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

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FC032

Acumentrics Corporation

Strategic Partners

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TECHNOLOGY
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Sumitomo
Corporation

MiSource

Northeast
Utilities System

- *~ 95 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

Overview

Timeline

- Project Start: 7/28/2003
- Project End: 9/30/2011
- Percent Complete: 80%

Budget

- Project Funding
  - DOE Share=$23,976,894
  - Contractor=$8,114,740
- Funding Received FY 2010
  - $5,815,474

Barriers

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

Relevance/Objectives

- Improve Cell Power & Stability
- Cost Reduce Cell Manufacturing
- Increase Stack & System Efficiency
- Prototype Testing to meet system efficiency and stability goals
- Integrate to remote power and mCHP platforms to allow short and longer term market penetrations

Technical Approach

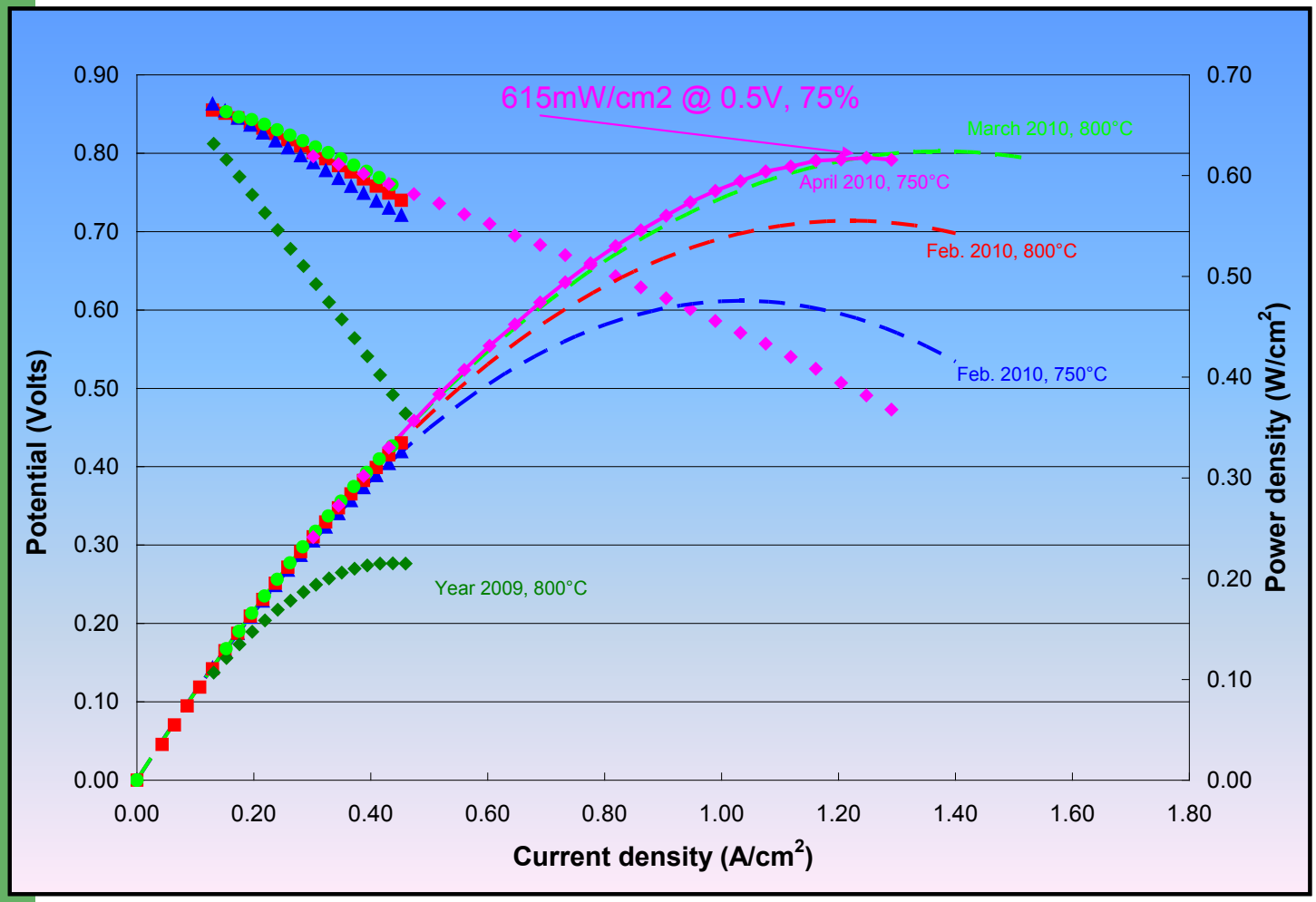
Perfect the individual System pieces followed by optimizing their integration:

- **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 heat removal and integrity while cost reducing components
- **System Performance:** Develop simplified controls and BOP to allow for a reliable, highly efficient unit.

Proposed Future Work-2010 Annual Meeting

- Assure cell stability
  - Correlate stability vs. current density
  - Demonstrate stability over thermal cycles
- Resolve thermal issues in stack due to higher power density
  - Test improved thermal management techniques
  - Compare results of CPOX and steam reformed systems
- Continue cost reductions on each product platform
  - Continue cell manufacturing automation
  - Continue “make/buy” decisions on generator and BOP components

