Development of a Low Cost 3-10kW Tubular SOFC Power System

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FC_28_Bessette

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Strategic Partners

GENERAL DYNAMICS
Strength on Your Side™

U.S. Department of Energy
Energy Efficiency and Renewable Energy

MTS GROUP

ONR Science & Technology

ChevronTexaco
Technology Ventures

MASSACHUSETTS TECHNOLOGY COLLABORATIVE

Sumitomo Corporation

NiSource

Northeast Utilities System

- *~ 80 Employees*
- *Manufacturing since 1994*
- *Based in Westwood, Mass.*
- *~40,000 sq. ft facility*
- *Critical disciplines in-house*
  - Electrical Engineering
  - Mechanical Engineering
  - Chemical Engineering
  - Thermal Modeling
  - Ceramics Processing
  - Manufacturing
  - Sales & Marketing
  - Automation
  - Finance

Acumentrics *Battery based UPS*

Uninterruptible Power Supplies for Harsh Environments

Industrial-UPS®
Commercial

Rugged-UPS®
Military

Features:

- Sealed electronics
- Able to withstand vibration
- Unity power factor input
- Wide input 80VAC - 265VAC
- Isolated 120 / 240VAC output
- Hot swap battery case
- Parallelable to 20 kWatts

Overview

Timeline

- Project Start: 4/1/2008
- Project End: 9/30/2011
- Percent Complete: 25%

Budget

- Project Funding (BP1)
  - DOE Share=$6,041,012
  - Contractor=$2,013,671
- Funding Received
  - $2,949,425

Barriers

- Cell Power Density
- Stack Power Density
- Cell Cost Reduction
- System Cost Reduction
- System Efficiency
- Lifetime

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Objectives

- Improve Cell Power & Stability
- Cost Reduce Cell Manufacturing
- Increase Stack & System Efficiency
- Prototype test meeting system efficiency and stability goals
- Integrate to a mCHP Platform

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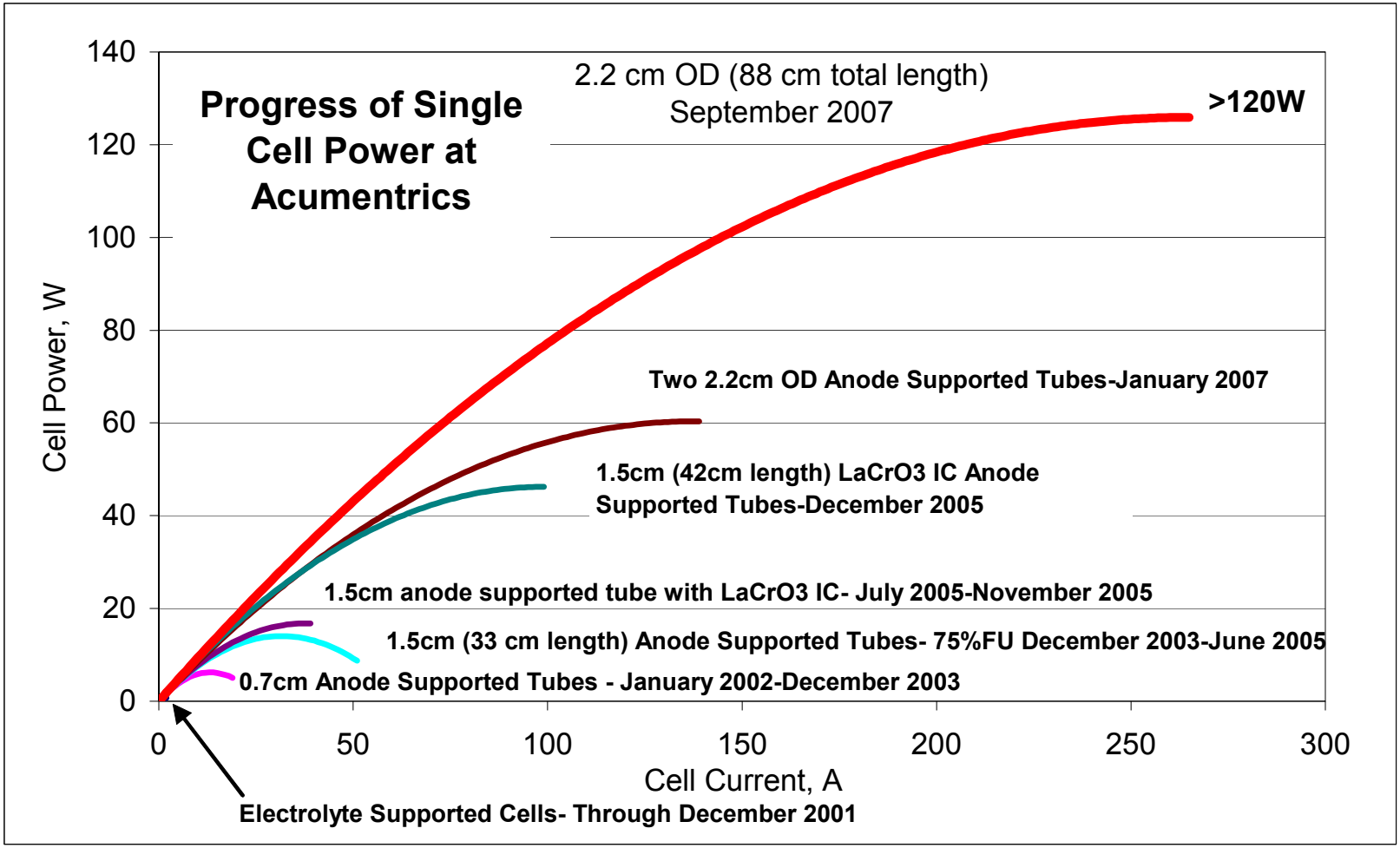
Approach

- Perfect the individual System pieces followed by optimizing their integration:
- **Cell Technology:** Improve power & stability of the cell building block
- **Cell Manufacturing:** Improve processing yield & productivity while decreasing material consumption
- **Stack Technology:** Refine stack assembly and improve integrity while cost reducing component costs
- **System Performance:** Develop simplified controls and BOP to allow for a reliable, highly efficient unit.

