

**Presented at the Seventh Annual SECA Workshop
Philadelphia, PA
September 12-14, 2006**

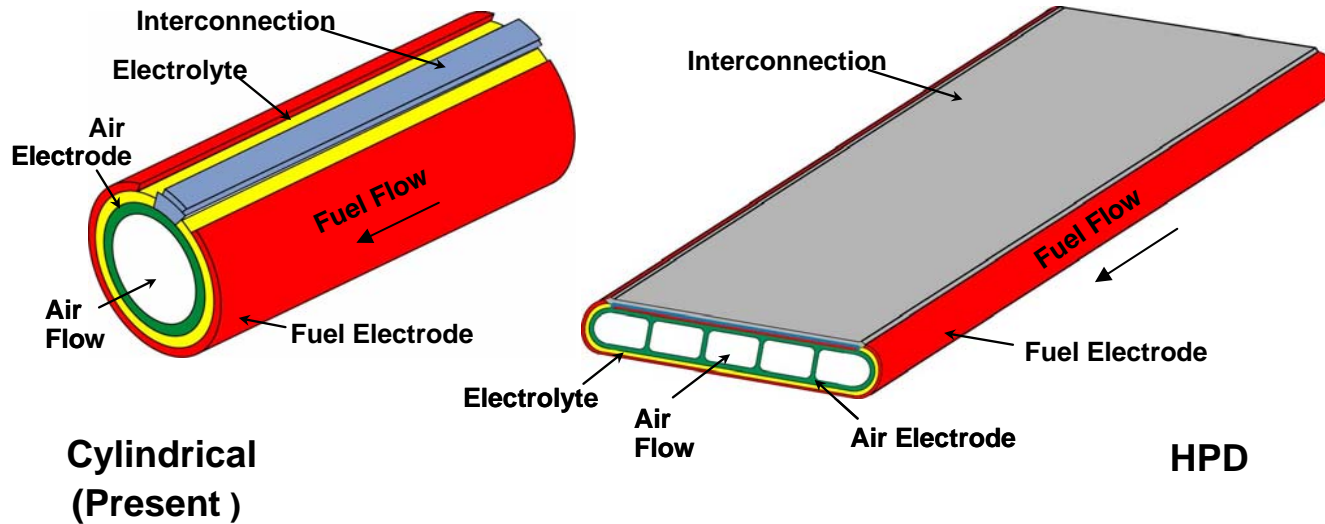
SECA Program Review

SIEMENS

**DOE Program Manager
Don Collins**

September 12 , 2006

- **Demonstrated significantly higher power density relative to tubular cells through materials and cell design improvements**
- **Confirmed excellent voltage stability (no noticeable voltage degradation) for first generation high power density (HPD) cells over 3000 hours of operation at 1000°C**
- **Fabricated phase 1 prototype with first generation HPD cells**
- **Tested phase 1 prototype system**
- **Developed and tested next generation high power density cells - Delta design**
- **Developed concepts for stack design with Delta cells**
- **Established a test facility to test Delta cells at high pressure**

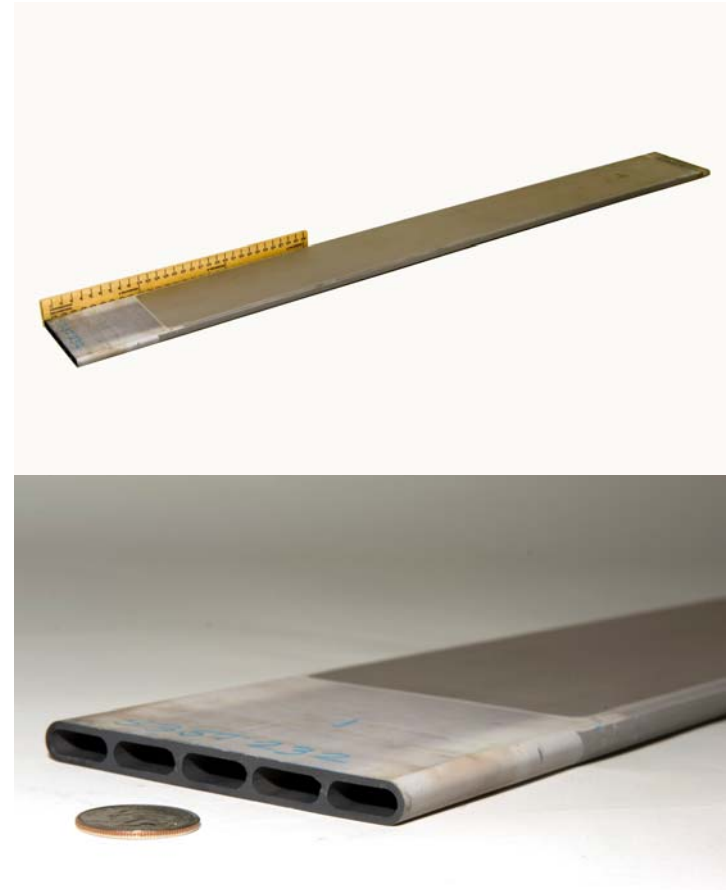


- Maintains seal-less design
- Potential to eliminate air feed tubes
- Reduction in ohmic resistance
- Increase in cell power density
- More compact stack

- 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)

