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

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This presentation contains no proprietary, confidential, or otherwise restricted information
Acumentrics Corporation

- ~ 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

Strategic Partners

General Dynamics
U.S. Department of Energy
Ariston
ChevronTexaco Technology Ventures
MASSACHUSETTS TECHNOLOGY COLLABORATIVE
Suntomo Corporation
NiSource
Northeast Utilities System
Overview

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

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

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

- 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
Cell Stability at Increased Current & Power

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

\[ \Delta V_1 = -18 \text{mV/1000hr} \]
\[ \Delta V_2 = -18 \text{mV/1000hr} \]

150mA/cm²

\[ \Delta V_1 = -14 \text{mV/1000hrs} \]
\[ \Delta V_2 = -19 \text{mV/1000hrs} \]

250mA/cm²
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

Life Chart: 032211 CTS 14

Elapsed Time (hours) vs. Potential (Volts) and Temp. (°C)
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

Flat Tube Radiator Style

Shell and Tube

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
• 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 6-8 units
- 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

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

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

**Environmentally 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 1kWeI and 2.5kWeI 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/cm² 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-assemblies

- 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.
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