Acumentrics Progress



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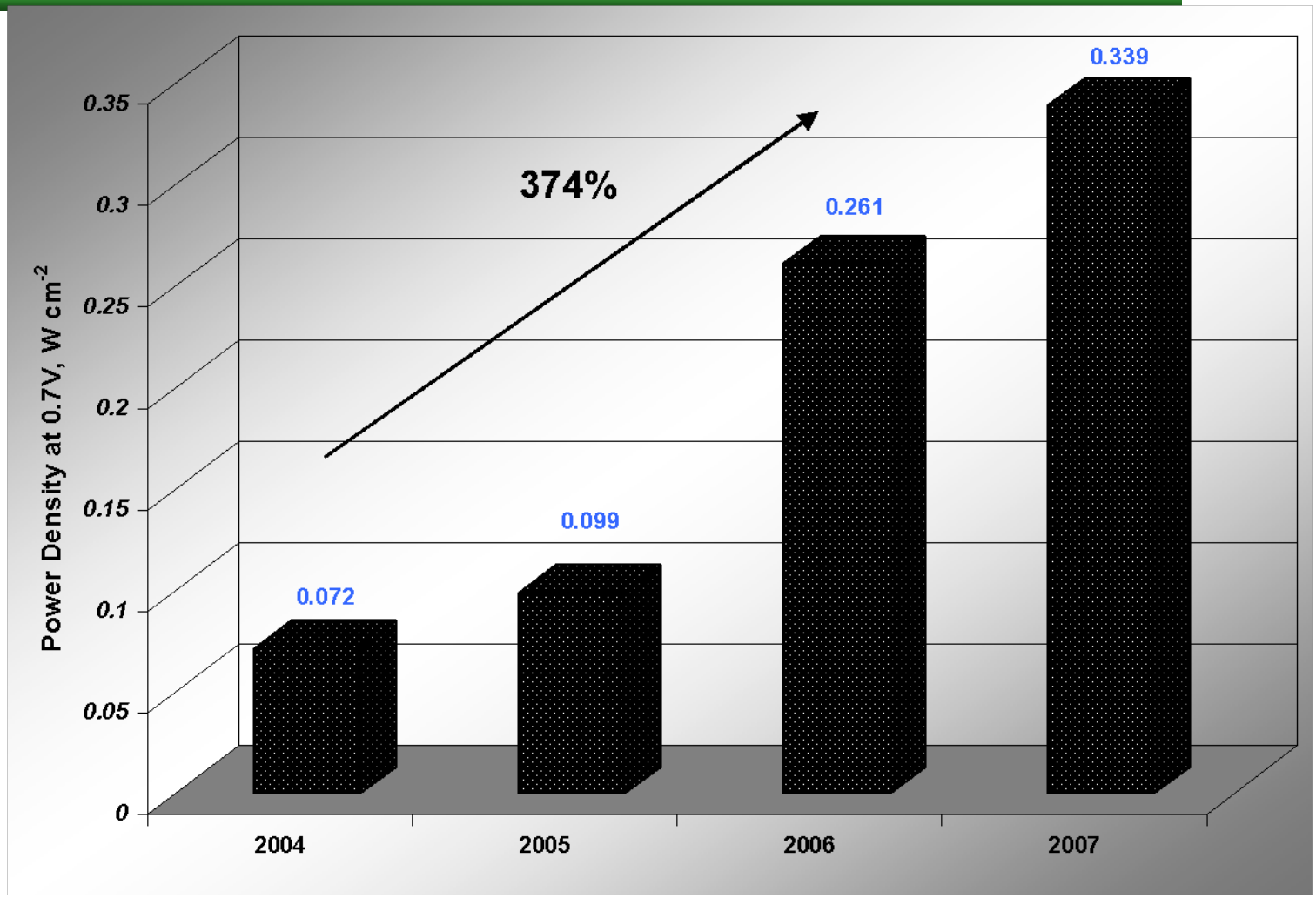
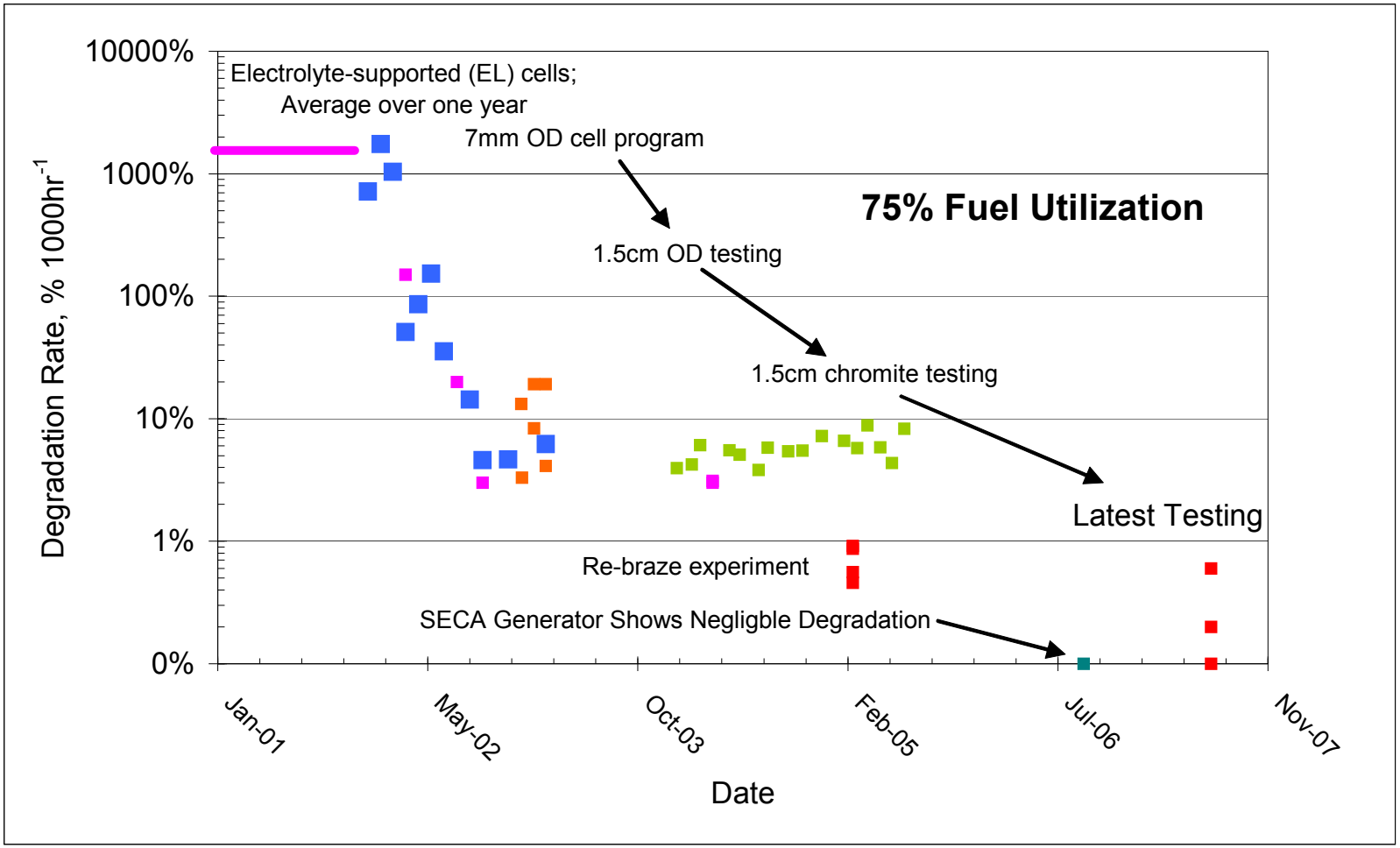
Power Density Improvements