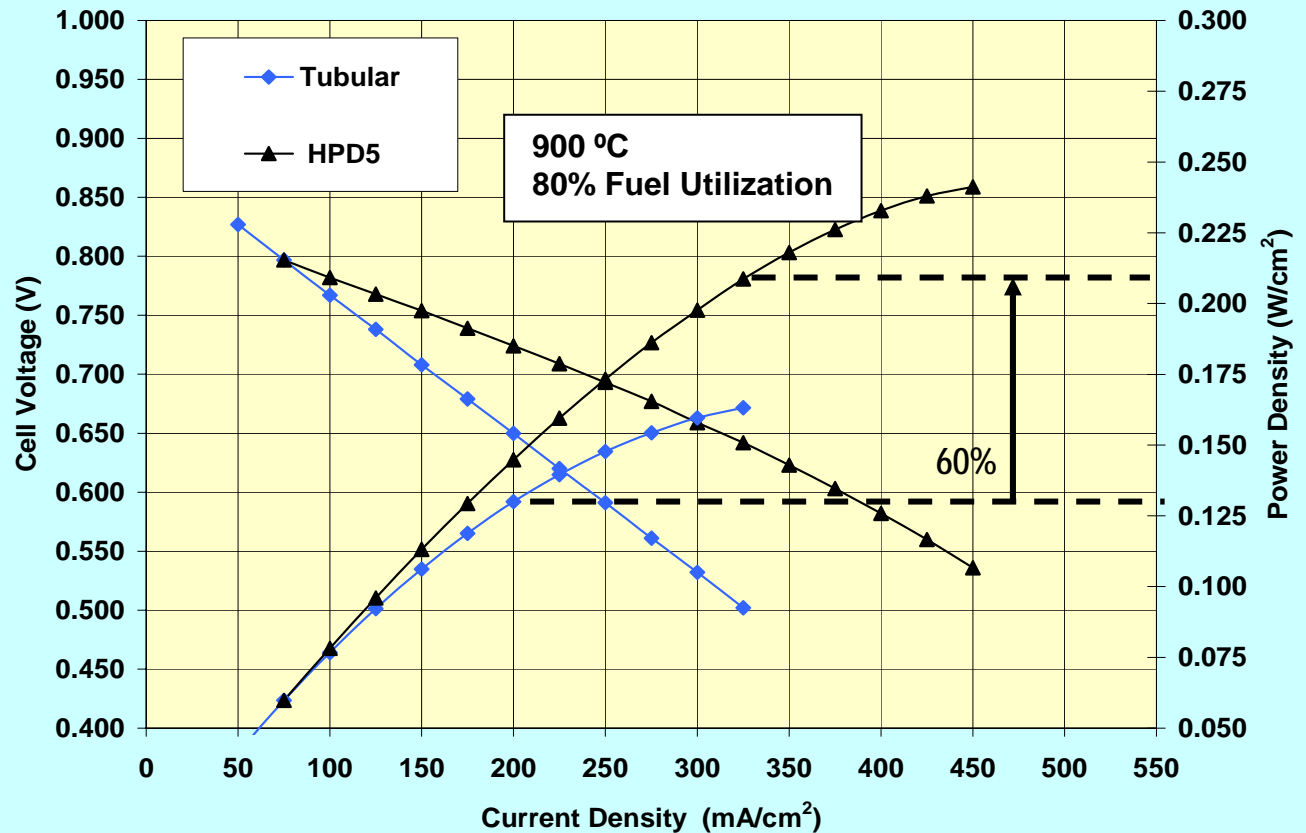
Active Length: 75 cm

Active area: ~900 cm²



Cell Performance at 900°C – HPD5 VS. Tubular

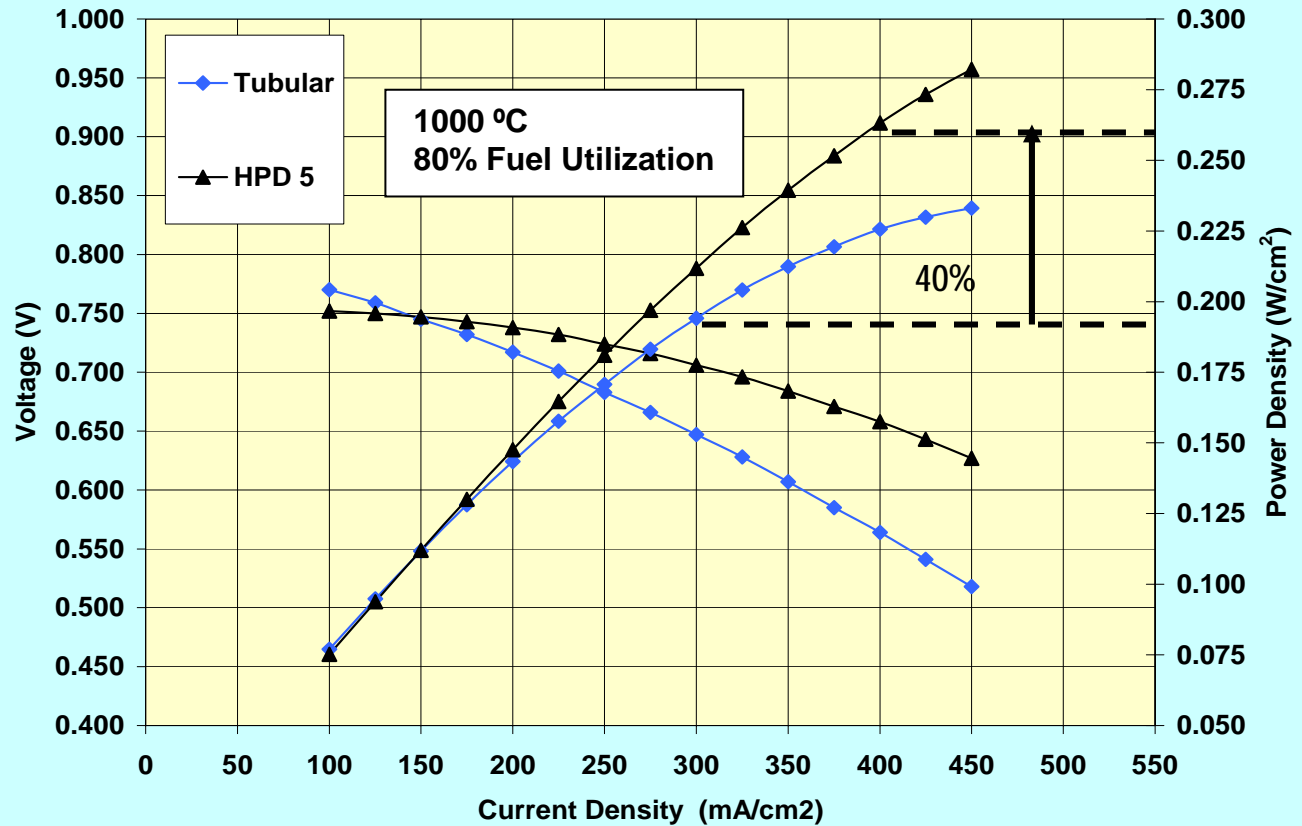
~60% power density enhancement for HPD5 relative to tubular cell at 0.65 V



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Cell Performance at 1000°C – HPD5 VS. Tubular

