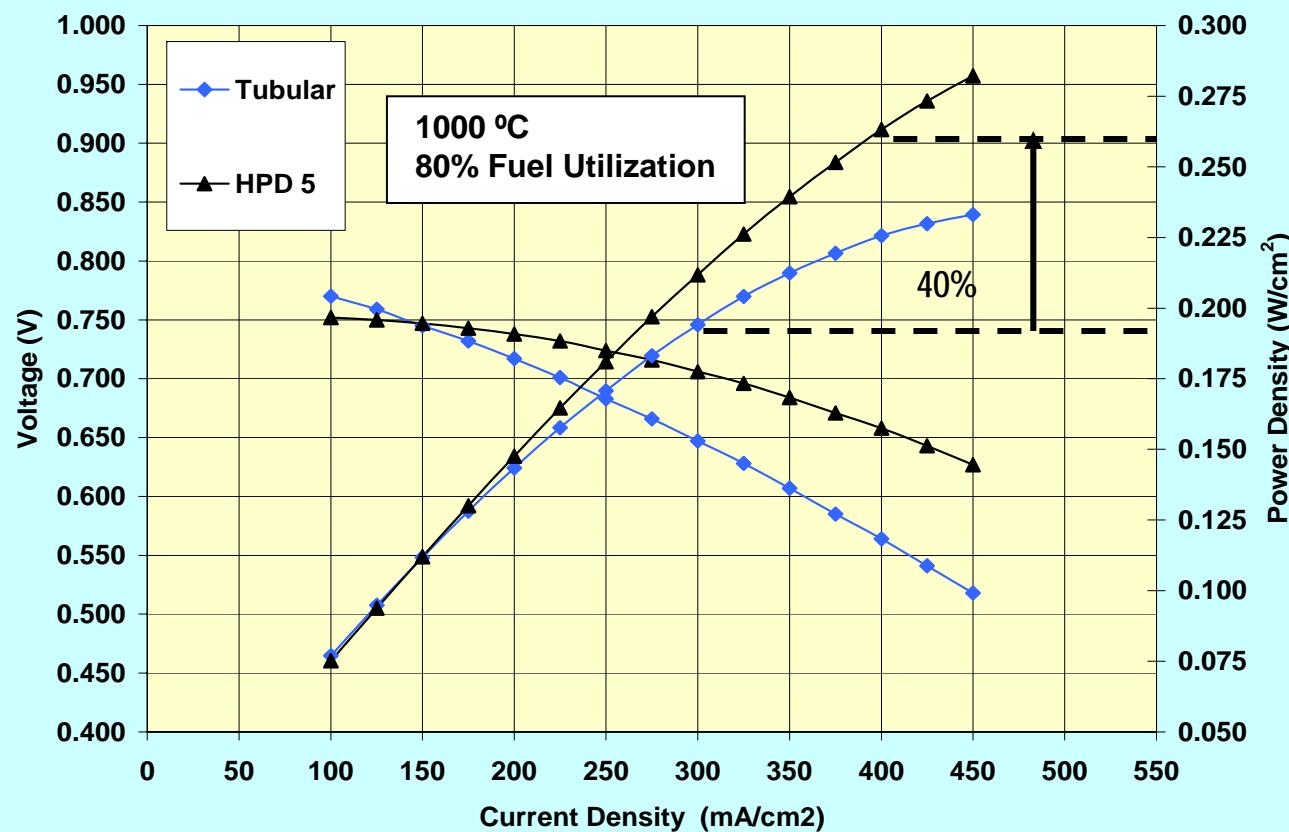
~60% power density enhancement for HPD5 relative to tubular cell at 0.65 V



Cell Performance at 1000°C – HPD5 VS. Tubular

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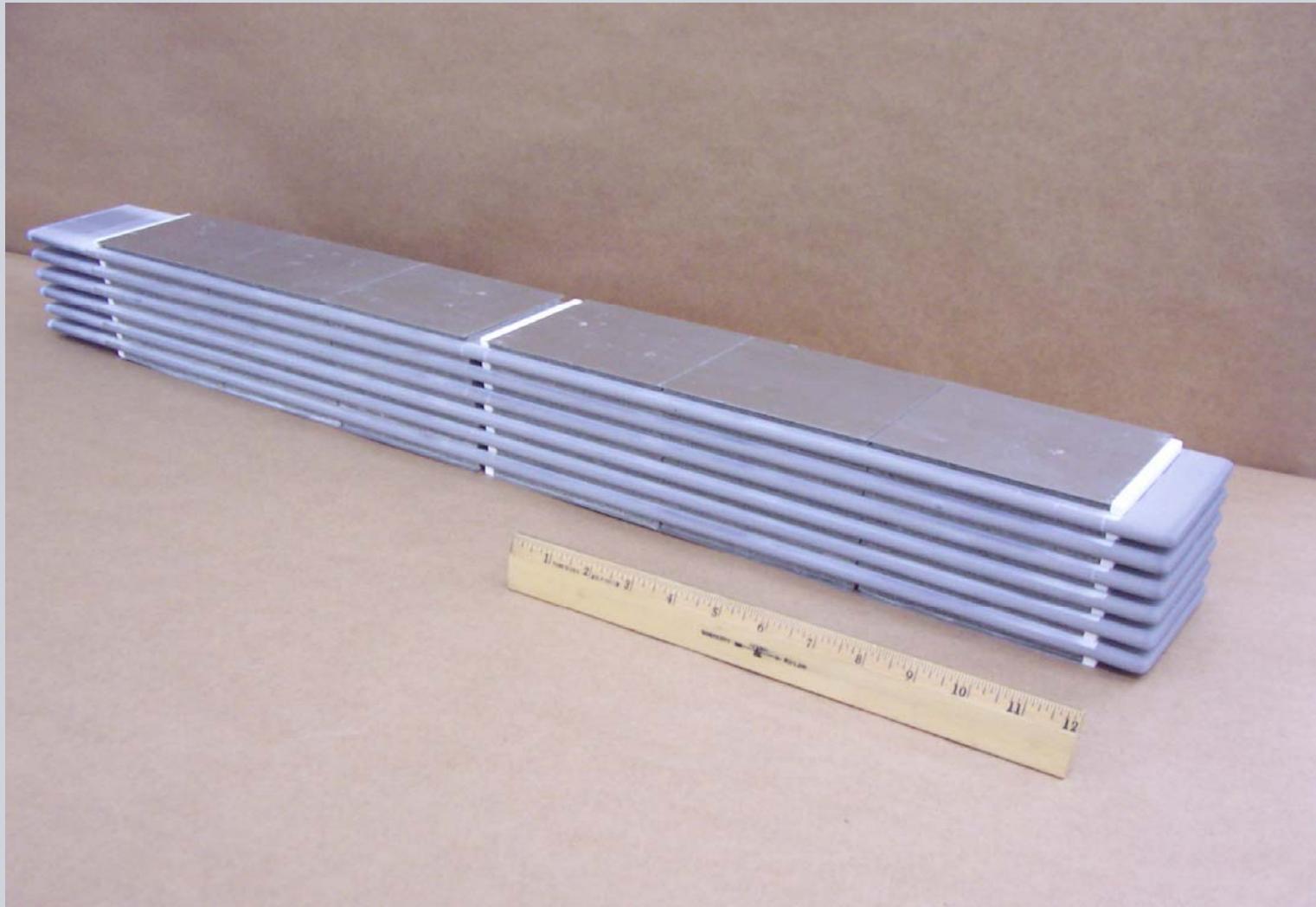
~40% power density enhancement for HPD5 relative to cell at 0.65 V