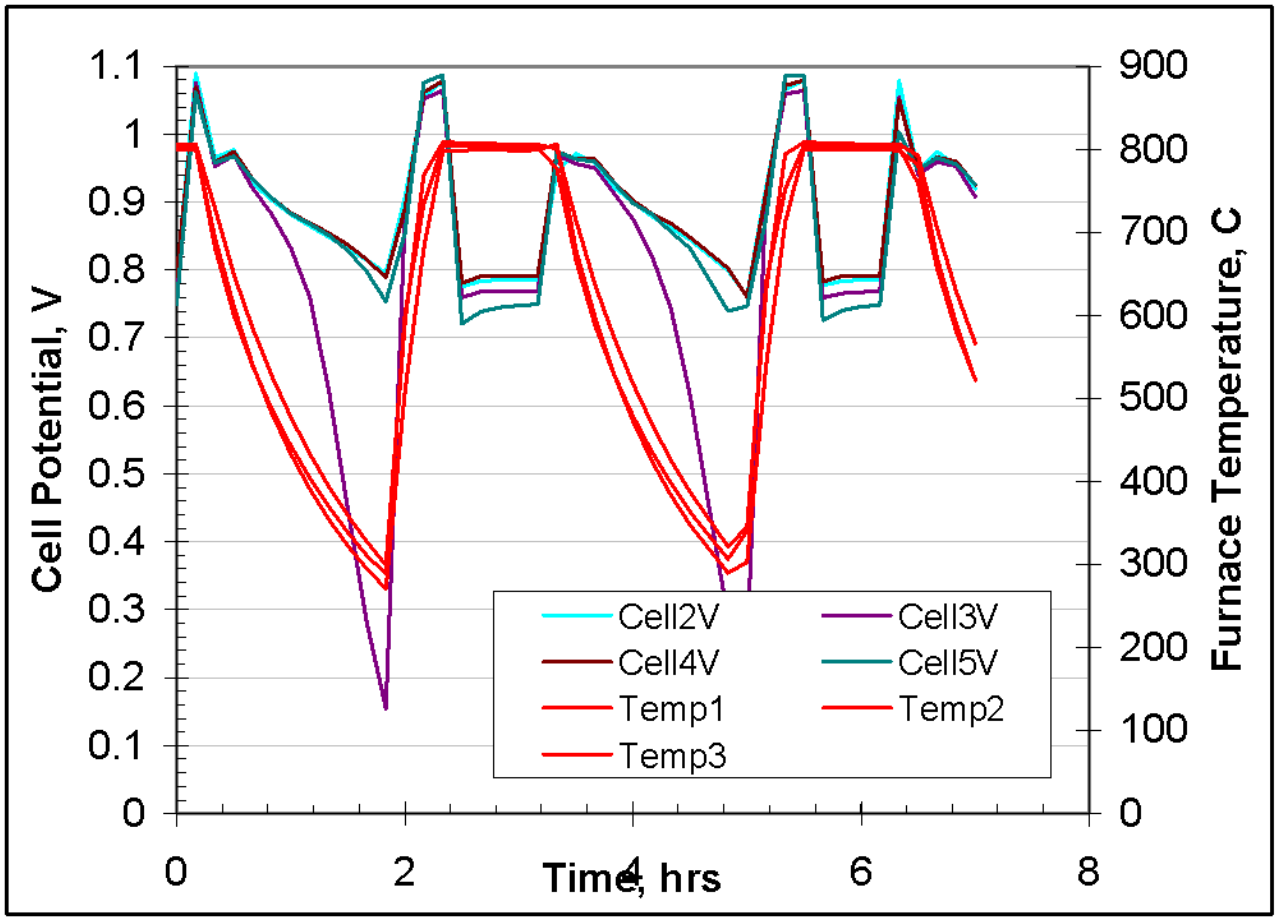
Degradation Progress



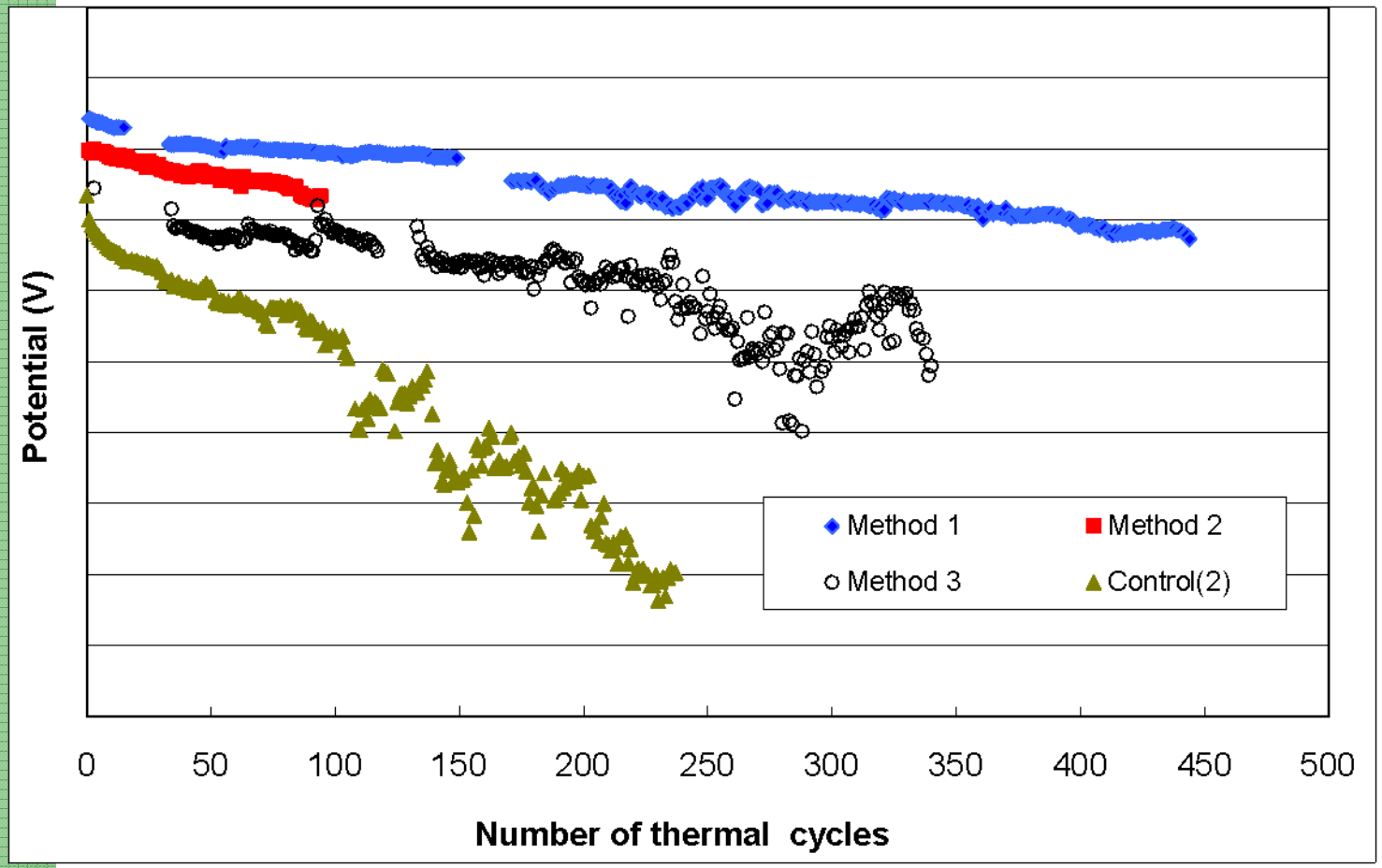
Electrical Testing- Thermal cycles

Loaded Cell performance graphs show a loss rate of about 1%/100TC

~4000hr run time/1500hrs at power

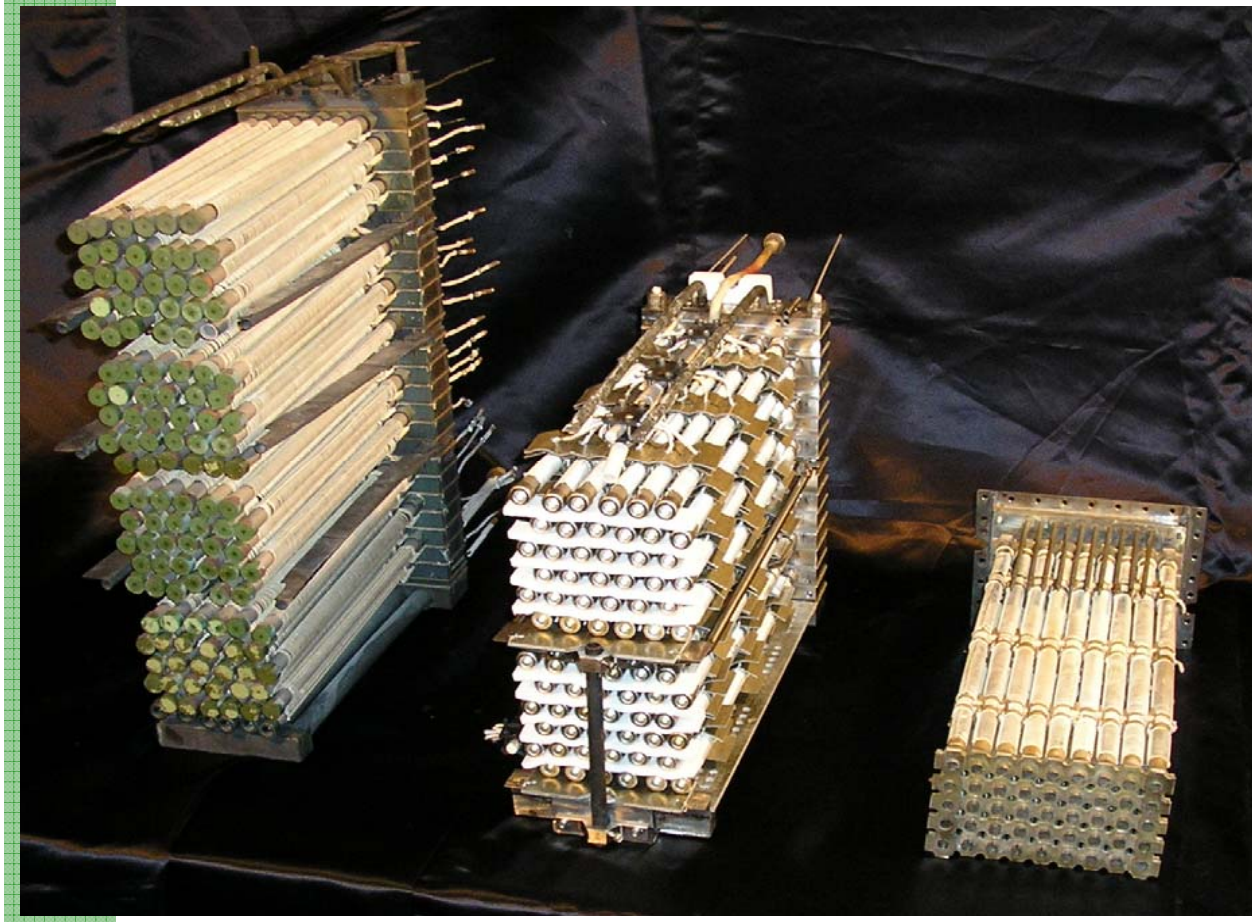


Single Cell Thermal Cycling



- Average of 5 cells
- Shows loaded performance after each thermal cycle
- Degradation from >10%/100T/C to less than 1%/100T/C

Stack Size Reduction



Number of tubes for 1.25 kW reduced from 126 to 72 to 45

Weight reduced 75% from 92 to 23lbs

Volume reduced 82% from 1.55 to 0.28 cu. ft.

Tube Fabrication Improvements