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

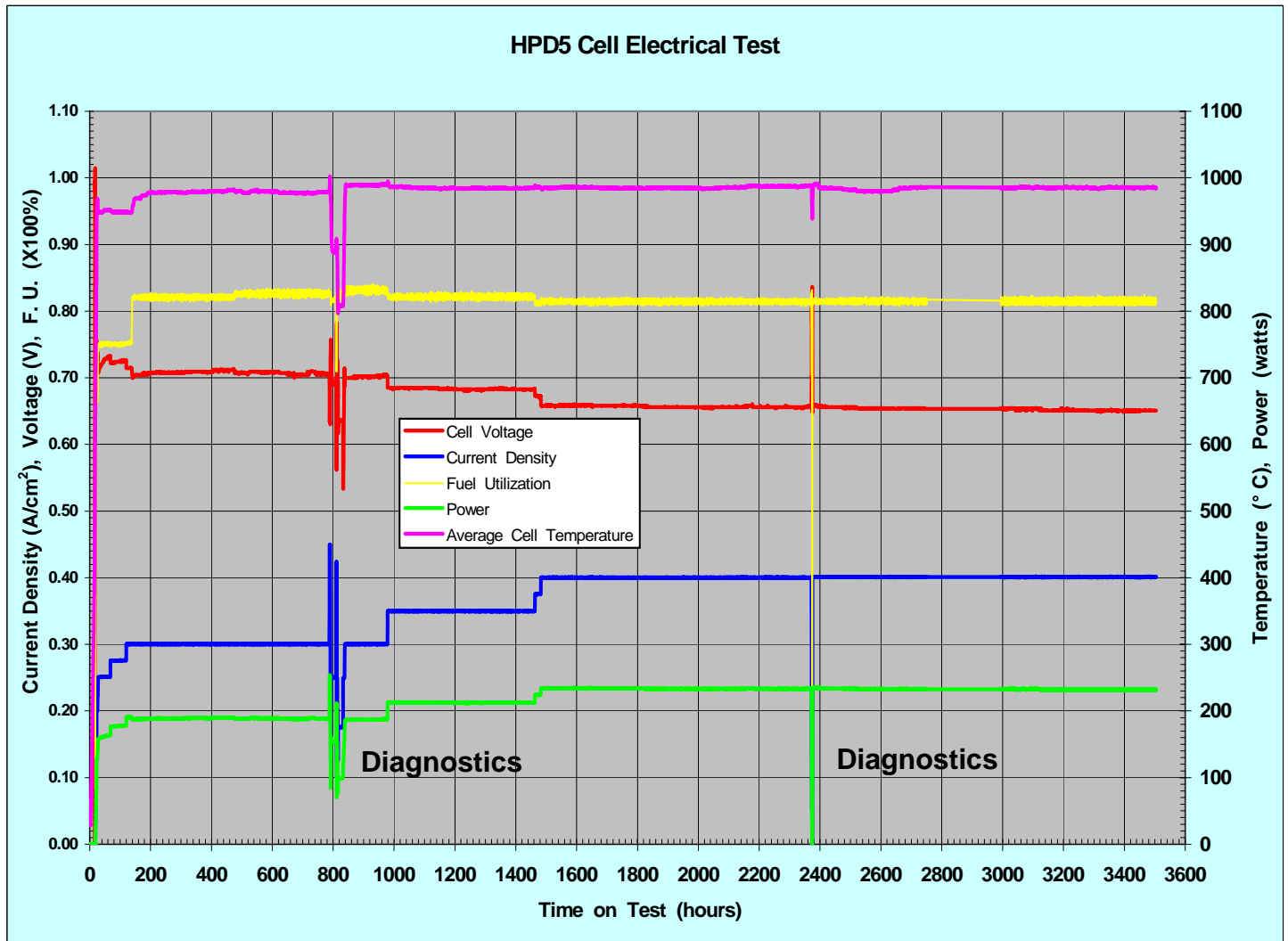


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HPD5 – Voltage Stability

Exceeded program goal of stable voltage for 3000 hours at 1000°C

HPD5 cells were used in the phase 1 prototype



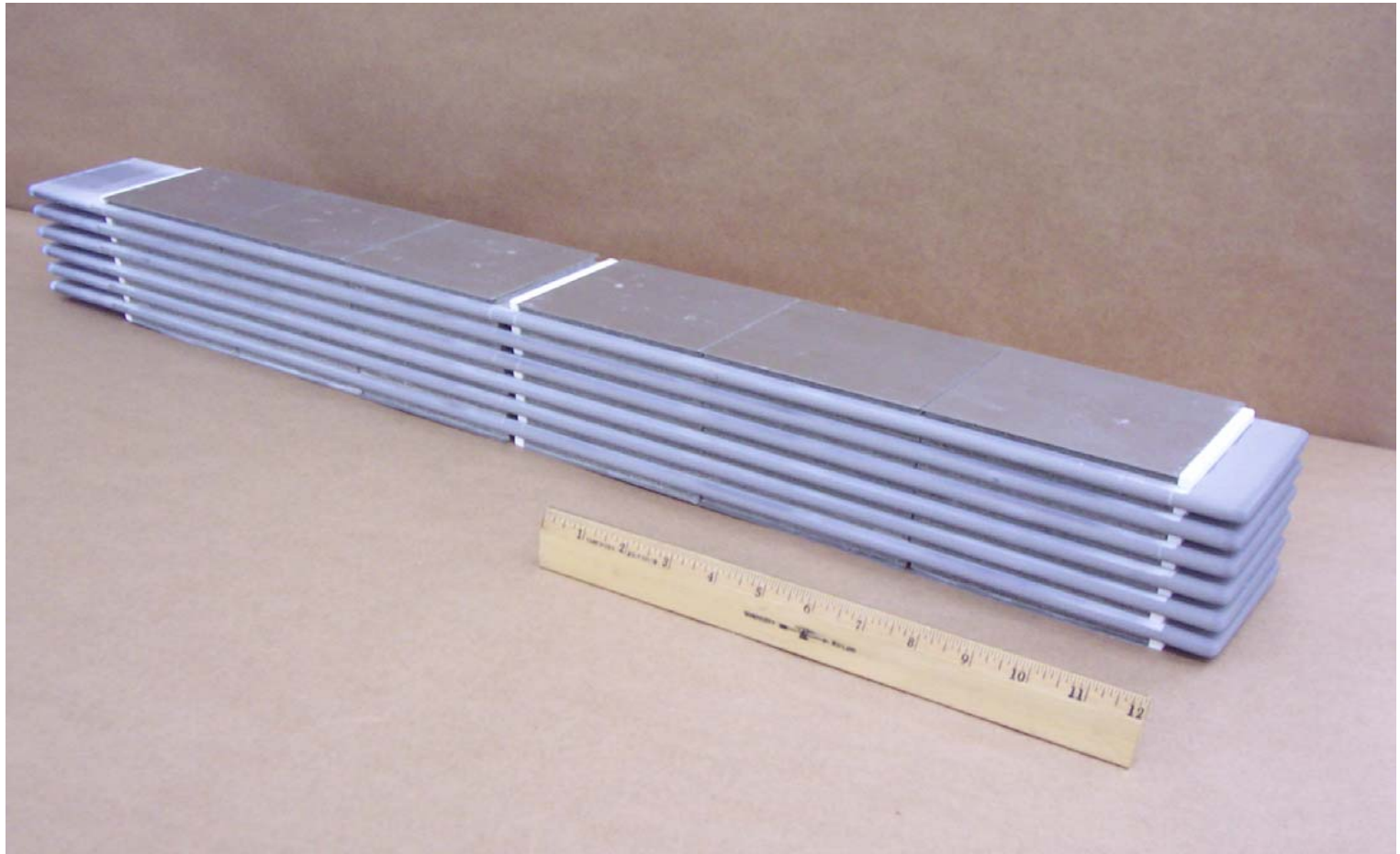
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- **36 HPD5 cells – six bundles of six cells each**
- **Internal recuperator**
- **Internal fuel reformer**
- **Fuel: Pipeline natural gas**
- **Stack: Siemens; BOP: FCT**
- **Fully integrated power system**
- **Testing in progress (~ 1400 hours)**

HPD5 Cell Bundle - 6 Cells

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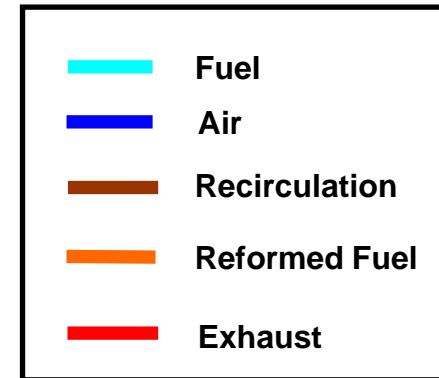
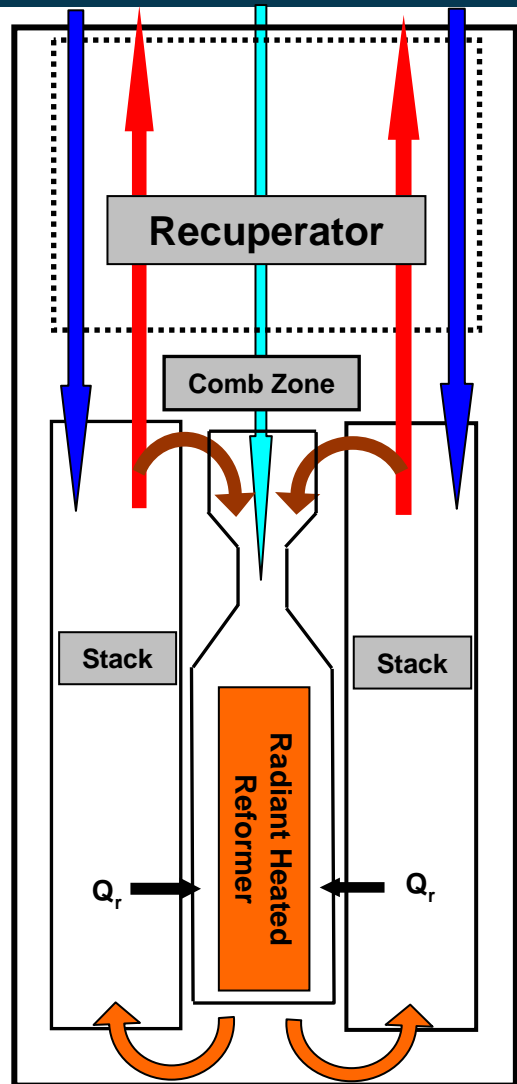
Active cell
length: 75 cm