HPD5 Cell Bundle - 6 Cells

**Building
block for a
generator**

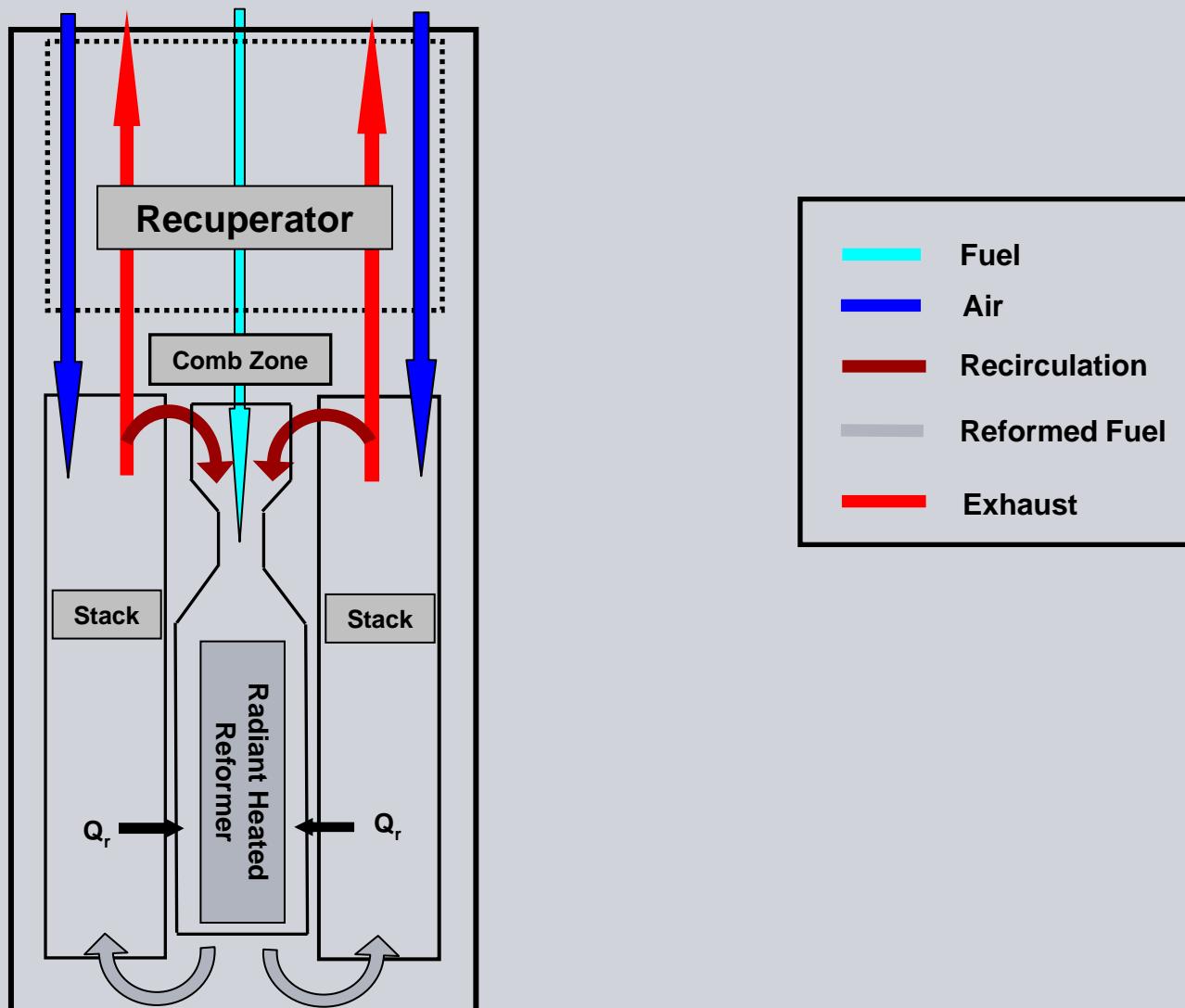
**Active cell
length:75 cm**



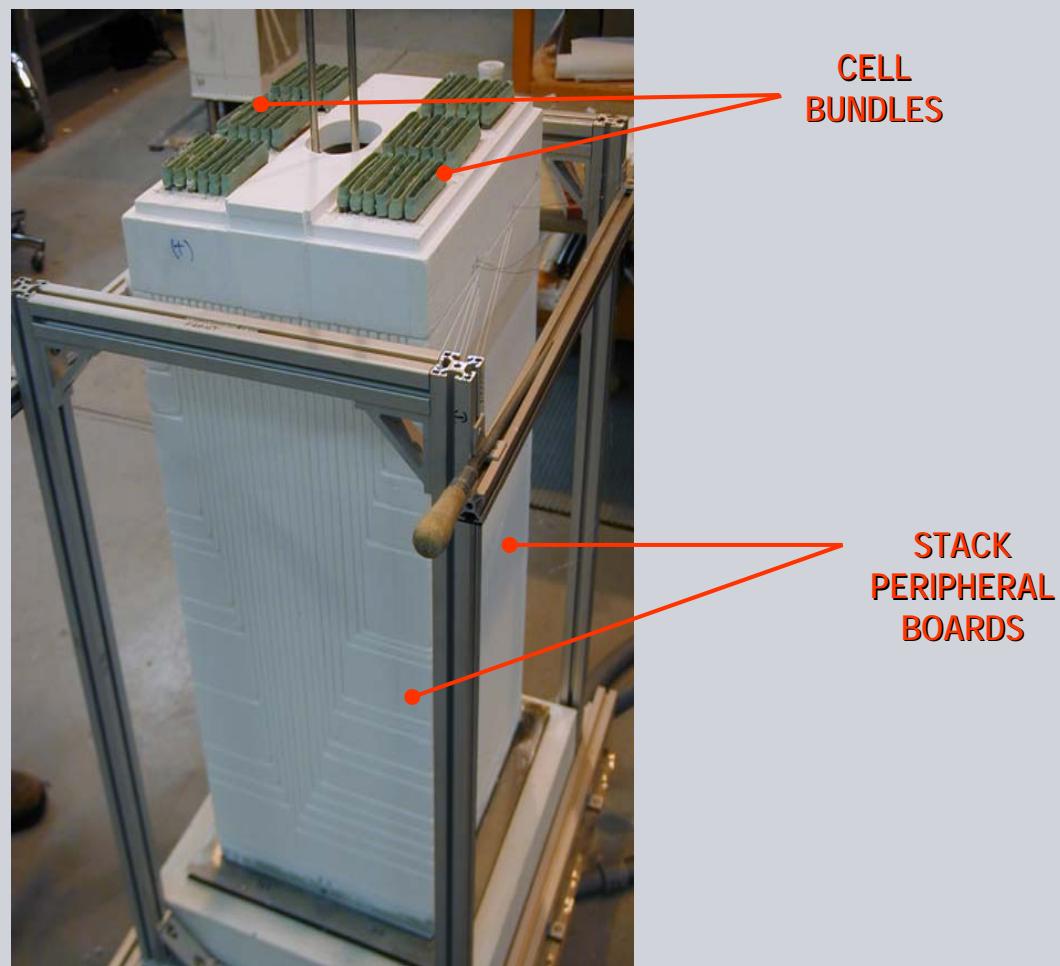
Phase 1 Prototype System

- 36 HPD5 cells – six bundles of six cells each
- Internal recuperator
- Internal fuel reformer
- Fuel: Pipeline natural gas
- Fully integrated power system