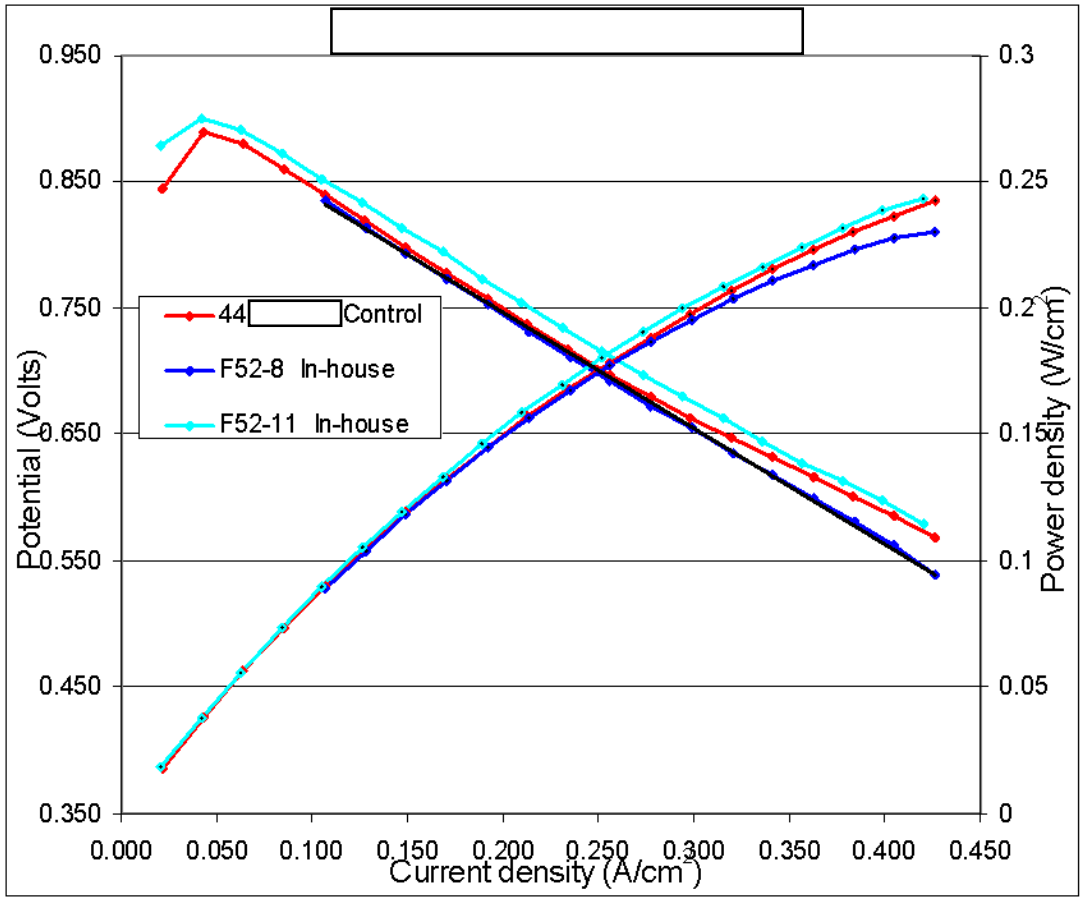
Q4 - 2008

Q1 - 2009

Isostatic pressing implementation:

- Thinner tube substrate wall possible – 45% reduction
- Integral closed end – eliminates one braze joint
- Significant through process yield improvement – 55% to 80%, due to firing orientation
- Simplified process - replaces mixing, extrusion, drying and one cutting operation
- Throughput up to 32 tubes per hour, immediately ready for firing

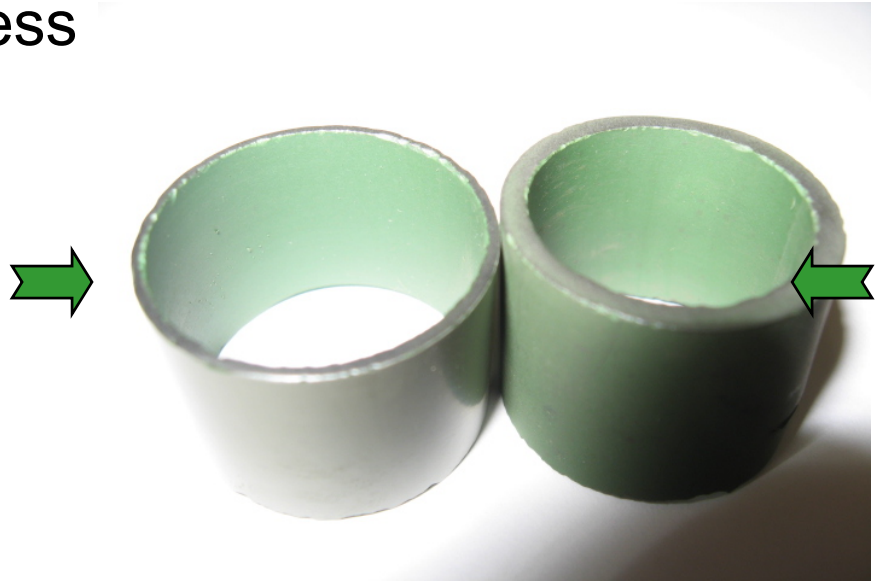
In-house Isopressed Tubes



- Cells made from in-house isopressed tubes performing well
- Peak power per cell approximately 57 watts on cell test