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Phase 1 Prototype - Flow Schematic

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Phase 1 Prototype System

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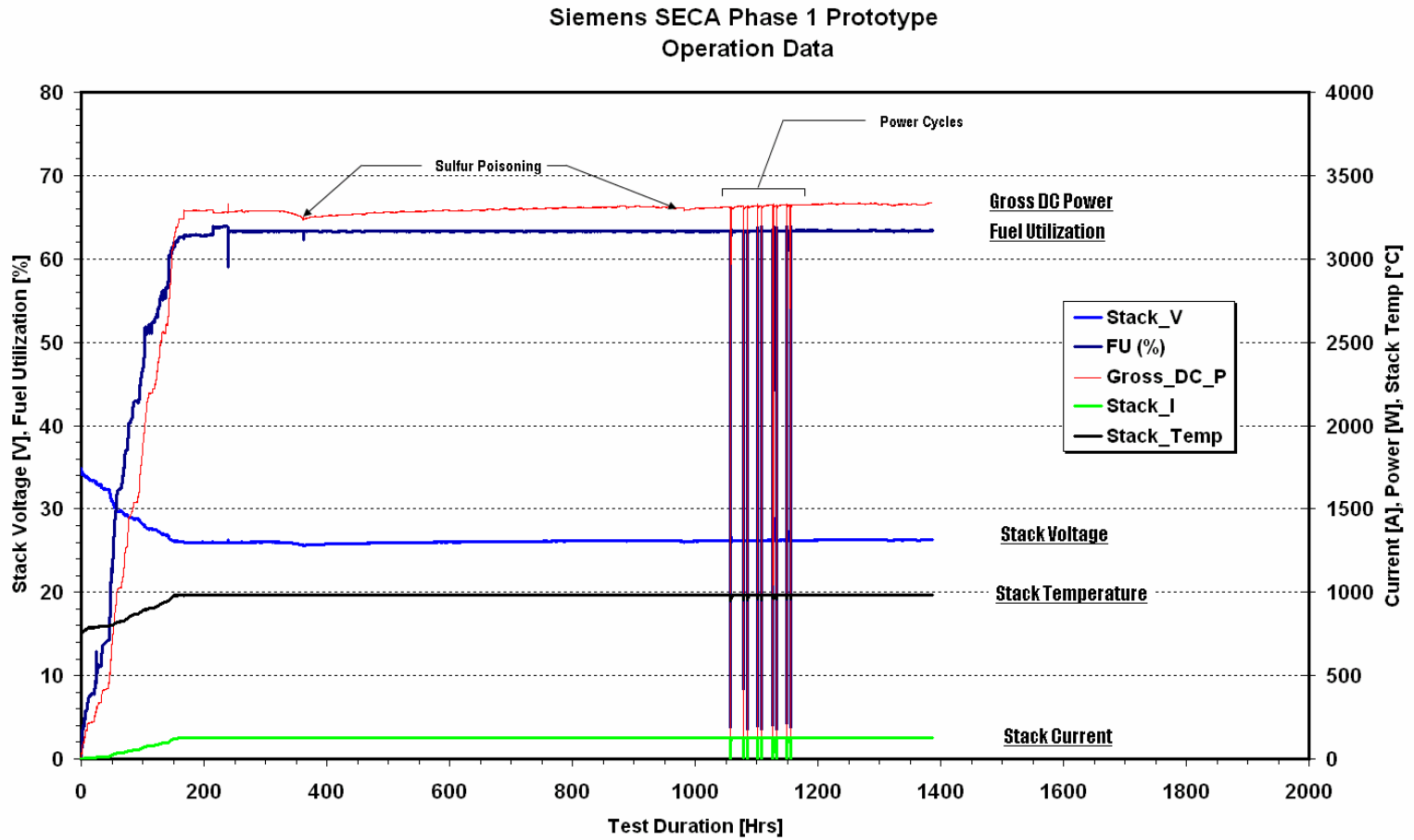
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Power Generation 11
Stationary Fuel Cells

Phase 1 Prototype System Performance

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Net DC efficiency at operating conditions: 35%

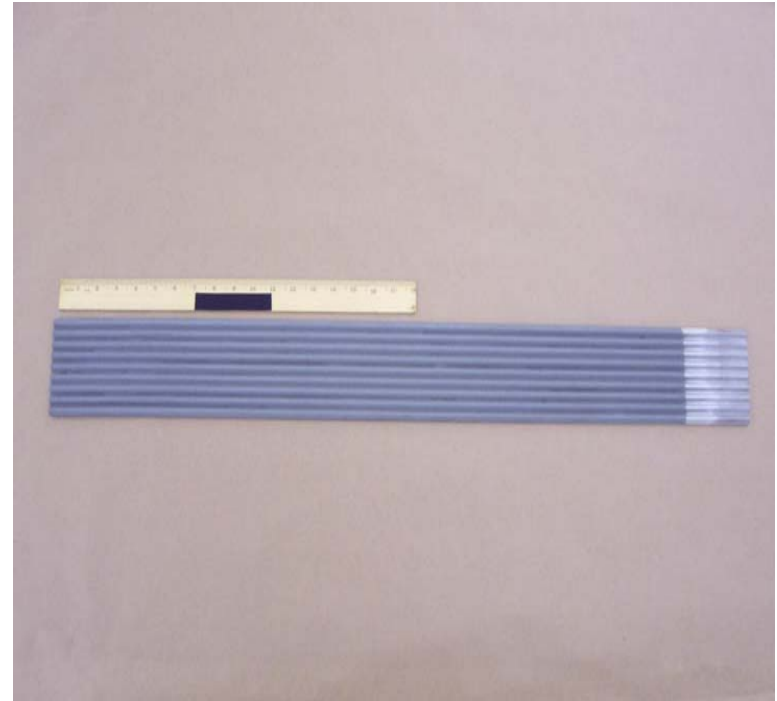
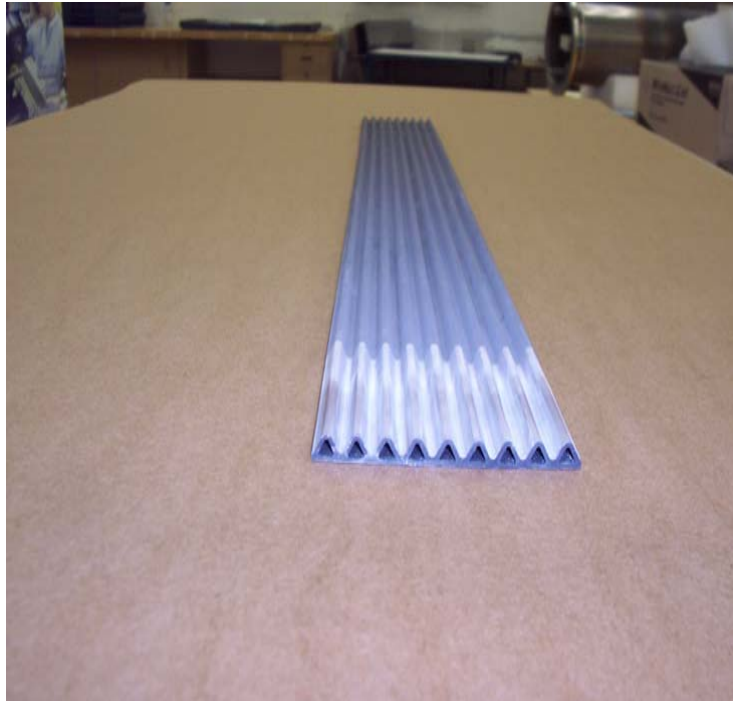