Technical Accomplishments & Progress

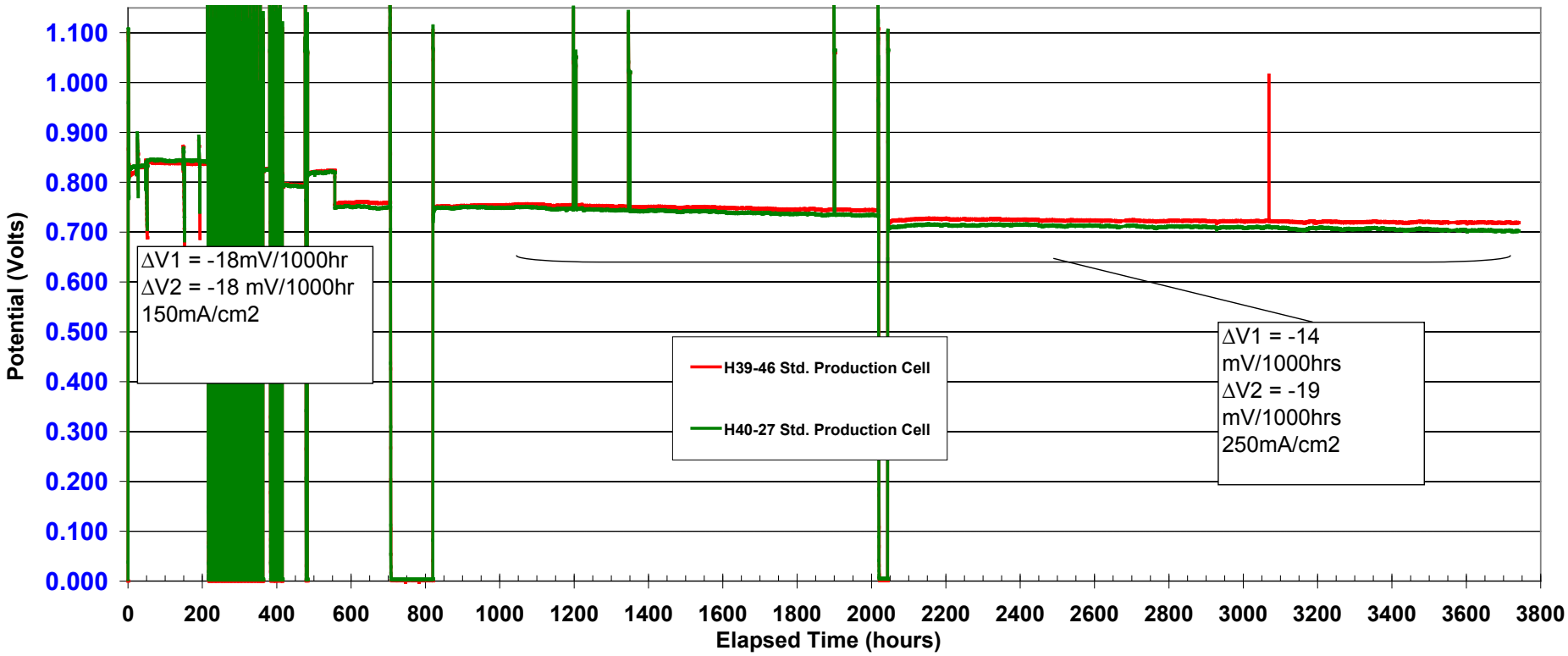


- Focus in 2009 through mid-2010 was power/cell enhancement
- Focus in back half of 2010 and start of 2011 has been stability and integration to systems

Results from 2010 AMR

Cell Stability at Increased Current & Power

- Equal or less mV loss per 1000hr while increasing current density 67%



New High Temperature Furnace Implemented

Quality Improvements

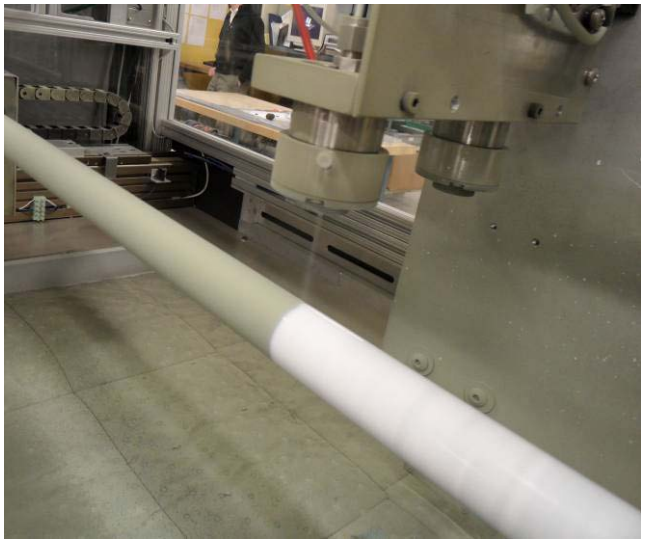
- Thermal gradients reduced by 50% - uniform shrinkage
- 60% reduction in the occurrence of electrolyte contamination defect

Throughput Improvements

- 4 x Increase in throughput.
- Firing times reduced by as much as 50% - active heating/cooling
- Reduced energy requirement per cell by 50%, therefore reducing cell cost

Electrolyte Co-sintering Development

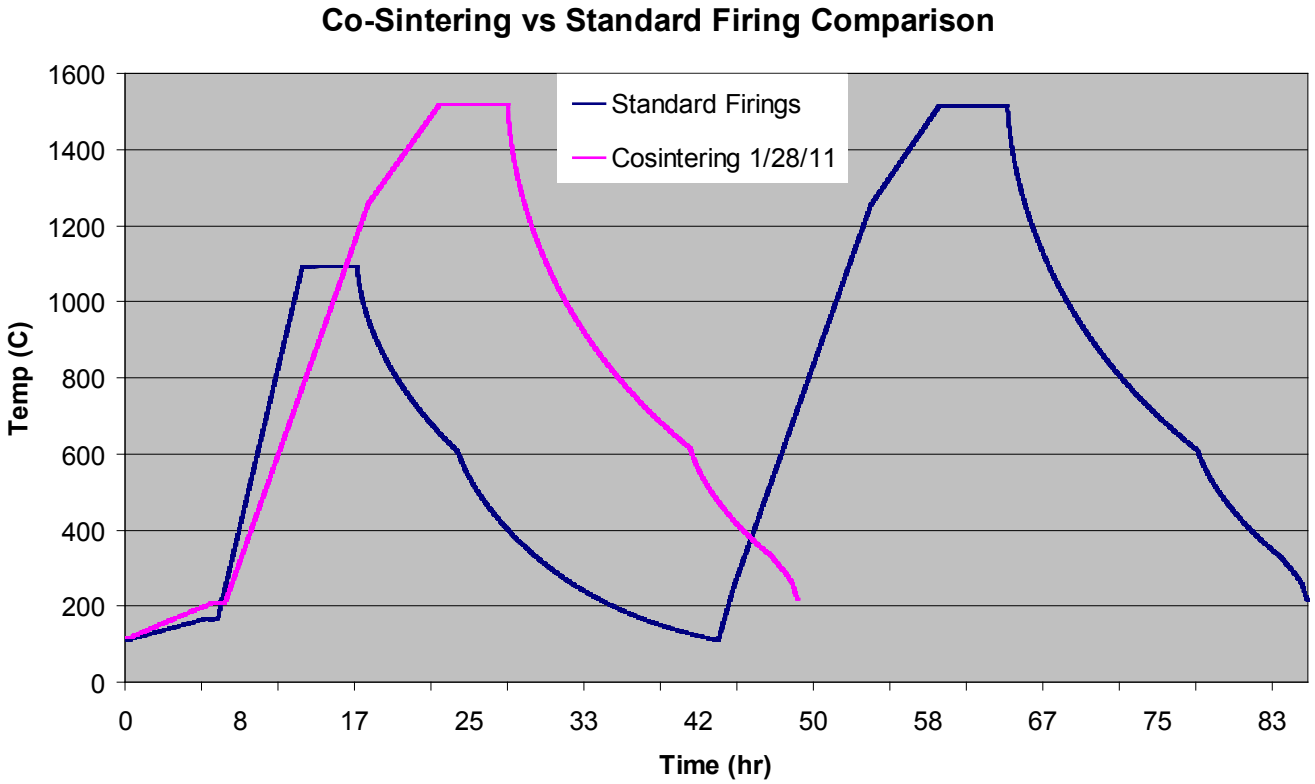
- Presently developing co-sintering of the base tube and electrolyte
- This requires the development of a spray technique for application of electrolyte