Tube Wall Thickness Reduction

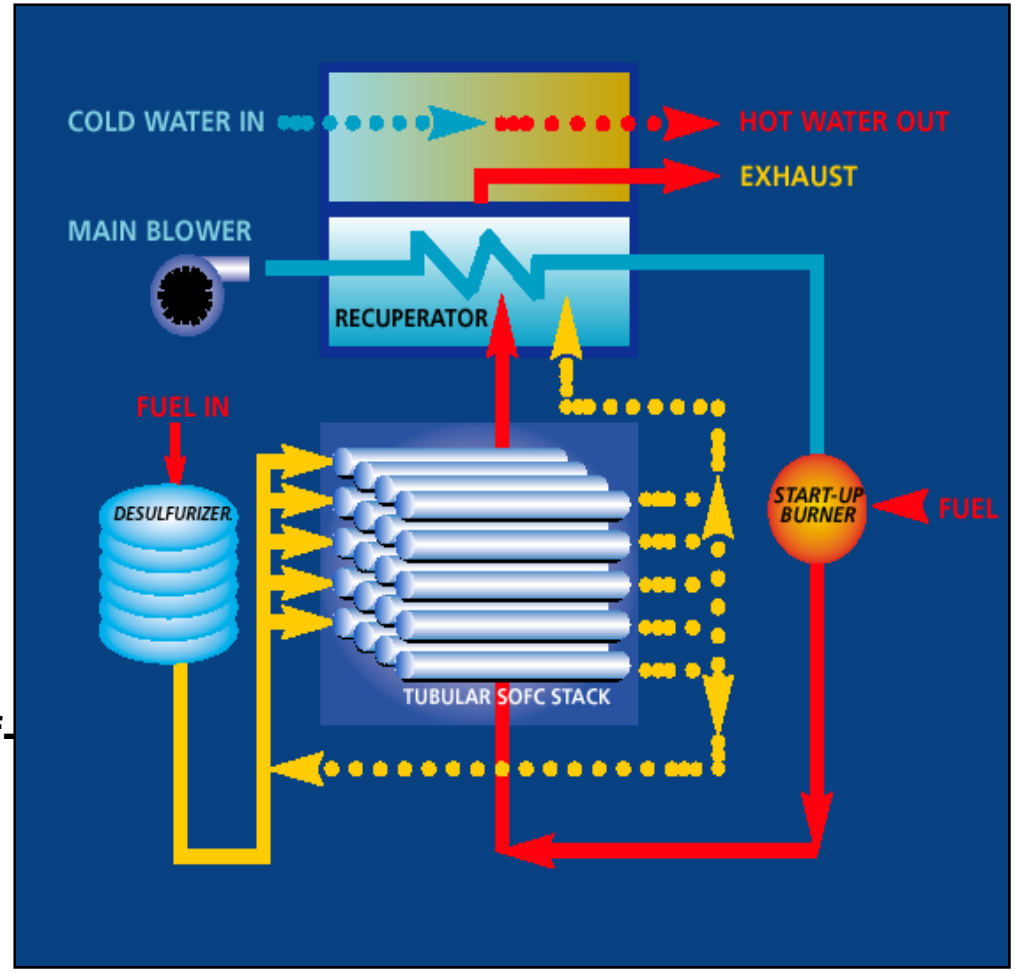
Fabricated and tested 35% and 45% reductions in wall thickness



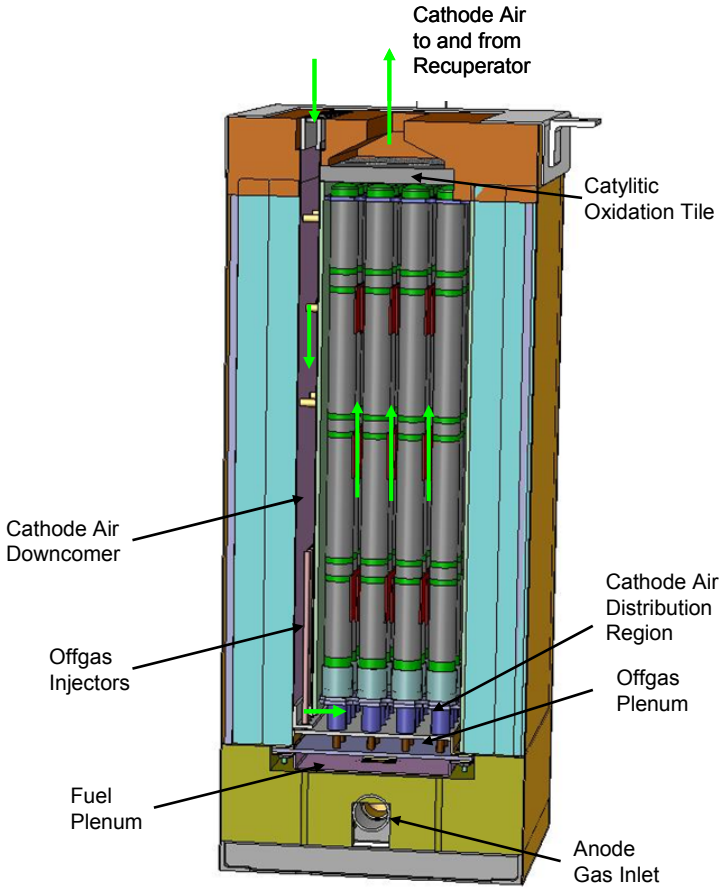
Achieved Equivalent Performance of that with standard wall thickness

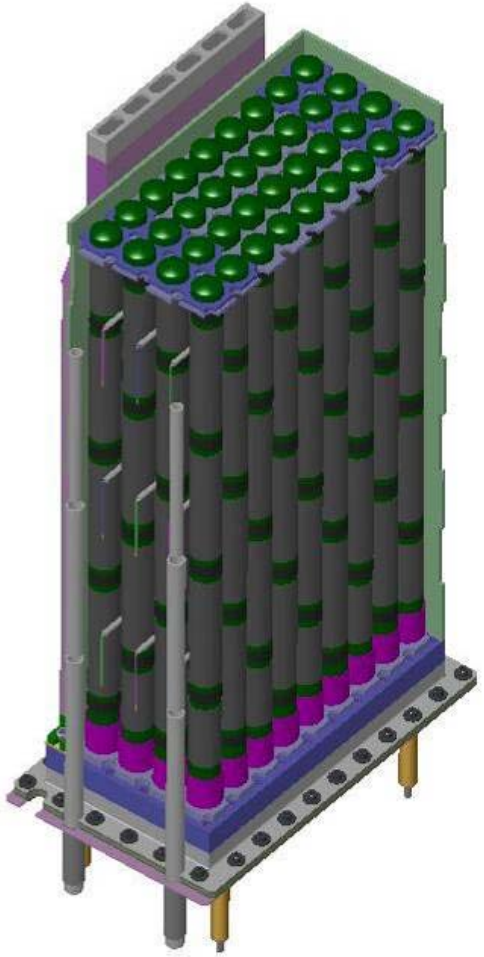
System Operation

- Tubular Cells
  - **Inherent strength and tolerance to rapid temperature change**
- High Operating Temperature (800 C)
  - **Internal fuel reforming and cogeneration opportunity**
- Standard Manufacturing Process
  - **Low capex**
- Standard Components
  - **Standard HVAC balance-of-plant components**
  - **Leverage 12 years DC/AC conversion experience**