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Phase 1 Prototype System Performance Summary

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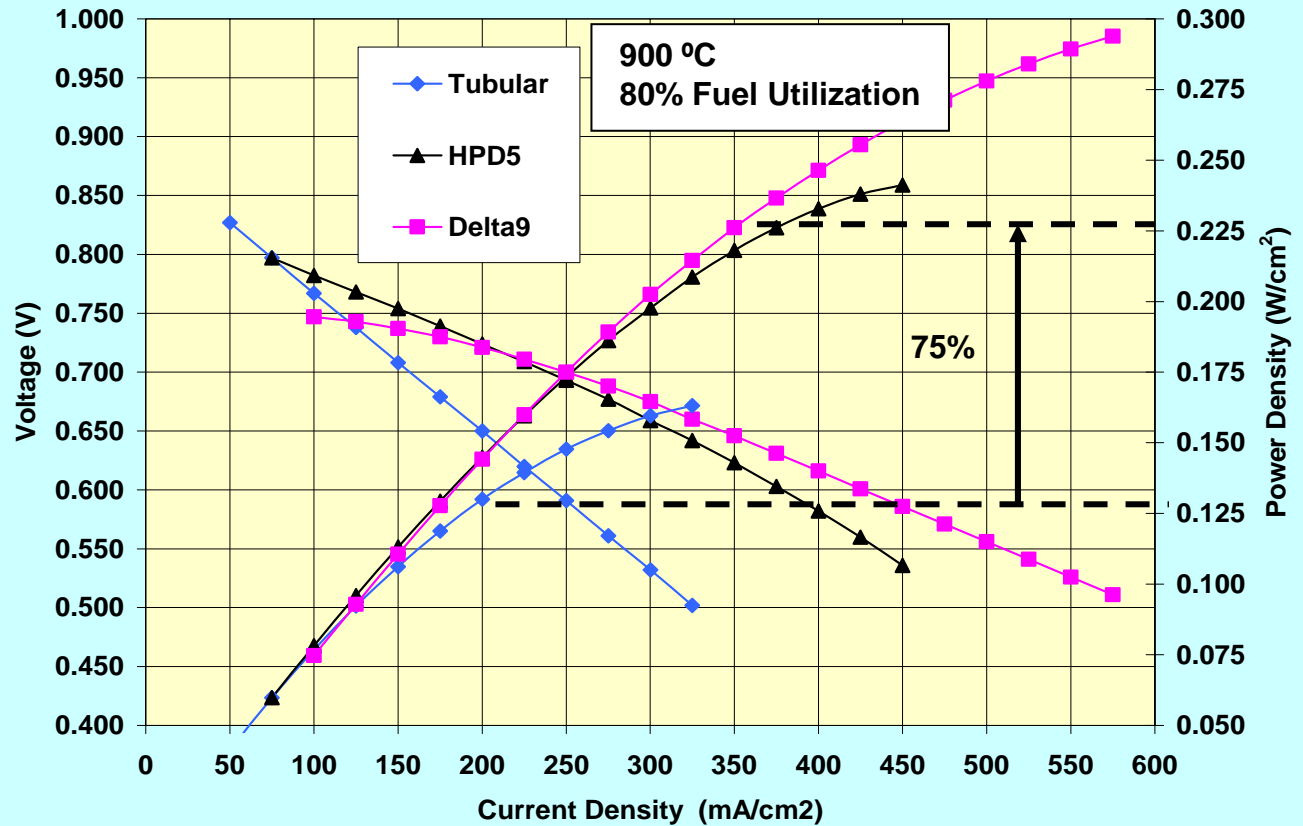
Stack Current	126 Amps
Stack Voltage	26.2 Volts
Gross DC Power	3.3 kWe
Average Cell Voltage	0.73 V
Fuel Utilization	68%
Av. Stack Temp at Mid-elevation	982 °C
Net DC efficiency at operating power	35%
Operating hours	~1400 (Test continues)
Voltage Degradation	0
Current Cycles	9
Thermal Cycles	0
Availability	100%
Peak Power	TBD
Peak Efficiency	TBD



Active length: 75 cm
Active area: 1200 cm²
Built-in fuel channels – more compact bundle/stack

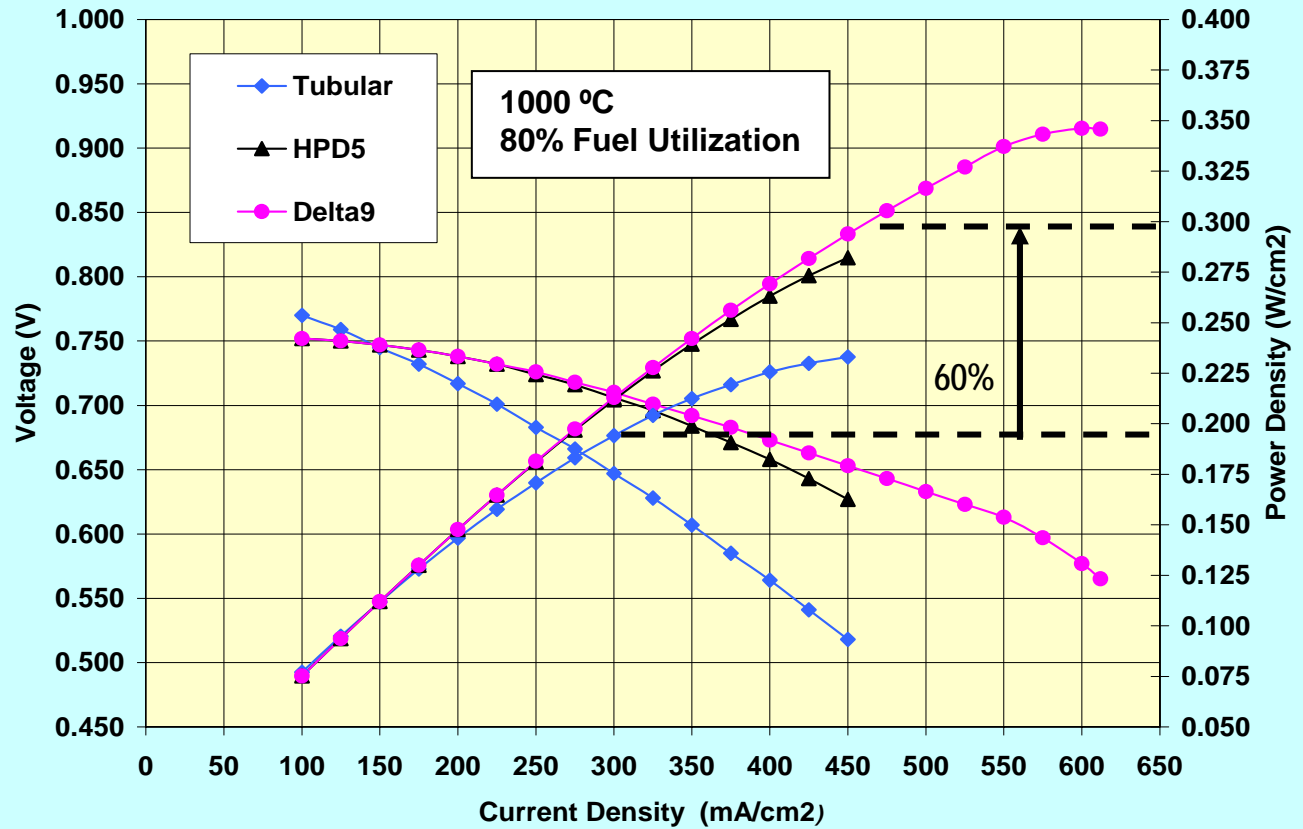
Cell Performance at 900°C – Delta9 vs. Tubular