- Spraying has the following advantages over the present dipping technology:
  - Reduced potential for electrolyte contamination
  - Reduced breakage of the base tube during electrolyte application

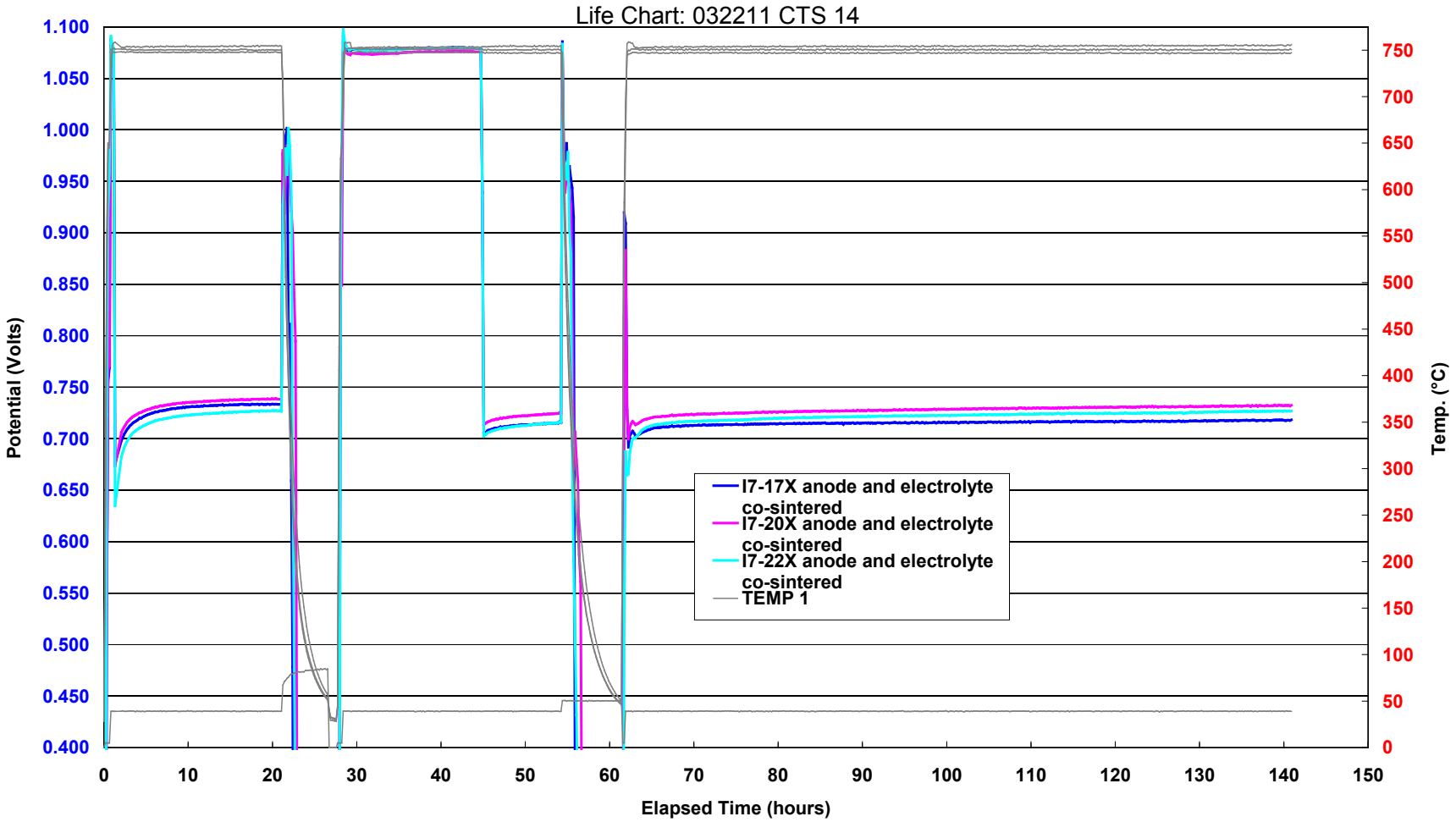
Electrolyte Co-sintering Development

- Through implementation of Co-sintering, Acumentrics will realize the following:
  - Dramatic reduction in processing time
  - Significant increase in cell yield
  - Significant reduction in cell cost