Prototype - Flow Schematic

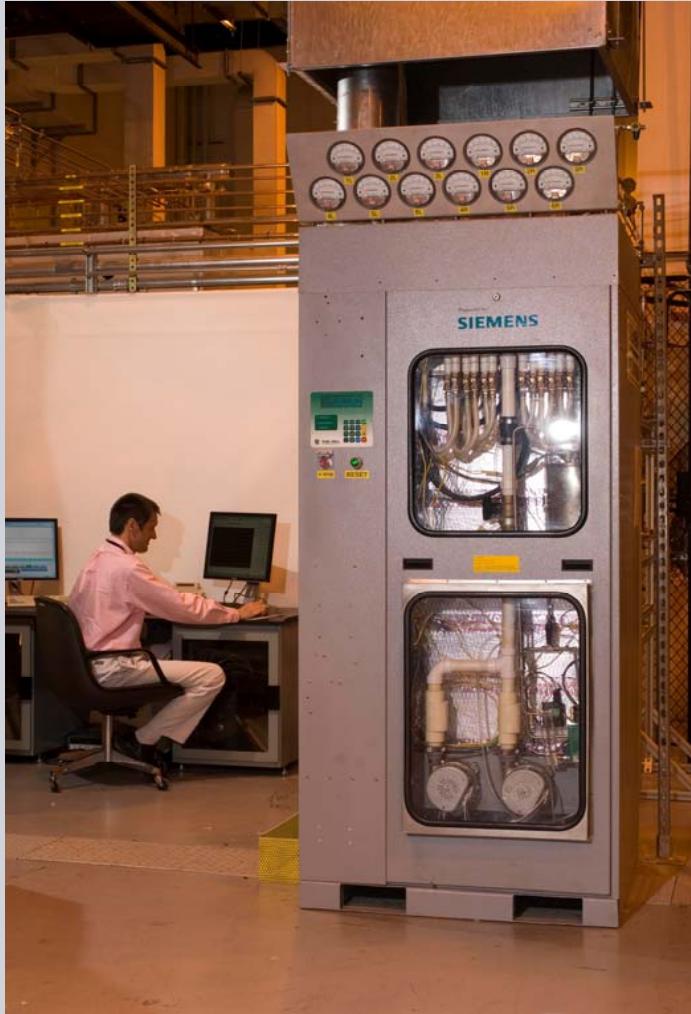


Prototype Cell Stack



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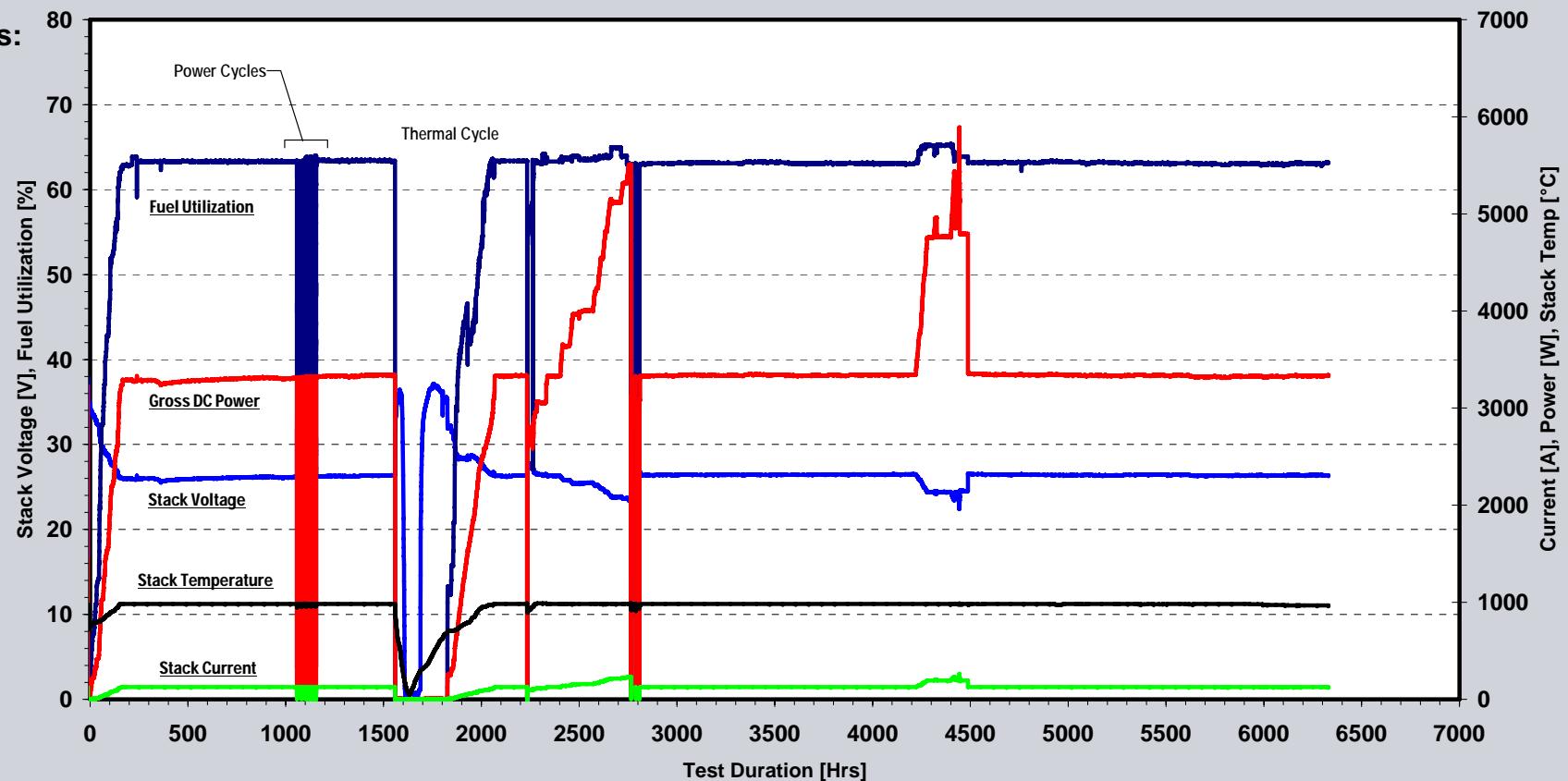
Prototype System