~75% power density enhancement for Delta relative to tubular cell at 0.65 V



Cell Performance at 1000°C – Delta9 vs. Tubular

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



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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

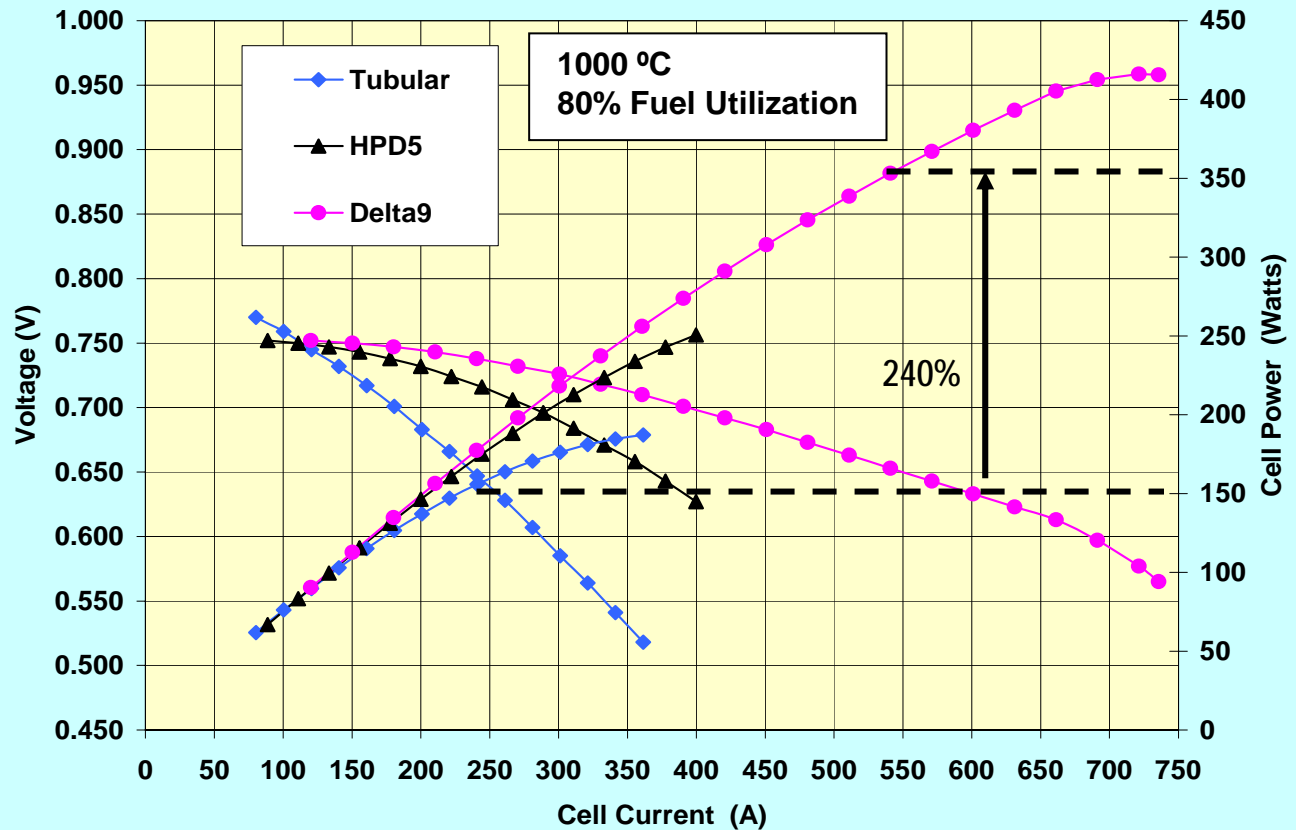
Peak power delta9 cell: 410 Watts

Active Lengths

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

Active Areas

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

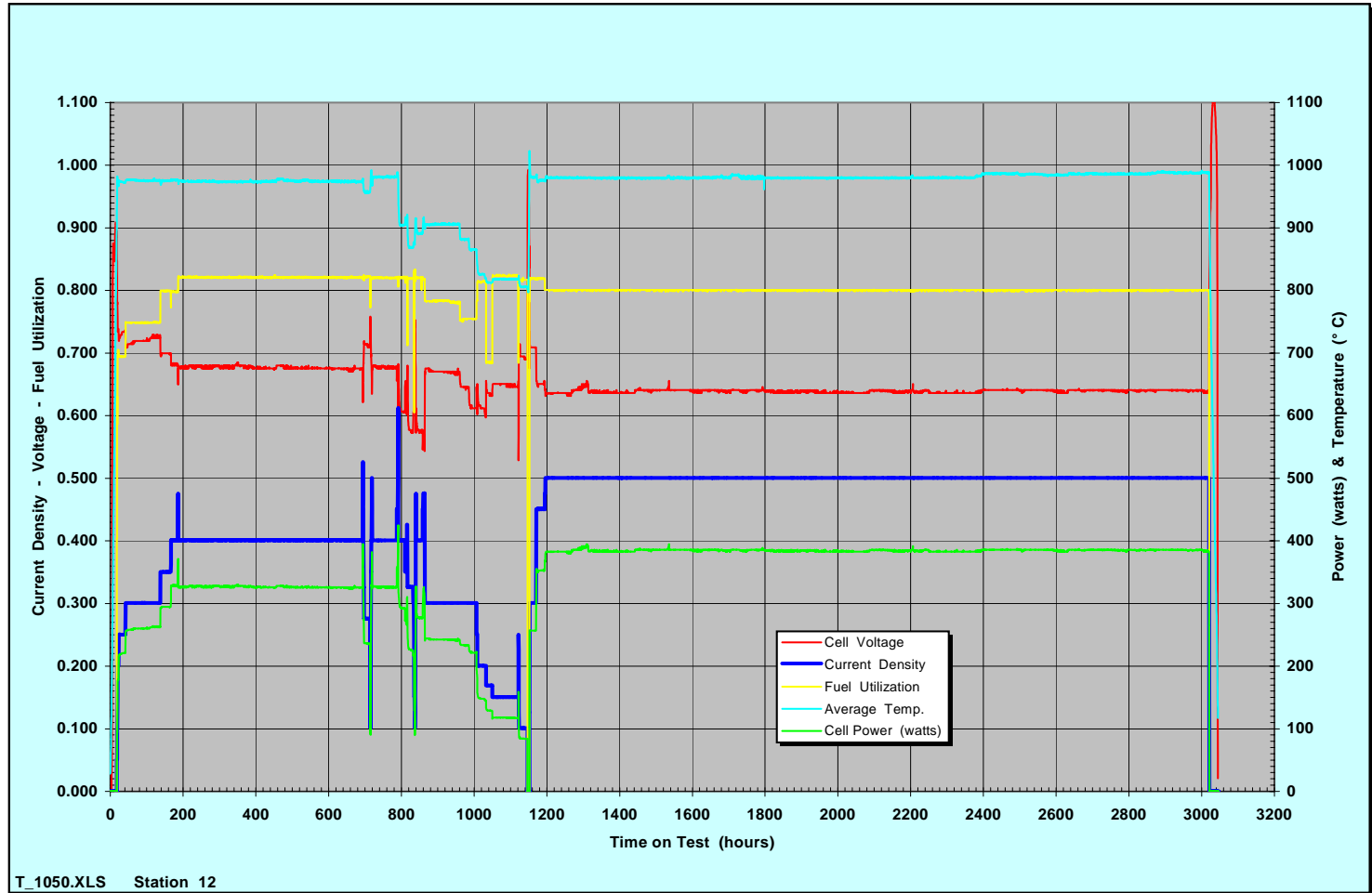