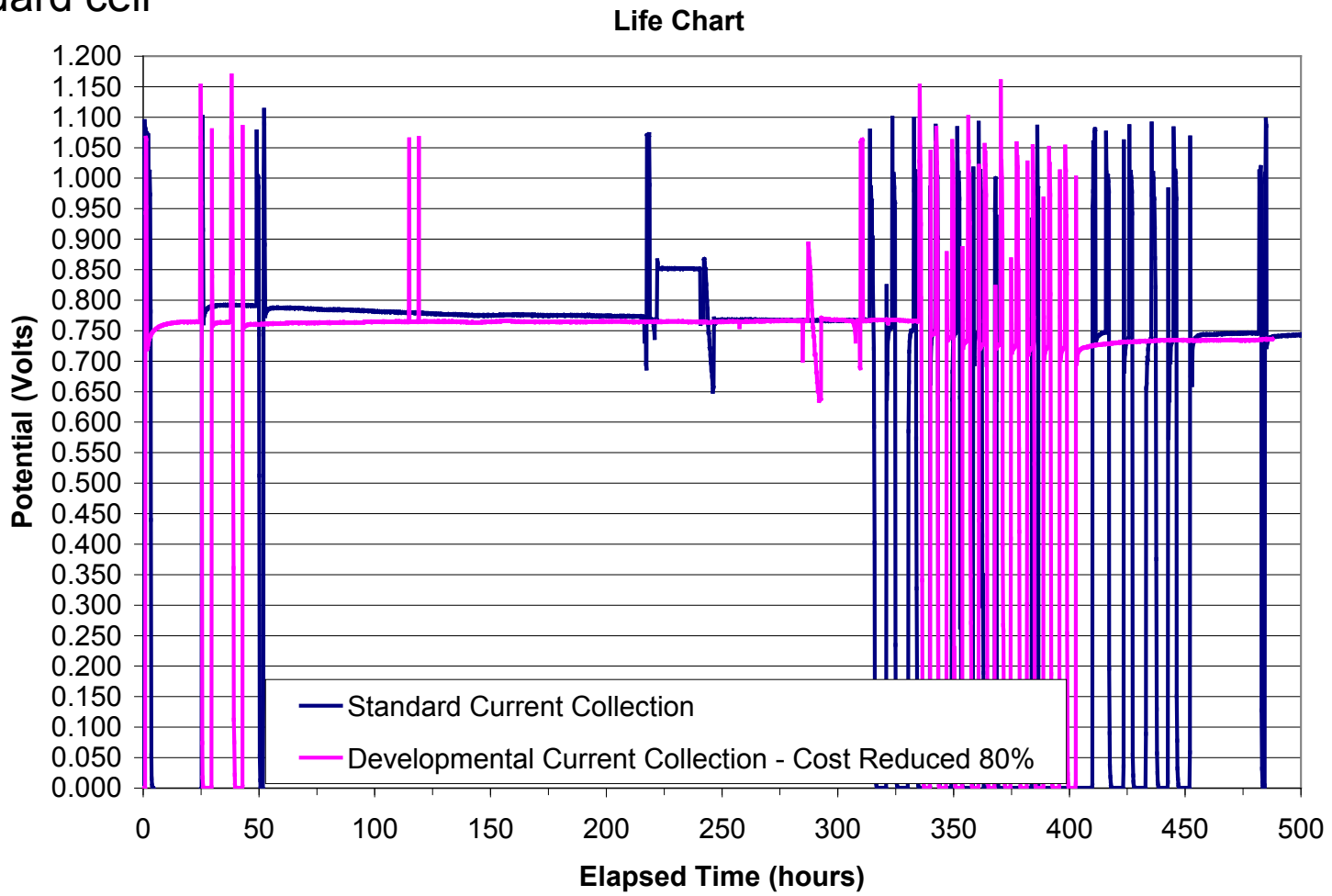
Electrolyte Co-sintering Development

- Early testing of co-sintered cells within 2% of performance of standard cells



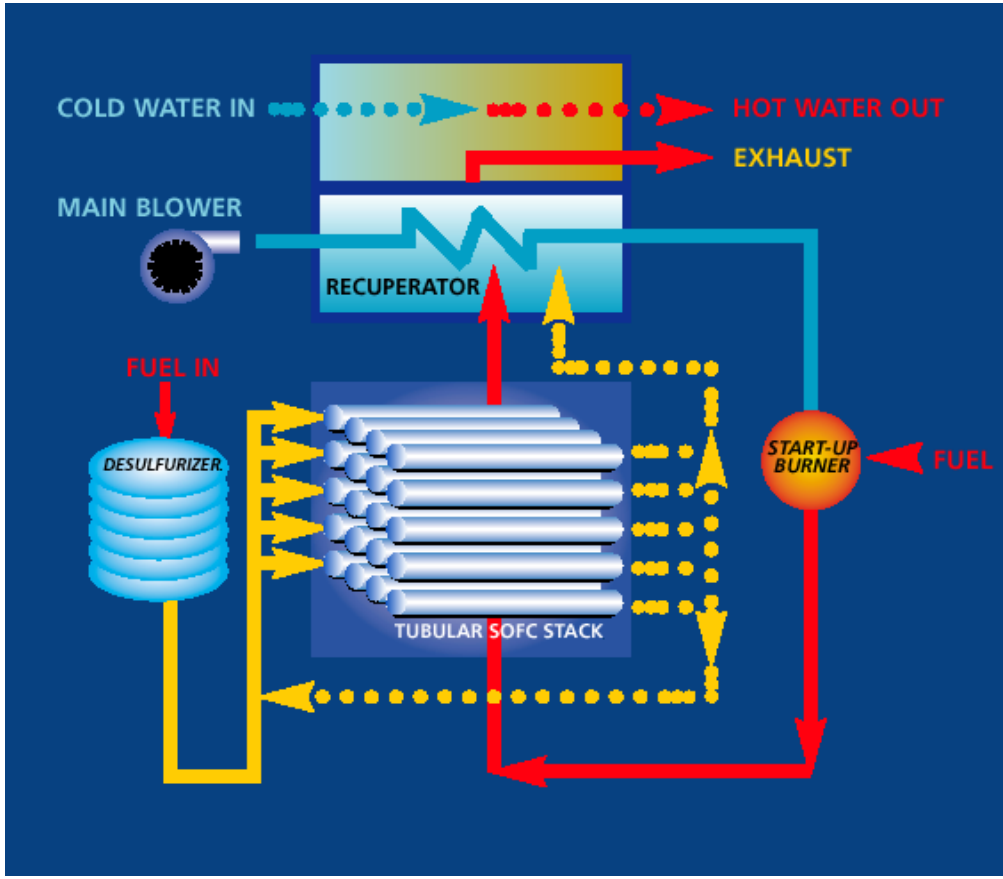
Current Collection Developments

- Early stability and performance of reduced current collection comparable to standard cell