Prototype System Performance

Net DC
efficiency
at
operating
conditions:
35%

Siemens SECA Phase 1 Prototype
Operation Data

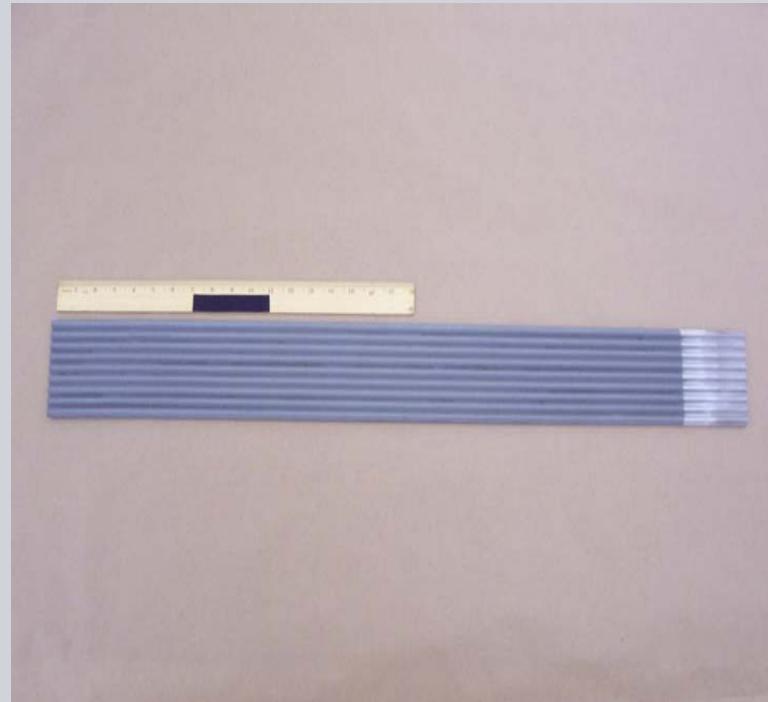
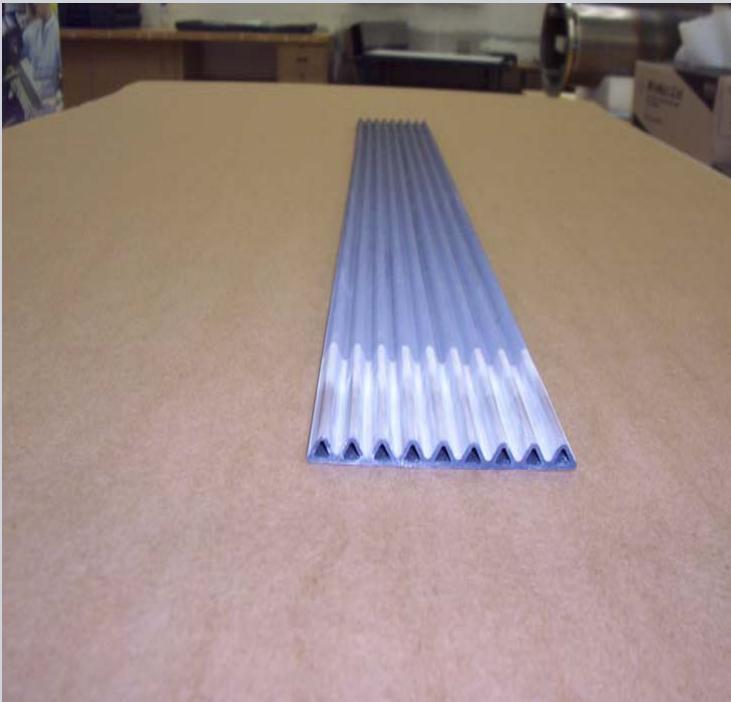


Prototype System Performance Summary

Performance Parameter	Requirements	Results
Net DC efficiency	35%	38%
DC Peak Power (kW)	3-10	5.9
Steady State Degradation	< 2% per 500 hrs	0
Thermal cycle	1	1
Power cycle	9	9
Availability	80%	100%
Test Duration (hours)	1500	6300
System Cost (\$/kWe)	800	691

To further increase power density and power per cell, we are looking at ways to increase the cell active area