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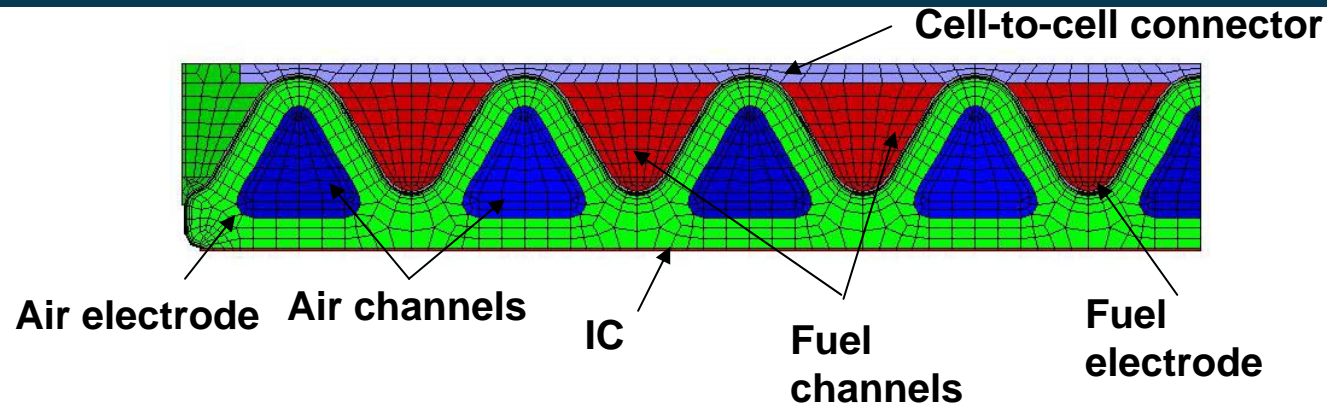
Delta9 Voltage Stability

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



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CFD Mesh

Fluent – Electrochemistry and temperature distributions in a stack environment

Ansys - Thermal stresses

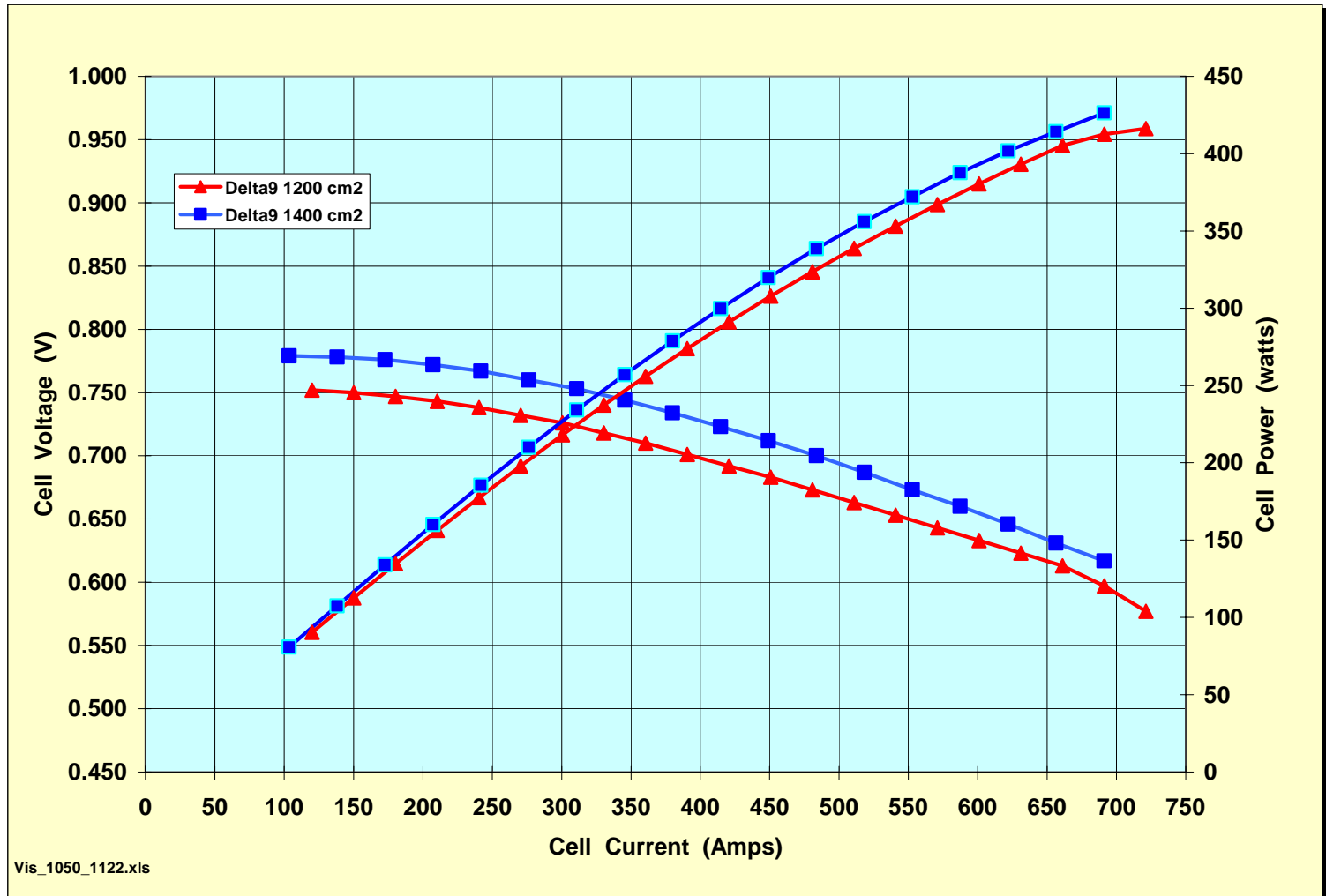
Optimization parameters

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

Cell Power with Increasing Active Area

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Tested
Delta9 cell
with 90 cm
active length