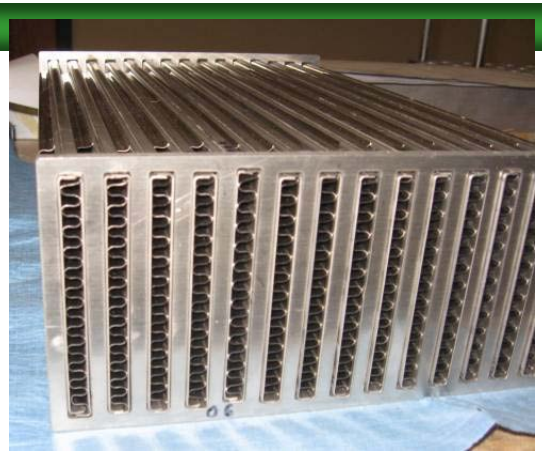


System Operation

- 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



In-House Brazed Recuperator Manufacture



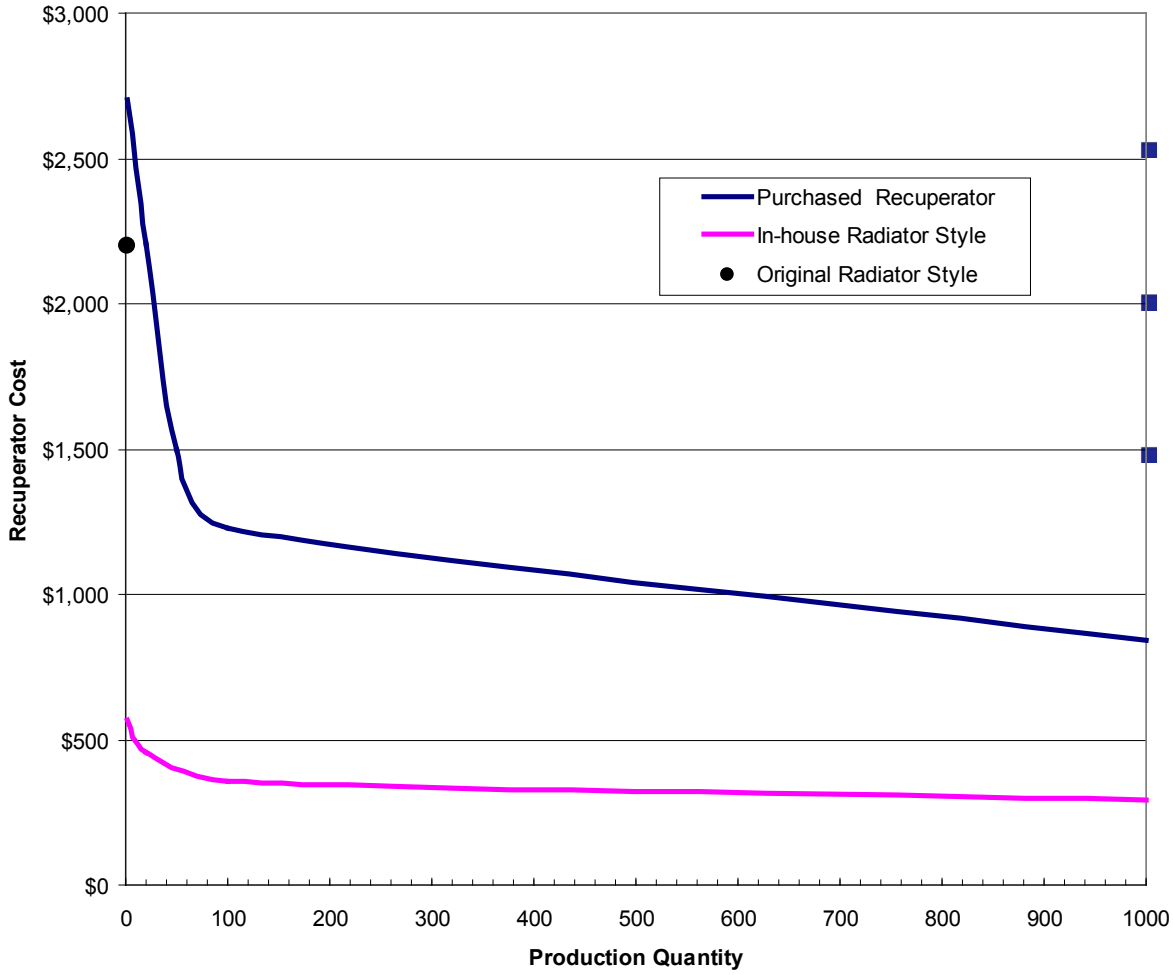
- Demonstrated removal of all labor intensive welding
- Equivalent leakage to welded design
- Designed & built for mass production