Next Generation HPD Cell – Delta



Active length: 75 cm

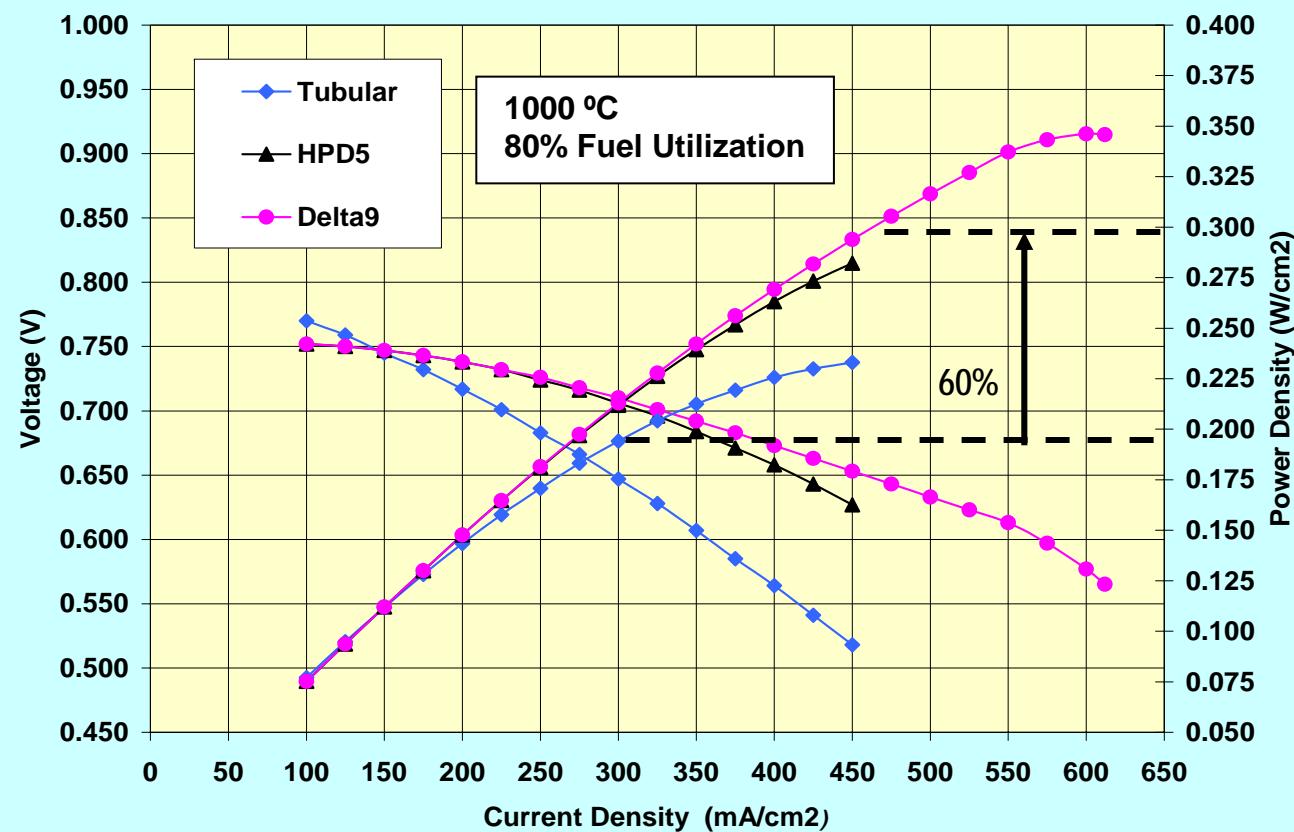
Active area: 1200 cm²

Built-in fuel channels – more compact bundle/stack

Cell Performance at 1000°C – Delta9 vs. Tubular

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~60% power
density
enhancement
for HPD5
relative to
cell at 0.65 V