Fuel Cell Module





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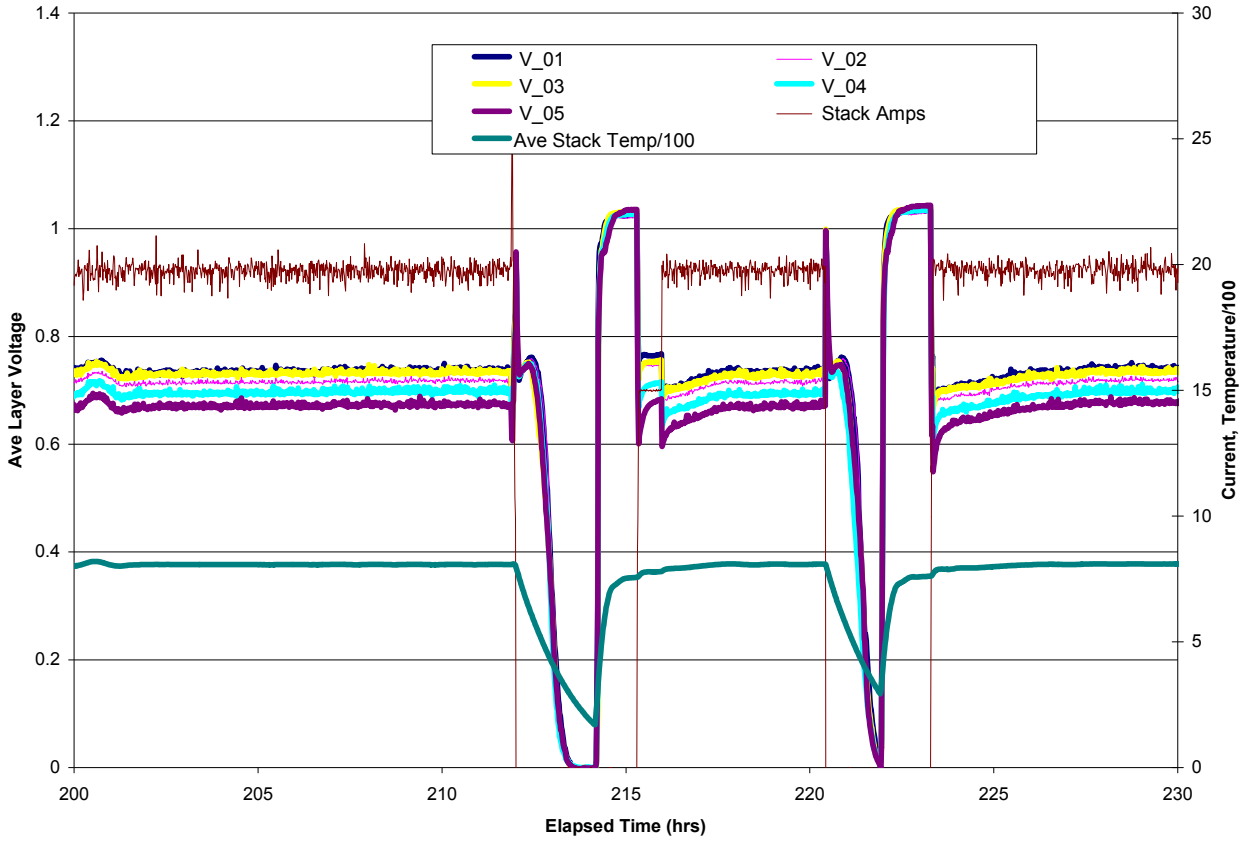
36 Cell Stack Assembly

Stack Stability Testing



Schedule:

- About an hour down to ~200C
- Less than 30 min back to power
- Run
- Redo

20 thermal cycles

Purgeless cycles

Excellent recovery

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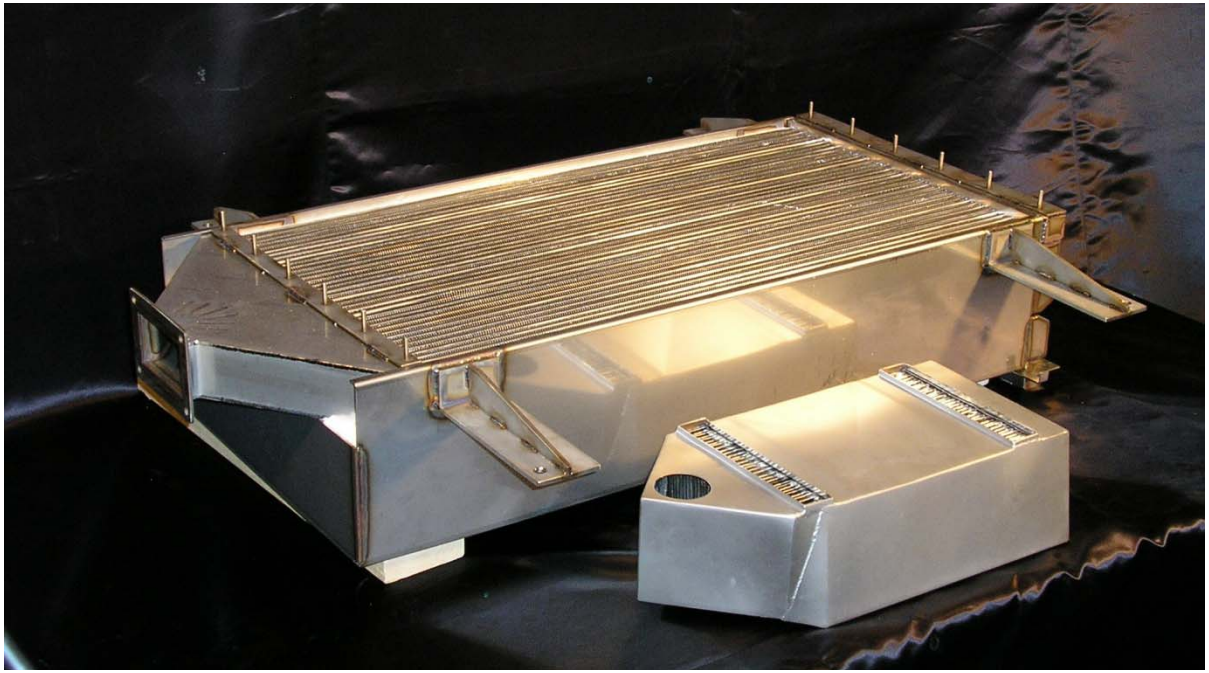
Recuperator Advancements

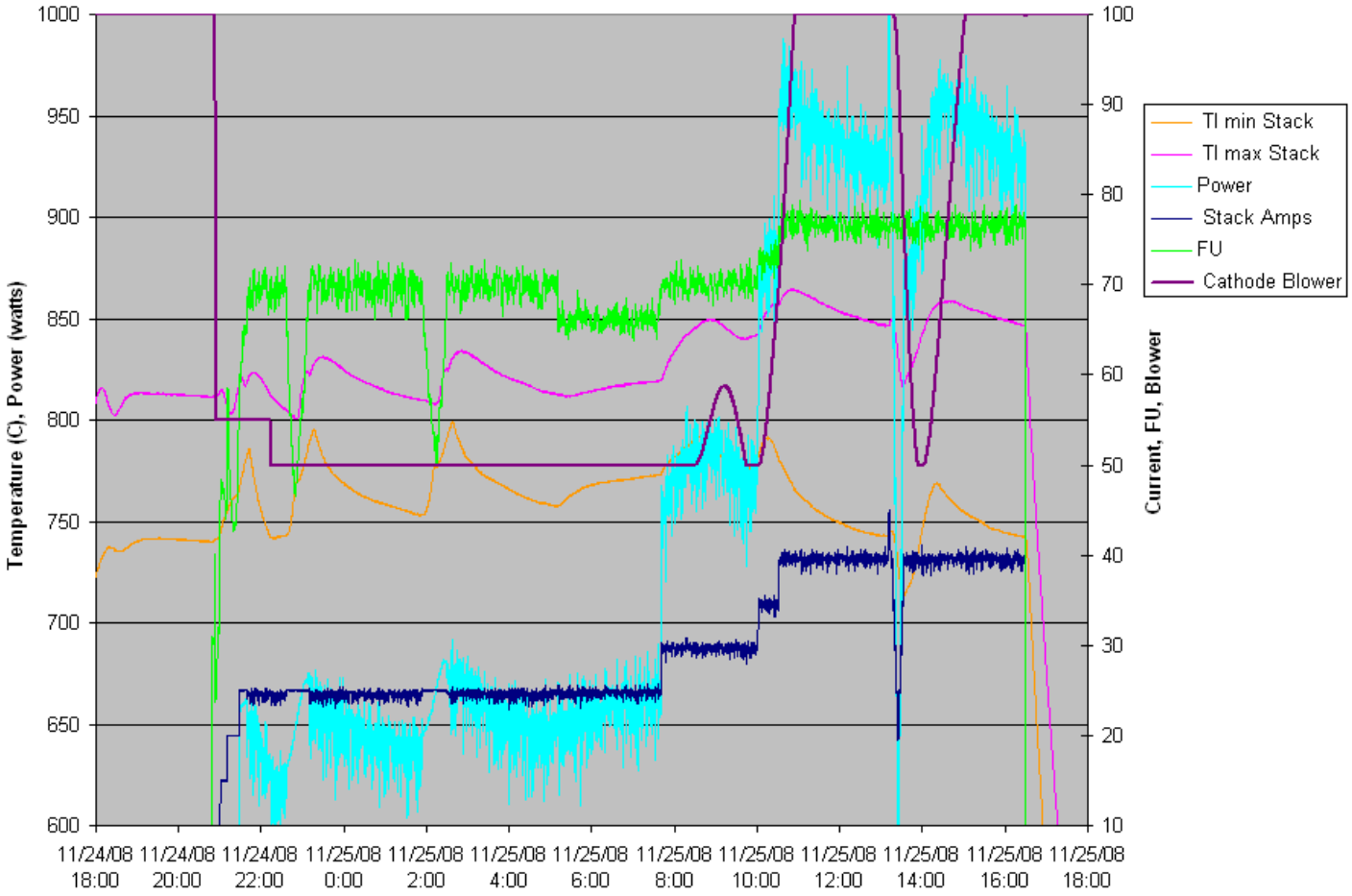
Reductions:

- 94% in Volume
- 88% in Weight
- 74% in Qty 1 Cost

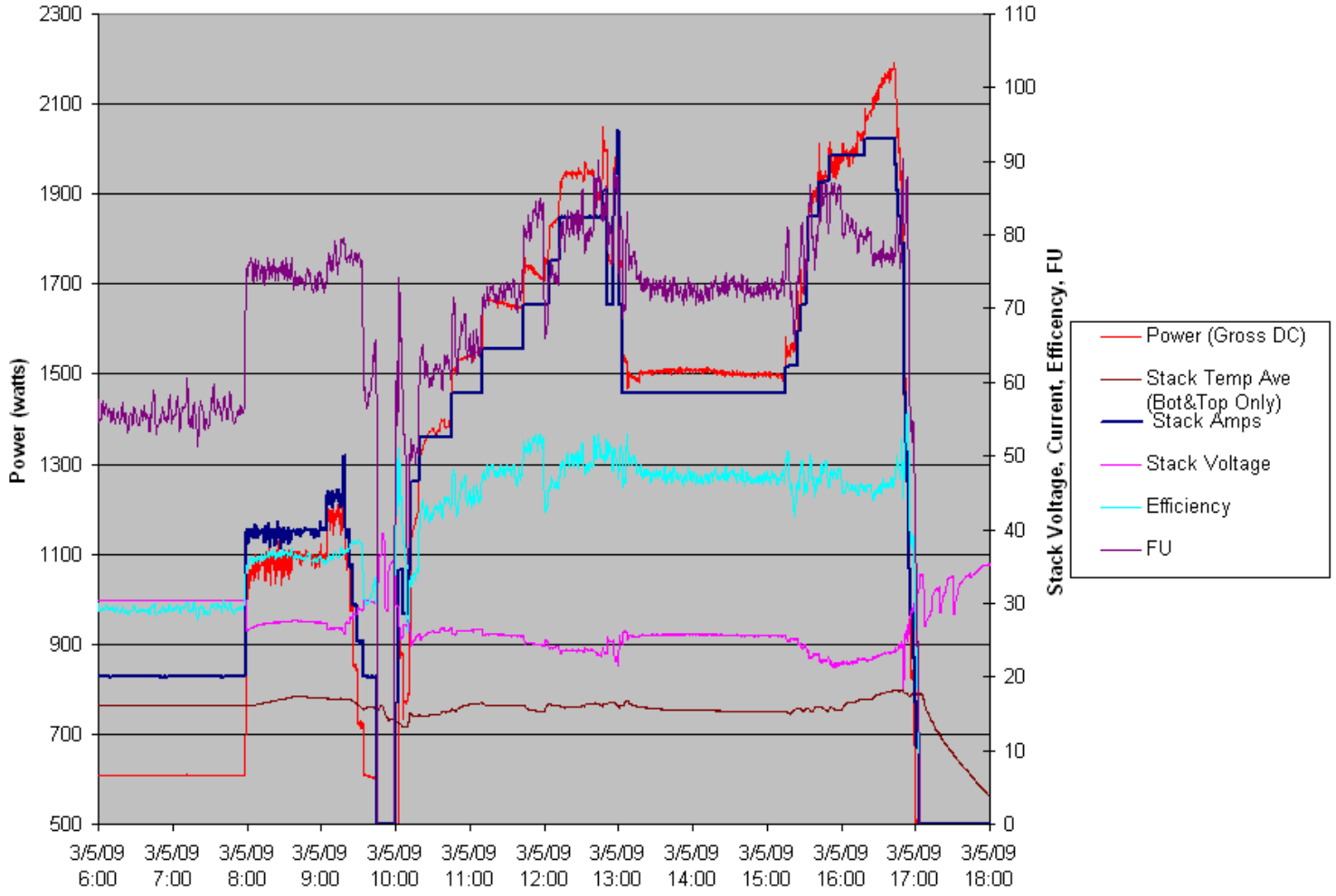


Generation 1	2.0ft^3	143 lbs	$4200 Qty 1
Generation 2	0.12ft^3	17lbs	$1100 Qty 1
Generation 3	0.12ft^3	17lbs	$550 Qty 1