Shell and Tube

Flat Tube Radiator Style

Single Panel

Recuperator Cost Reduction

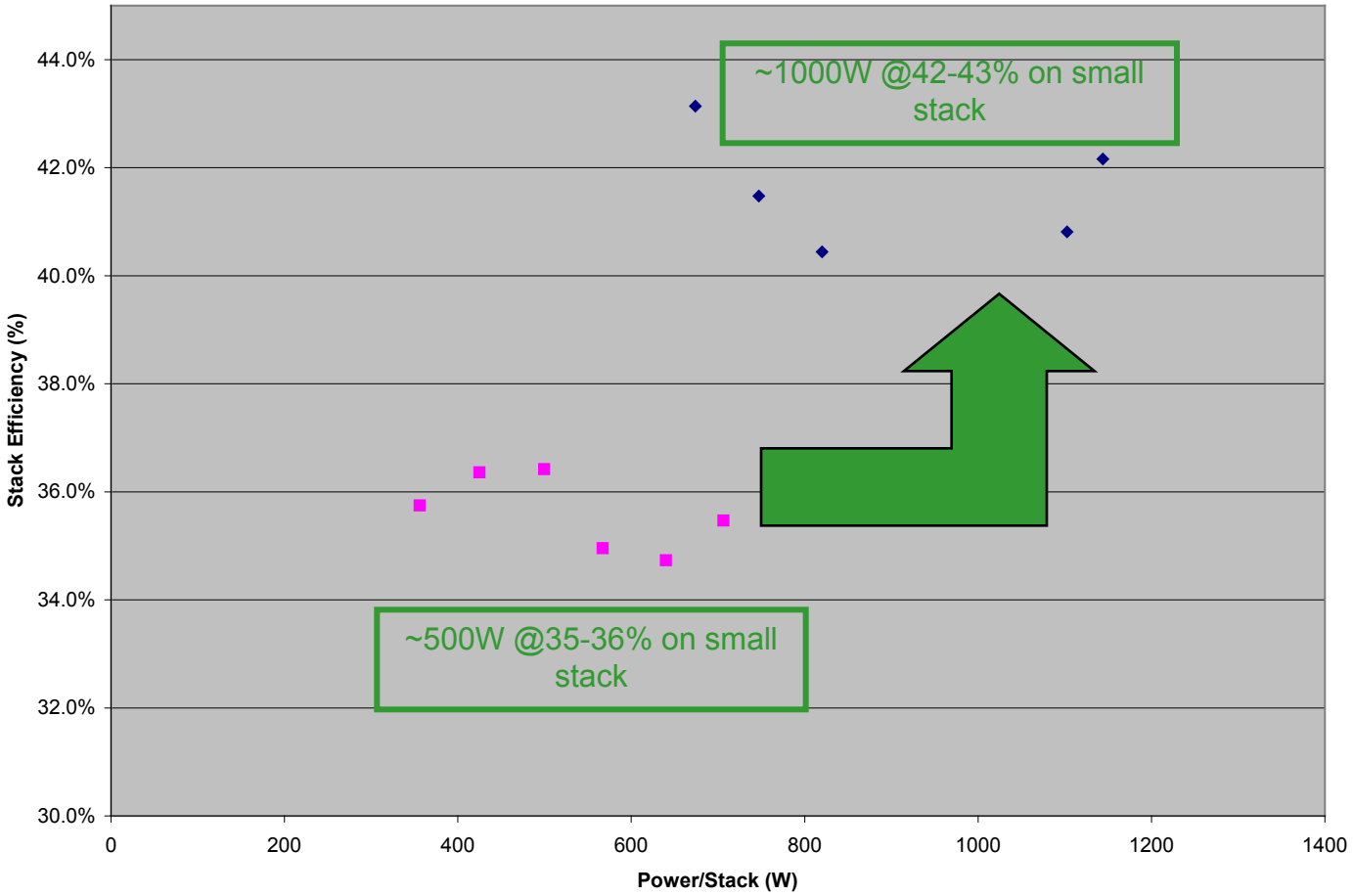


Lower Operating Temperature allows lower cost raw materials

Lower Required Effectiveness by better thermal balancing

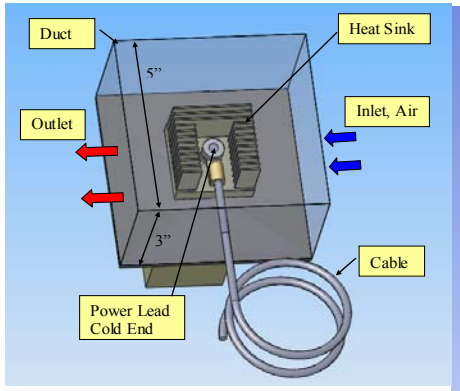
Simplified Design and Manufacturing Process

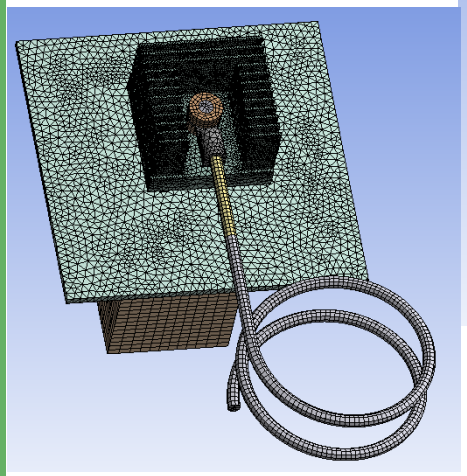
High Efficiency POX Operation

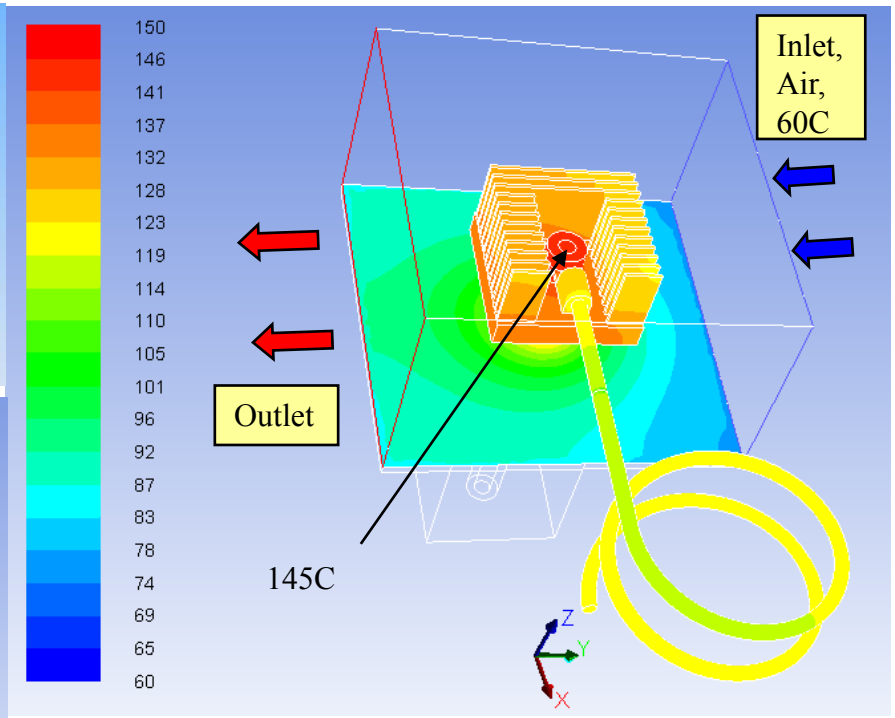


- Modeled in 2010 AMR increased cell power & reforming enhancements could significantly improve generator performance
- Demonstrated a 100% increase in power per stack-maintaining thermal balances
- Demonstrated a 7-10% gain in overall efficiency

CFD Modeling





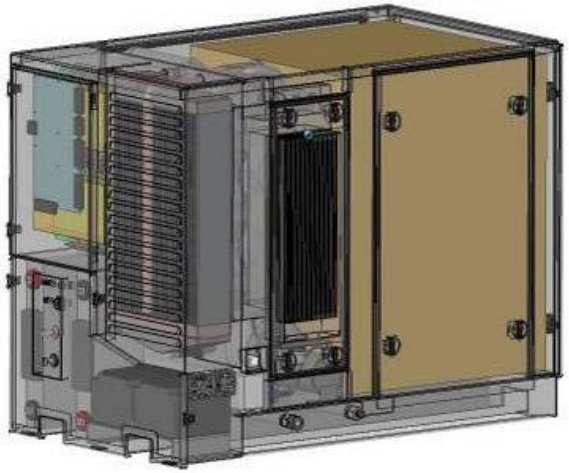


- Developed a method to direct electronics cooling air across power leads to minimize fan count.
- Also results in lower parasitic power improving overall efficiency.