Power Per cell at 1000°C – Delta9 VS. Tubular

~240% higher power per cell for delta9 cell relative to tubular cell at 0.65 V

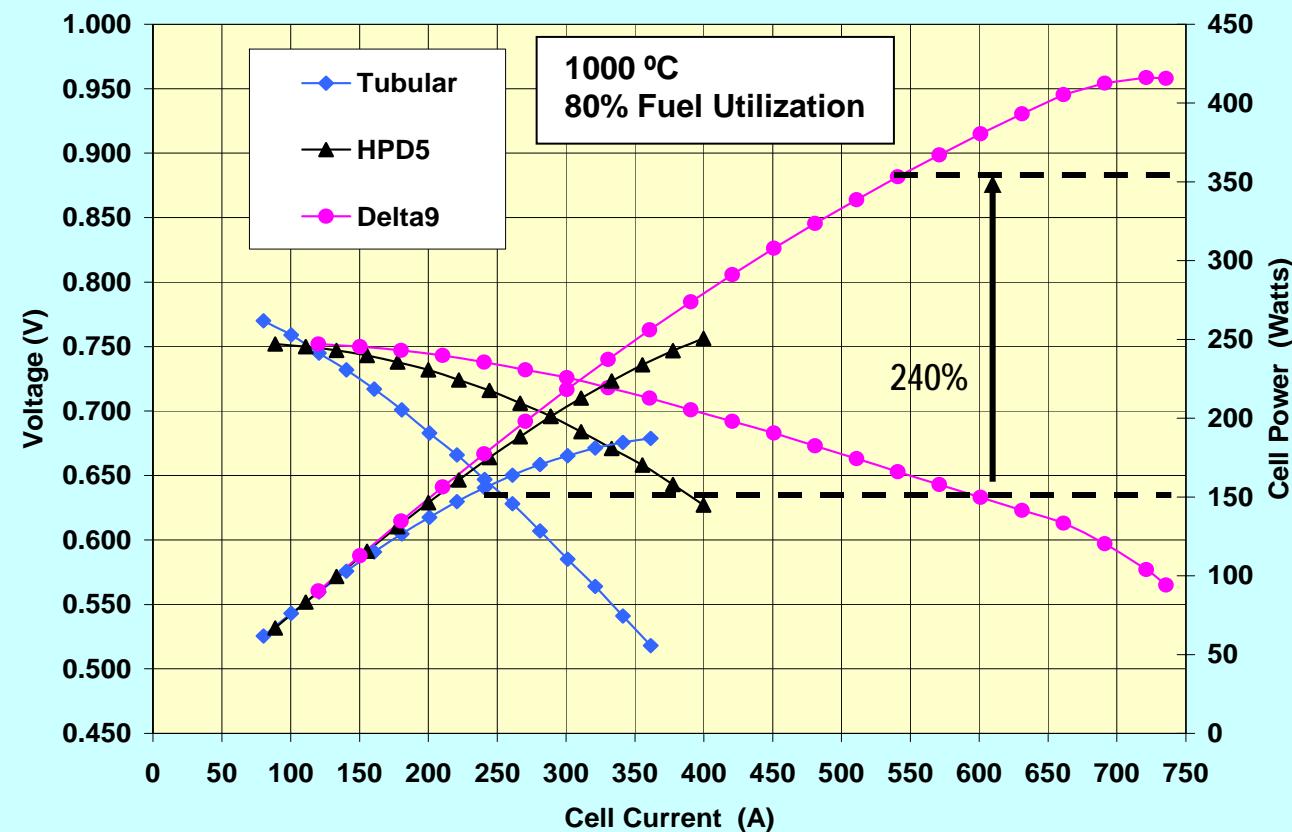
Peak power delta9 cell: 410 Watts

Active Lengths

Tubular: 150 cm
HPD5: 75 cm
Delta9: 75 cm

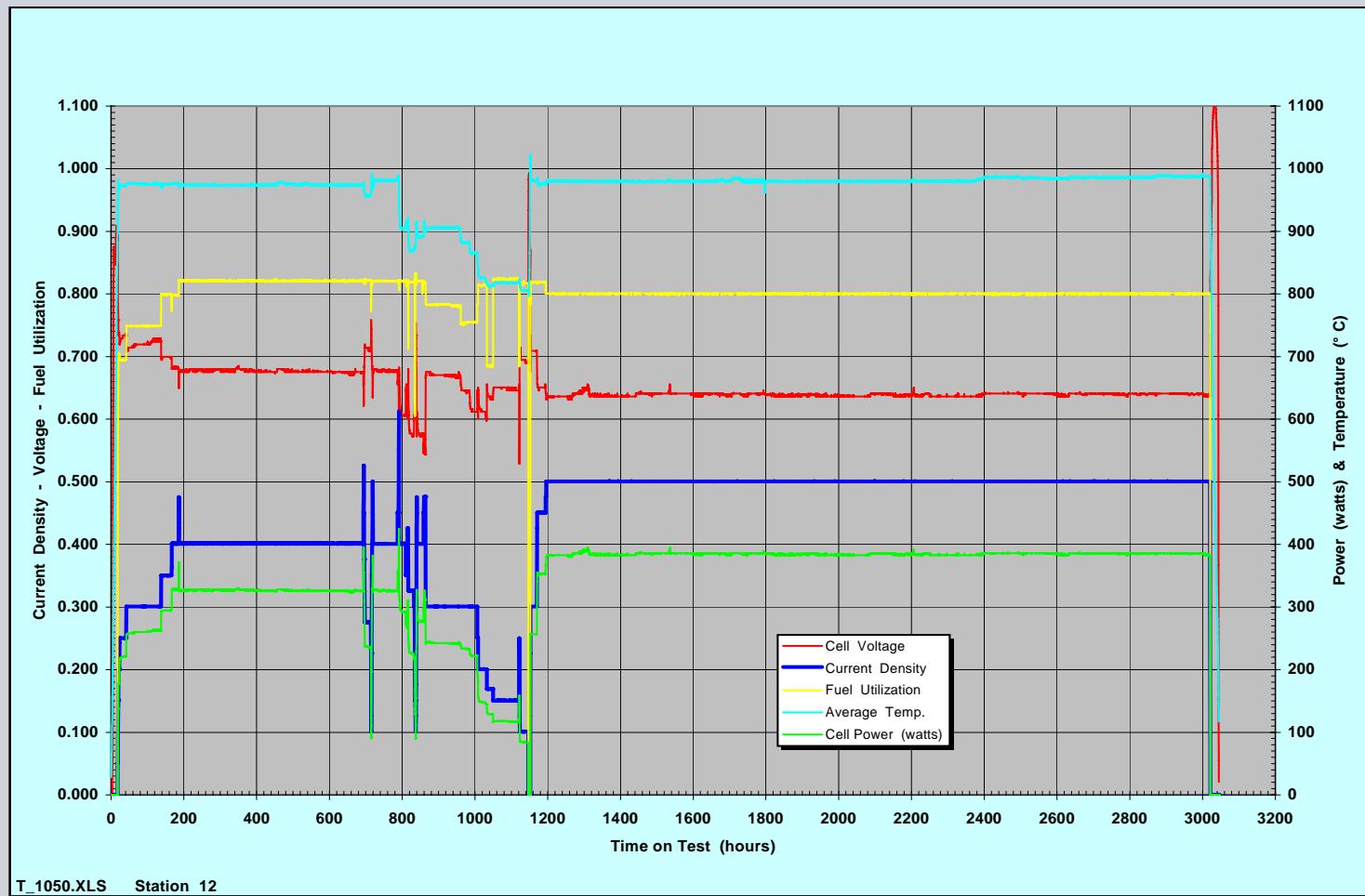
Active Areas

Tubular: 850 cm²
HPD5: 900 cm²
Delta9: 1200 cm²



Delta9 Voltage Stability

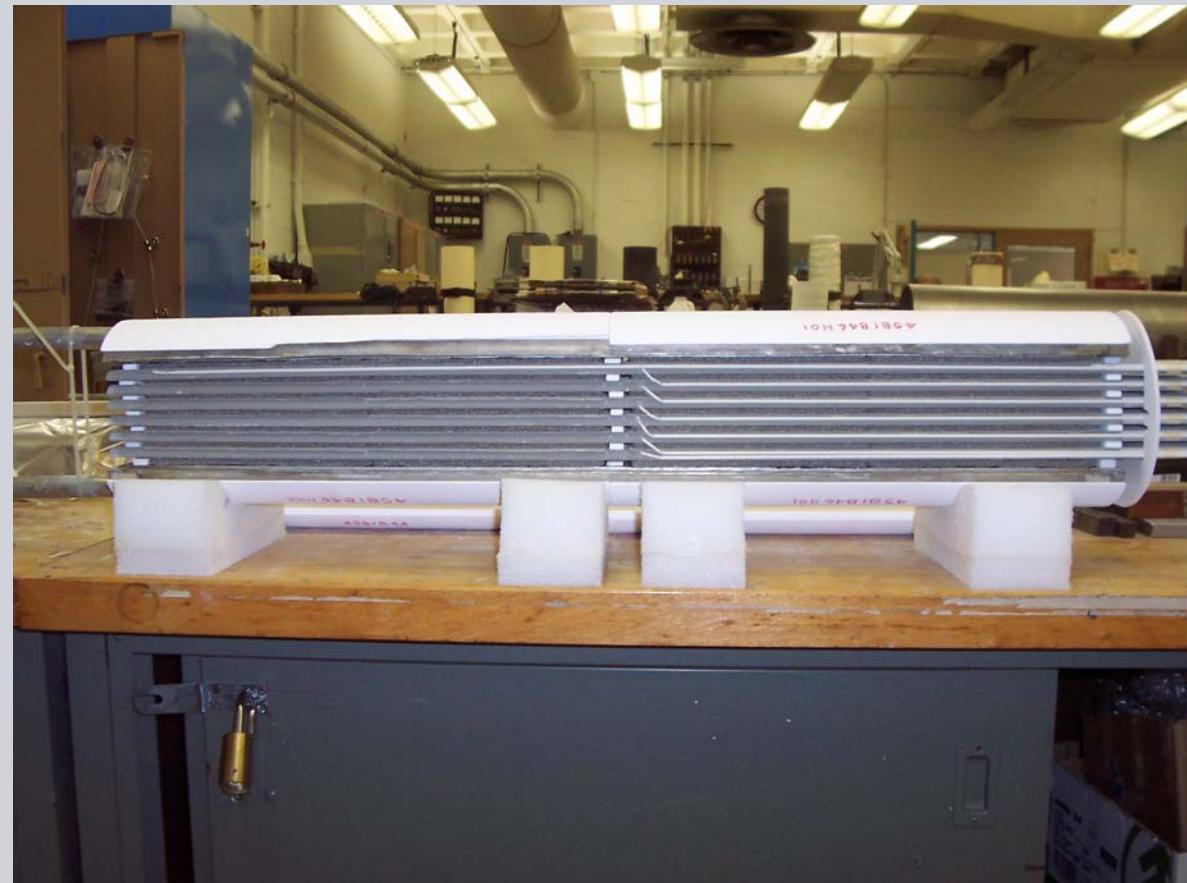
Stable voltage for 3000 hours at 1000°C with increasing current densities