Vis_1050_1122.xls

Stretching Cell Fabrication Limits – Delta13

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Delta13
Width:15 cm

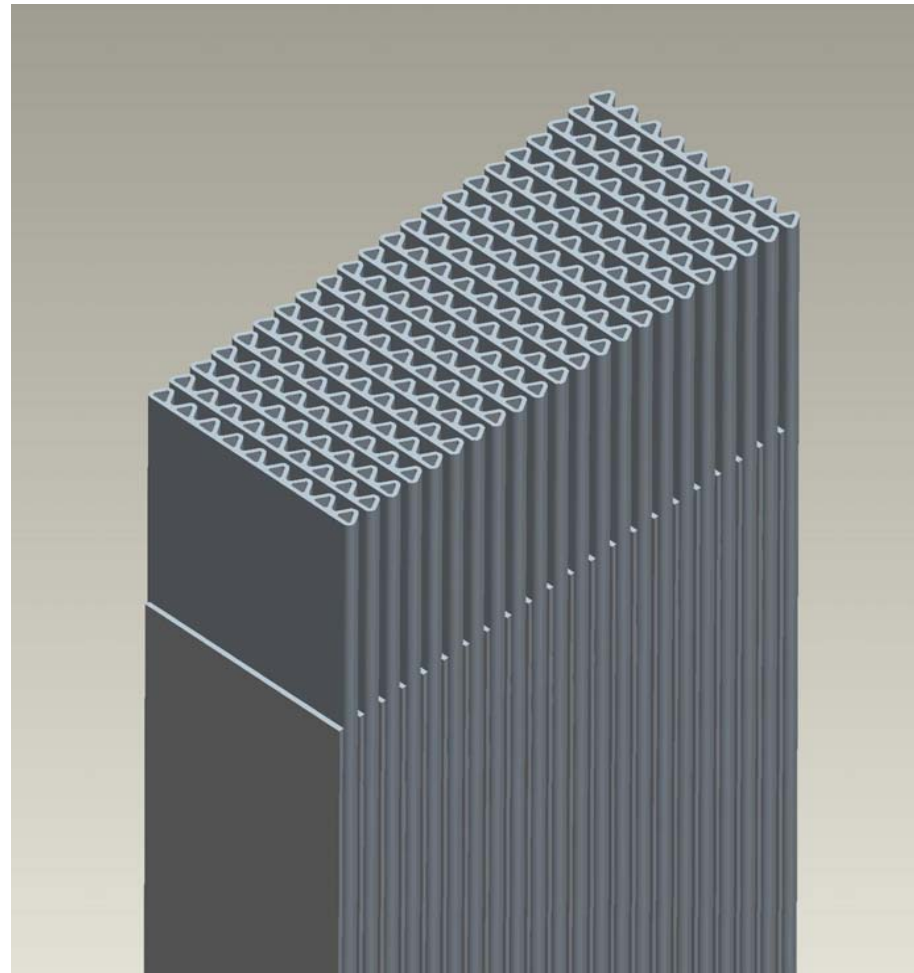


Delta9
Width:10 cm

Target width: 15 cm
Target active length: 100 cm
Target active area: >2000 cm²

**20 cell
bundle
concept**

**8-12 kWe/bundle
depending on
optimized cell
active area**

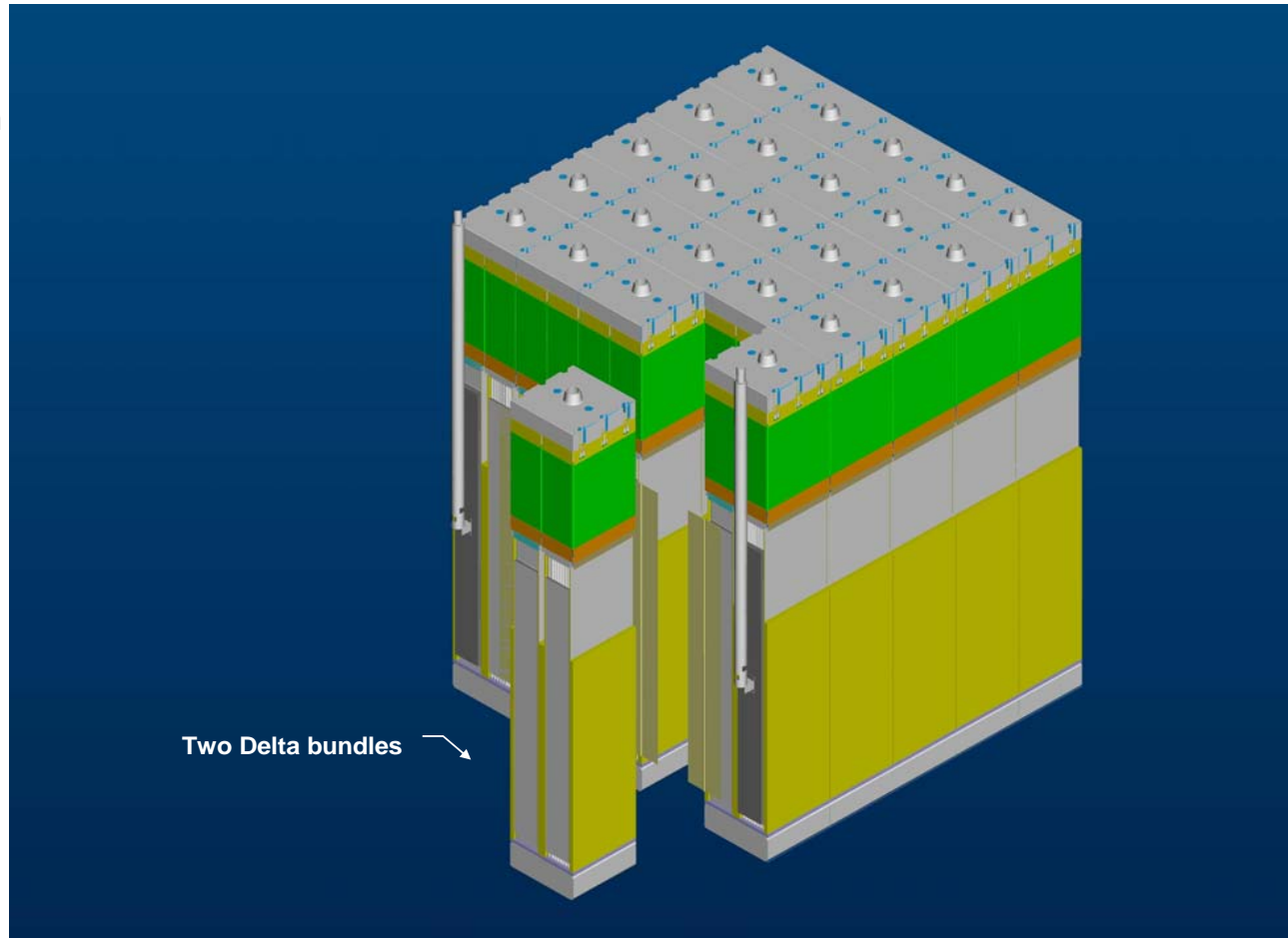


Stack Concepts with Delta Cells

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1.3 m X 1.6 m X 1.3 m

20-Cell Bundles
1000 cells
400 – 600 kWe Module



Two Delta bundles

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Objectives

- **Characterize cell performance up to 30 atm, range of fuel utilizations, air utilizations, and temperatures**
- **Verify model predictions**
- **Verify stability of cell materials at high pressure**
- **Verify voltage stability**

Capabilities

- **Operating pressure up to 30 atm**
- **High pressure fuel supply**
- **Metered fuel humidification system**
- **Current up to 1000 amps**
- **Single or multiple cells**

- Pressure vessel installed



Upper head



Lower head

- **Fabricated HPD cells and demonstrated significantly higher power density over tubular cells – met program milestones for power enhancement and voltage stability**
- **Phase 1 prototype test progressing well. Excellent voltage stability. Expect to meet program milestones in September**
- **Delta cell development shows promise, particularly in further lowering costs**
- **Pressurized cell testing with delta cells planned this year**
- **SECA program tasks transitioning into coal based hybrids**

- **DOE-NETL**
- **Don Collins, NETL**
- **Siemens Stationary Fuel Cells Team**
- **Fuel Cell Technologies, Kingston, Ontario**
- **Blasch Precision Ceramics, Albany, NY**