Product Portfolio

Remote Power

Military Generators



mCHP

Remote Power

- Product developed due to continued need for power in off grid areas
- Solar limited due to size/cost as well as reliability in harsh environments
- Capable of operation on pipeline gas as well as commercial propane. Operation on low sulfur diesel well underway.
- >40 units delivered to the field – over 30,000hrs cumulative on last 6-8units
- Higher efficiency than incumbent – 2-3X of generators

Remote Power

- Remote Power (Boston) Installed and running since January 2010
- Cape Cod installed and running since September 10th 2010
- Shipped 4 Units to Texas, Installed at two sites, running since Aug 3rd
- Additional site added after 60 day site acceptance test

Boston

Operating over 10,000 hours continuous operation on gas transmission line

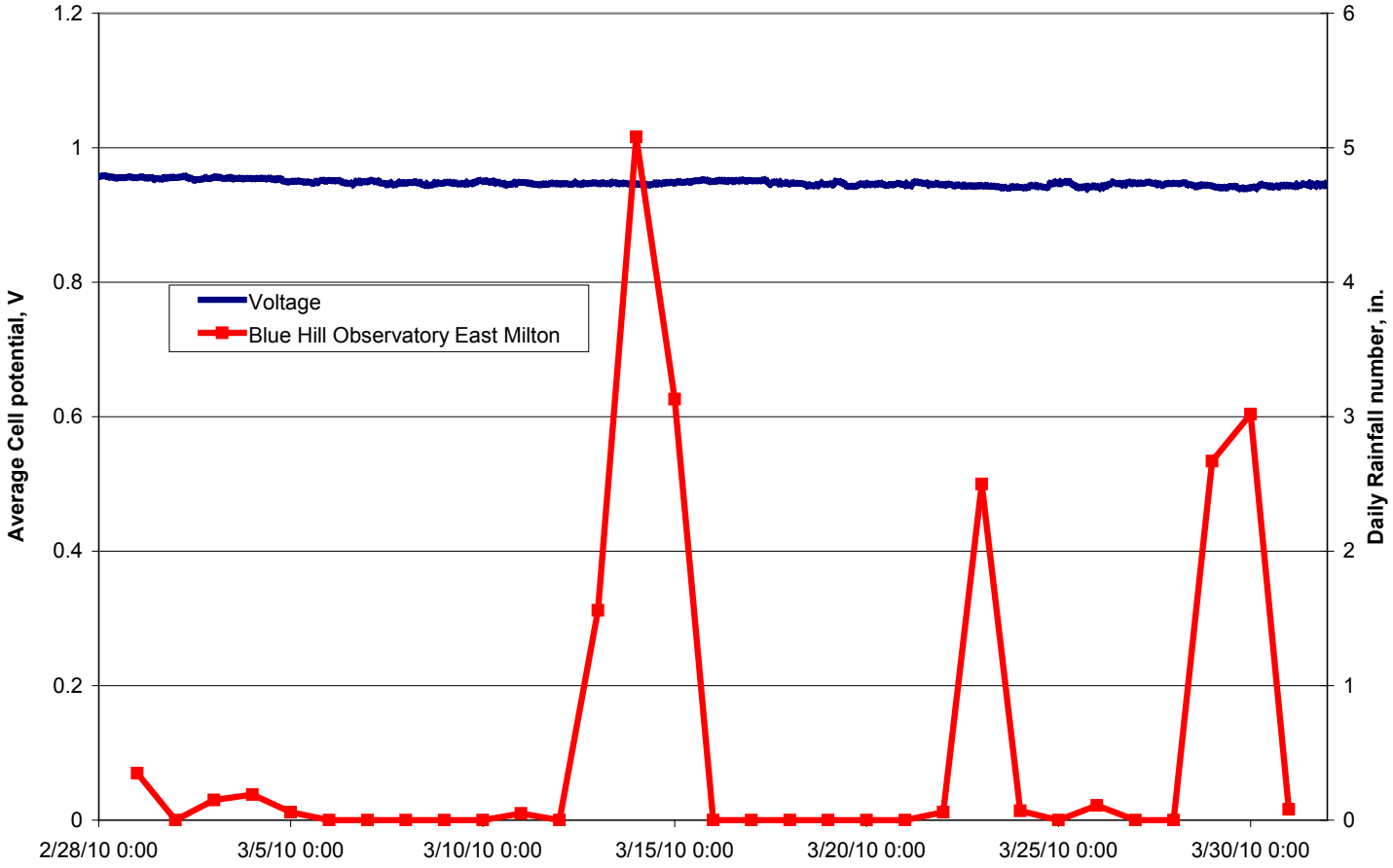
Cape Cod

Texas

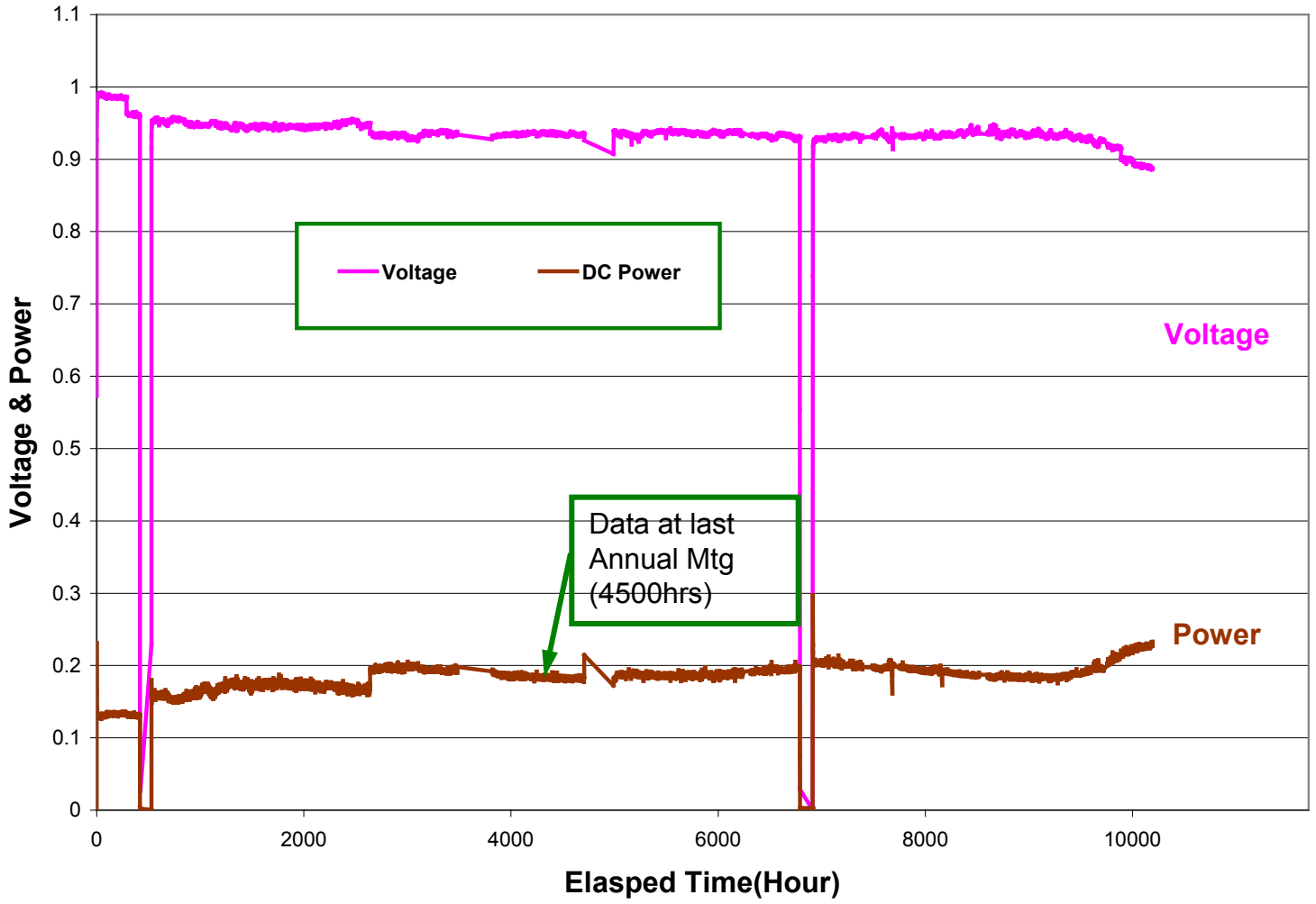
Producing between 380-500W each at two remote sites

