Status of the Acumentrics SOFC Program

Dr. Norman Bessette
SECA Annual Workshop
Boston, MA.
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Acumentrics Corporation

- ~ 75 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

Courtesy of the NASA & EIT Consortium
Acumentrics

Battery based UPS
500Watts - 20kWatts

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
Acumentrics Corporation

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<th>Alliance Investments</th>
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How Acumentrics Fuel Cells Work

Solid Oxide Fuel Cell
SOLID STATE (Ceramic) CONSTRUCTION

AIR (Circulates freely around outside of tube)
O₂

4e⁻ — (LOAD) — 2O²⁻ — (Oxygen ions) — 4e⁺

WATER & CARBON DIOXIDE

STEAM

H₂O ↔ H₂ & CO₂ ↔ CO

METHANE C₄H₄
PROPADE C₃H₈
BUTANE C₄H₁₀
(CₙH₂n+2)

CATHODE ELECTROLYTE ANODE

Electrolyte layer only conducts Oxygen ions through it
Acumentrics Fuel Cell Evolution

2000 – 2001
Electrolyte supported
*Tubular SOFC Systems*

700 Watts

200 Watts

25 Watts

Q3 2000

10 Watts

Q3 2001

Q1 2001
Acumentrics Fuel Cell Evolution

2002 – 2003
Anode supported
* Tubular SOFC Systems

Stack Design Attributes
- Anode support tubes
- Brazed seals
- Stackable design
- Welded electric connections
- Low thermal mass
- Withstands heat expansion

Stackable Manifold design
- 5 Watt Tubes
  - Q2 2002

High Power Anode Tubes
- 20 Watt Tubes
  - Q3 2003
Acumentrics Tubular SOFC POX System Overview
Acumentrics Tubular SOFC Steam Reformed System Overview
Acumentrics 2kW UPS

- Full on-line UPS
- For Cable/Broadband
- Operates on line pressure natural gas
- Fuel internally reformed by partial oxidation
- System Efficiency capable of mid 30% range
2002
Anode supported
*Tubular SOFC Systems*

- 45 minute start-up
- Excellent cycle capability
- Excellent load following
- Low pressure gas feed
- Direct in-cell reforming

5,000 Watt
APU Core Module

Q4 - 2002
5kW Auxiliary Power Unit
5kW Stationary CHP Unit
SECA Program
Product Objectives

- Culminate in a 10kW modular stack capable of meeting a number of market requirements.
- Widen our fuel choices.
- Build upon our knowledge of “ruggedized” products for harsh environments.
- Allow for modular build up to the 100kW class size.
- Allow for integration with military towable power units in the 5-20kW size.
Cell Production

• Tasks:
  – Improve Anode Conductivity
  – Accelerate Tube Firing
  – Reduce Silver Content

• Accomplishments to date:
  – Bisque firing capable of reduction from 48 to 12 hours
  – Silver Content reduced by over 50%
Cell Production Process

Mixing → Extrude Tube → Dry Tube → Cut to Size

Bisque Fire tube → Slurry Deposit Electrolyte → Sinter Electrolyte

Cathode Deposition → Cathode Firing → Apply Cathode CC → Finished Cell
Anode Tube Extrusion
Anode Tube Bisque Firing
Electrolyte Deposition
Cathode Coating Operation
Brazing Apparatus
Brazing Apparatus operating
Comparison of poorly brazed and well-brazed Joint
Low Cost Braze-Life Graph
Brazing

New Braze Materials have been validated reducing cost from over $1400/kW to less than $1/kW.

New Braze Cap manufacturing process has reduced cost from ~$6/cell to ~$0.50/cell
SECA Cell Testers
Two 7mm diameter cells on lifetest
Present 15mm History

![Graph showing voltage over elapsed time of test](image_url)
Cell Power Trend

- 7mm Anode Supported Tubes - January 2002
- 15mm (22 cm length) Anode Supported Tubes - Oct 2002
- 15mm (33 cm length) Anode Supported Tubes - December 2002
- 15mm (45 cm length) Anode Supported Tubes - January 2003
- 22mm anode supported tube - Projected December 2004

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Cell Technology

• Phase I will continue our evolution from 5W – 15W/tube to 25W/tube
• Phase II/III will further that work to 50W/tube
• The first 6 mo. of SECA funding has helped us advance 33% toward the first goal.
• Excellent start-up
• Excellent cycle capability
• Excellent load following
• No fuel pumps.
• Direct reformation

Anode supported

Tubular SOFC Systems
Generator Cost Reductions

- Early SECA work on manifolds has shown the potential for cost reduction from $690/kW to $80/kW with further advancement to <$50/kW expected.
- Work on recuperators has shown a path to <$25/kW – final designs are being validated.
Bended Tube Recuperator
Ceramic Recuperator
Control Electronics Evolution

• Programmable Logic Controllers, PLCs
  – Size 24” X 15”, $6000 per System

• Printed Circuit Board, PCB, Controller
  – Size 11” X 7.5”, $400 per System
System Pictures

- PLC System
- Control PCB
Control System Wiring

- Discrete wiring harness
- 150 through bulkhead connections
- Centralized control board
- System wiring cost $500
  - Limited opportunities for cost reduction
- The wiring costs more than the electronics!
Distributed vs. Centralized Control

• Several small intelligent I/O boards.
• CAN bus communication.
• Eliminates substantial wiring and cost.
• Modular, incremental and applicable to a wide variety of systems.
• Redundancy and fault tolerance is easier and more cost effective to achieve.
Fuel Cell Interface Converter, FC-IC

- Interfaces fuel cell to energy storage system
- Controls fuel cell output current
- Utilizes efficient automotive MOSFETs
- Interleaved buck – boost topology
- 6kW building block
- 30 - 90 V input, 30 - 60V output, 200 amps
SECA Power Conversion Tasks

- Complete design, fabrication and test of a 98% efficient 48VDC power electronics front end.
Low Voltage Inverter Development

- The FC-IC topology can be configured into an inverter.
- An interleaved topology and high frequency MOSFETs greatly reduce output filter requirements and cost.
- Preliminary efficiency measurements are in the 96-97% range.
FC-IC Based Inverter Development Platform
SECA Inverter Efficiency
Power System Projections

• Cost will be $100-$150/kW with the appropriate volumes.
• Efficiency will be 92-95%
• Device efficiency and packaging advances in the automotive industry will drive the cost towards the $50/kW goal.
Conclusions

• Been in the fuel cell business for 4 years.
• Completed over 1 year operation on previous generation cell technology.
• We have shipped 14 alpha & Beta units for field testing.
• Demonstrated the ability to operate complete systems on lie-pressure natural gas and commercial propane.
• Developed a scalable low-cost manufacturing process.
• Enhanced cell power by 15x in 3 years & are proceeding toward an additional 2-3x
• Developed the hardware & firmware for a low cost controller.
• Prototyped a low cost, high efficiency inverter capable of achieving SECA cost & efficiency targets.
Acknowledgement

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Don Collins, Project Manager