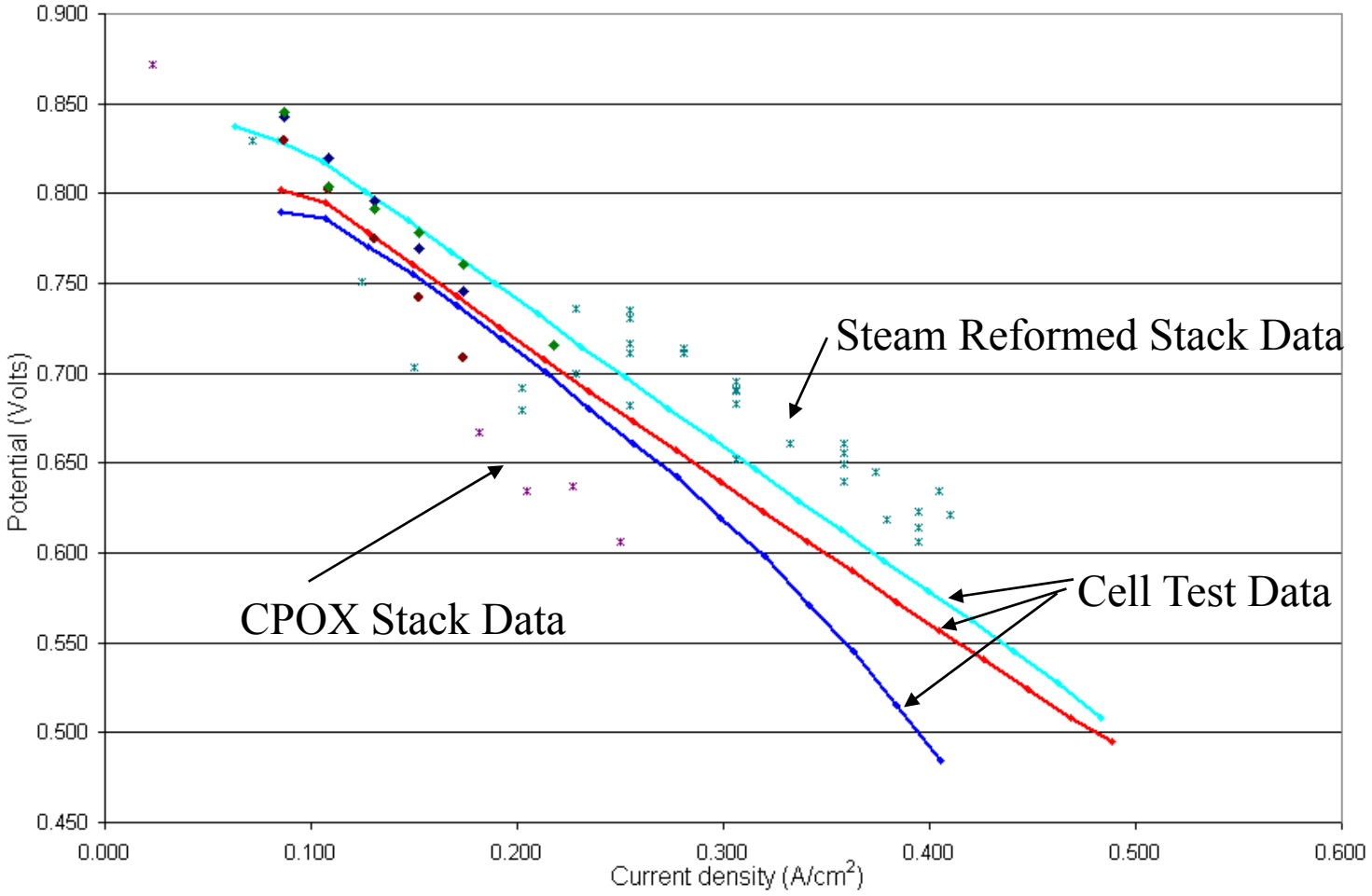
Improved Stack Efficiency- CPOX Results



Improved Stack Efficiency- Steam Reformed Results



Improved Efficiency: Cell vs Stack Comparison



mCHP vs. power plant and (condensing) boiler

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microCHP
simultaneous power and heat production

Primary energy
100%

Losses
10%

20% power

70% heat

90% useful energy

Primary energy 100%

40% Power plant

60% heating

Losses
24%

16% power

56% heat

4% Losses

72% useful energy

Common technology
separate power and heat production

= 10 – 25% lower primary energy consumption
= 10 – 25% lower CO_2 emissions
= 10 – 25% lower energy cost

Micro CHP

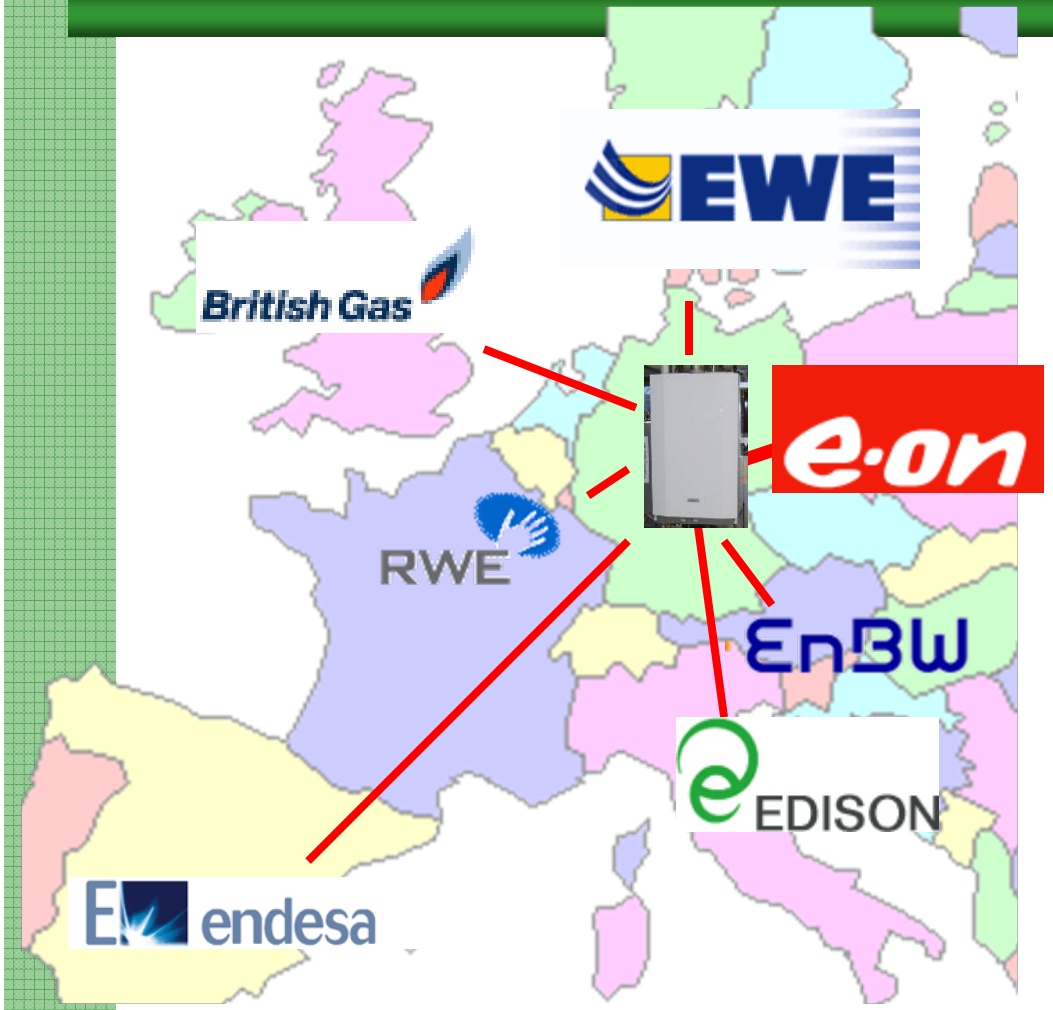
4 have been built to date

Has undergone & passed CE certification

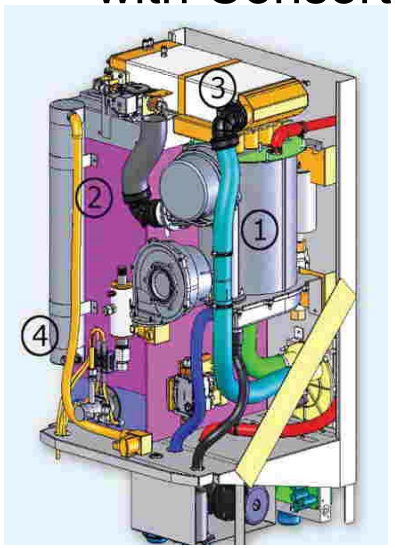
Undergoing testing this winter in Europe

1kWel AC out, 20kWth
Eff(Total)>85%,

1kW Home CHP Appliance



- 25% energy savings
- Prototype delivered 2007
- Demo with major European utilities
- Demonstration & Commercialization Program with Consortium of utilities



1 Booster Boiler
2 Fuel Cell Stack
3 Exhaust Heat Exchanger
4 Fuel desulfurizer

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Conclusions

- Significant progress in cell stability
- Advanced Cell Manufacturing automation & material reduction while maintaining cell performance.
- Single cells have shown tremendous capability both in thermal cycling and in operation under gradients
- Significant progress in stack size
- Generators and stacks have shown resiliency with purgeless thermal cycles
- The testing of a home heating appliance is currently underway

Thanks to

- Reginald Tyler of the DOE-Golden Office
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- MTS Group
- Technical Staff at Acumentrics