Environmental Conditions

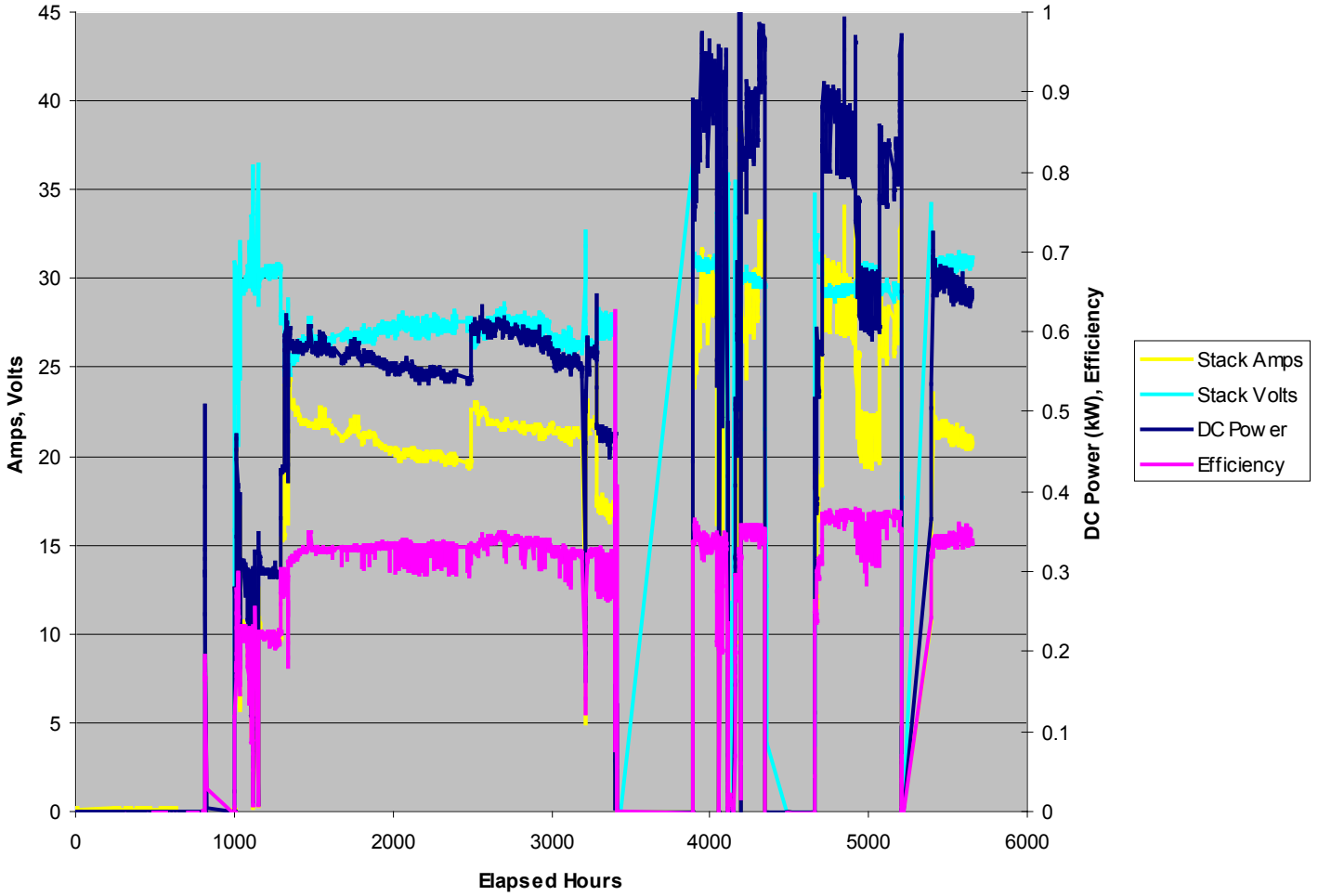
Remote Power Site Rainfall in March 2010-17.5” of Rain



Remote Power Durability Testing



Remote Power-Texas Sites



Collaborations - EFESO Program

Enviromentally Friendly Energy from Solid Oxide fuel cell

- Italian government program granted to Ariston thermal group and 15 partners including Acumentrics.
- Acumentrics is the first foreign company to be issued an Italian government grant for a green energy program
- Heavily dependent upon the previous and future support of the U.S. DOE.
- Three year, $1.1M program culminating in a 1kWel and 2.5kWel mCHP prototype.
- Brings in key technology contributors on inverters, balance of plant components, testing labs/Universities and certifying bodies

Proposed Future Work

- Assure cell stability
  - Continue testing at 250 to 400mA/cm^2 current density
  - Further demonstrate stability over thermal cycles through cell & stack testing
- Continue cost reductions on each product platform
  - Continue cell manufacturing automation-maintaining performance
  - Reduce Generator & BOP costs to levels allowable for remote power products – complete “make/buy” decisions on all major sub-assembleis
- Move from field testing of first market products to second market products
  - Continue to build on success of remote power units and accept commercial orders
  - Field demonstrate liquid fueled military units in the 1-3kW range.

Summary

- Demonstrated maintaining stability at increased current and power per cell
- Continue to advance cell manufacturing automation and process simplification while maintaining performance.
- Improved overall system efficiency
- Demonstrated stable system operation in real world conditions for >11,000hrs.
- Continue to make steady progress into short, medium, and long term markets for fuel cells.

Thanks to

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