Delta9 Cell Bundle Test

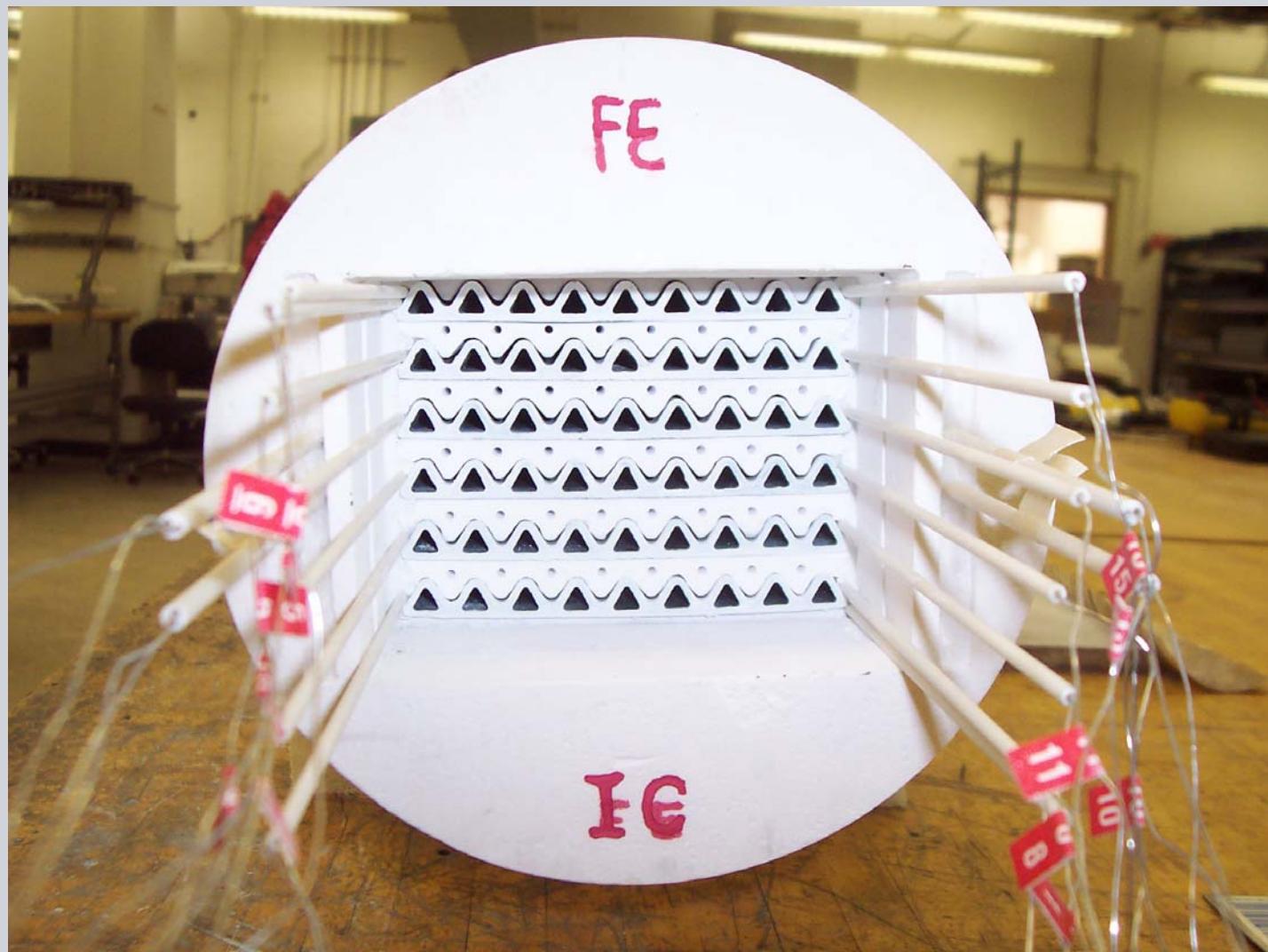
Six Delta9 Cells

Active Length: 75 cm

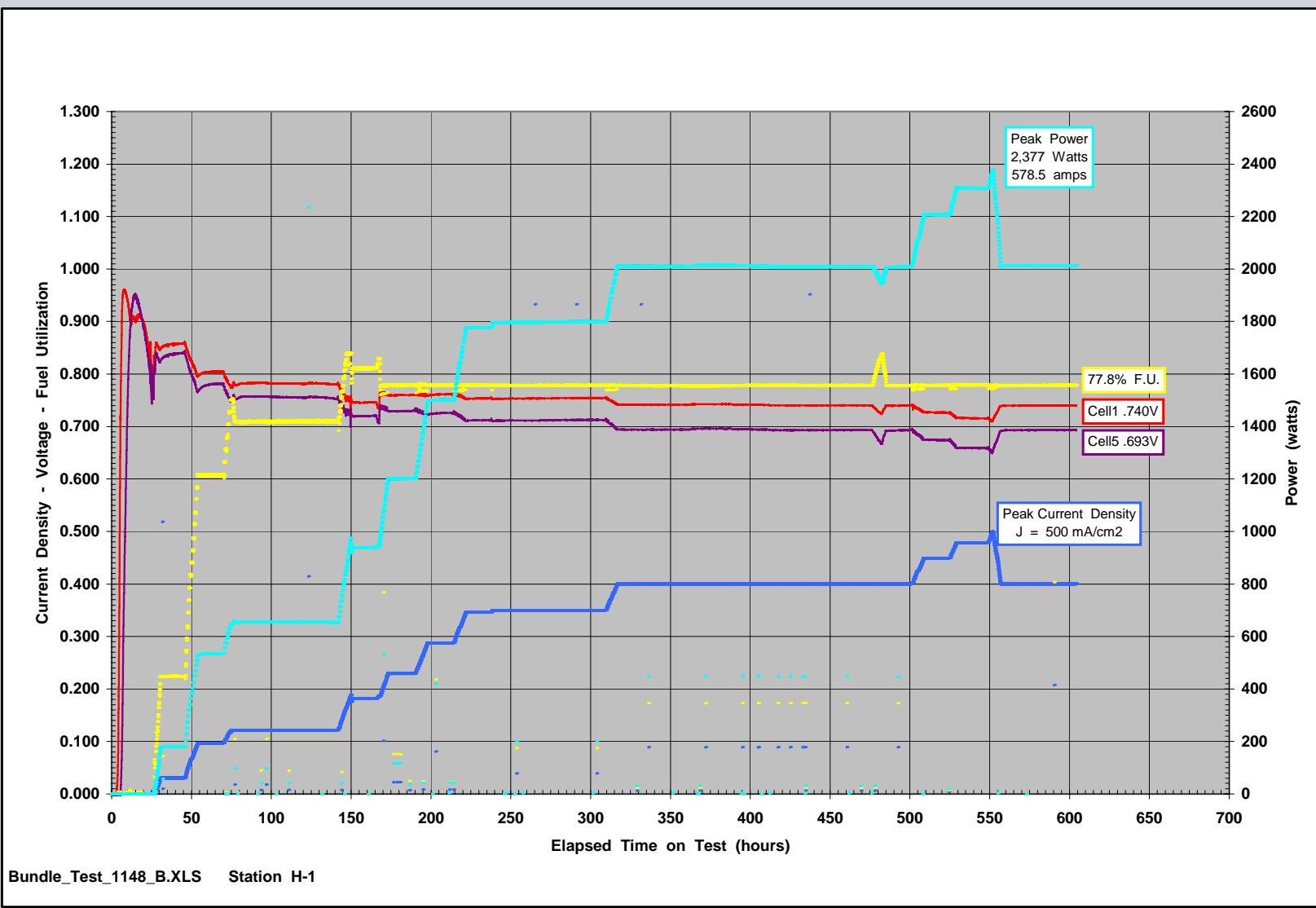


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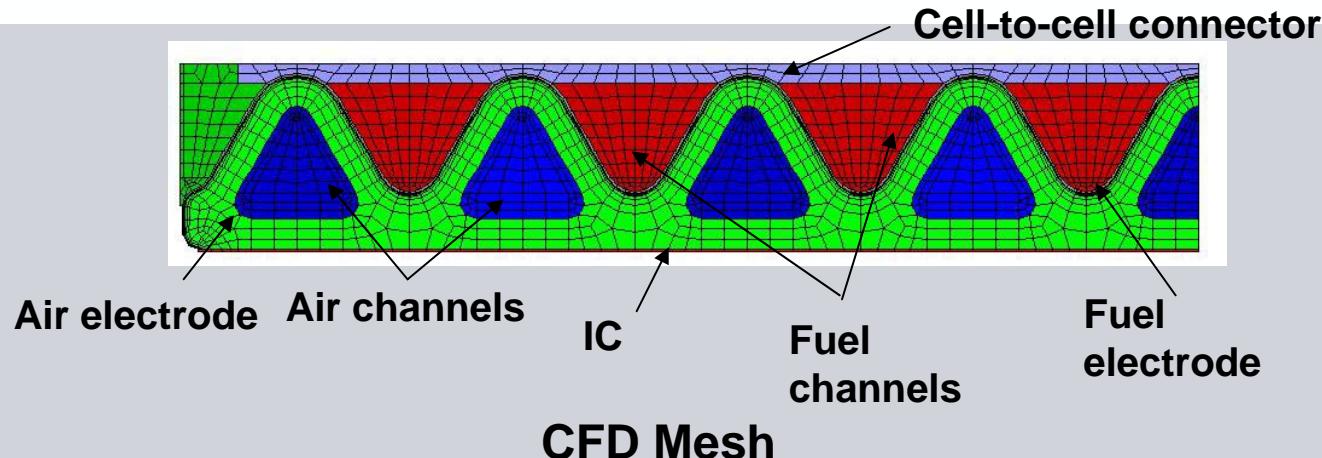
Six Delta9 Cell Bundle Test



Delat9 Bundle Performance (Av. Operating T = 950 °C)



Optimization of Delta Cell Design



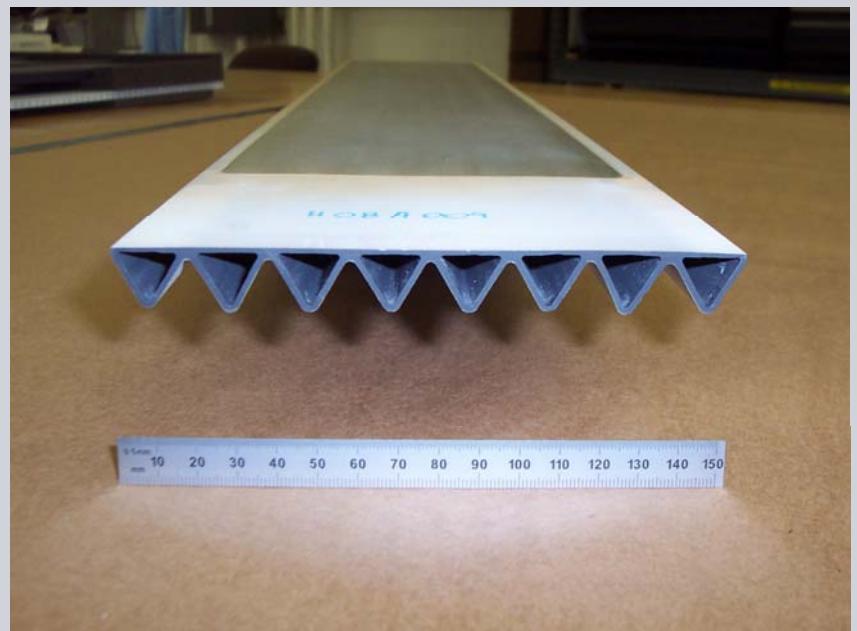
Fluent – Electrochemistry and temperature distributions in a stack environment

Ansys - Thermal stresses

Optimization parameters

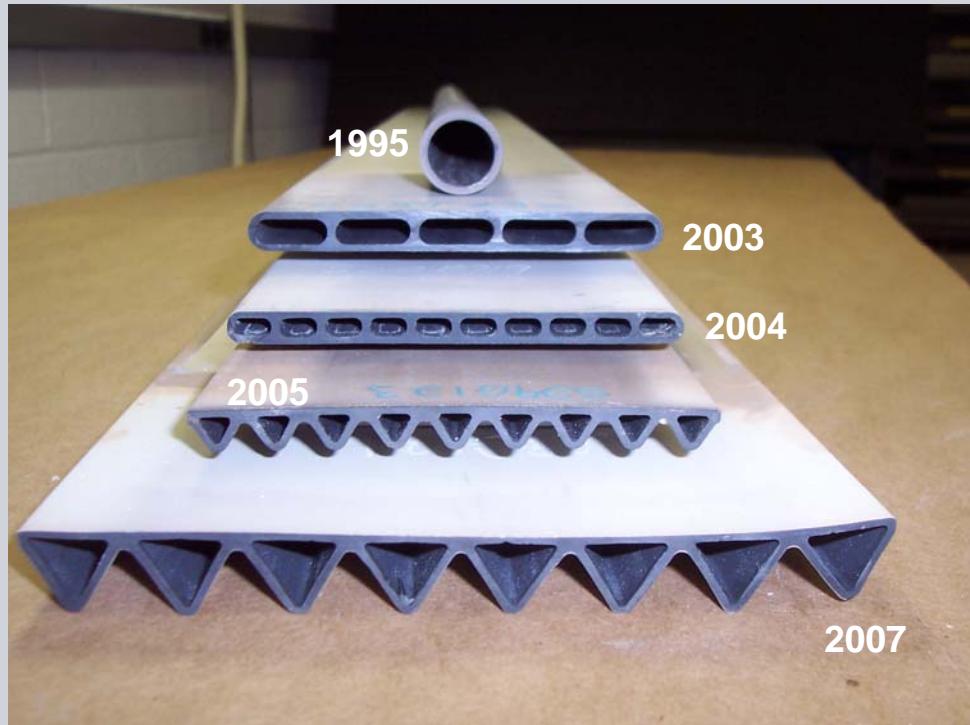
- Number of channels
- Cell length, width and height
- Channel opening and shape
- Wall thickness
- Net system power

Optimized Delta Cell Design



Delta8 Cell

Transition from Cylindrical to Delta8 Cell



	Length, cm	Cell Power (W)
Cylindrical	150	110
HPD5	75	190
HPD10	75	280
Delta9	75	410
Delta8	100	1000 (projected)

Fuel: Humidified hydrogen
Temperature: 1000 °C, isothermal
Fuel Utilization: 80%

Prototype System with Delta8 Cells

- 24 Delta8 cells
- Internal recuperator
- Cold air inlet plenum
- Precision cast ceramic open end holder
- High efficiency cathode air blower

Summary

- HPD and Delta cells have demonstrated significantly higher power density over cylindrical cells
- Phase 1 prototype test with HPD5 cells showed excellent voltage stability
- Delta8 identified as next generation cell – development of Delta8 cells ongoing
- Phase 2 prototype system with Delta8 cells under development

Future Work

- Continue development of Delta8 cells
- Test prototype system with Delta8 cells
- Design building block for Mwe class system – 96 or 288 Delta8 cells
- Develop large scale manufacturing processes for cells/stacks

Acknowledgements

- **DOE-NETL**
- **Travis Shultz, Don Collins - NETL**
- **Siemens Stationary Fuel Cells Team**