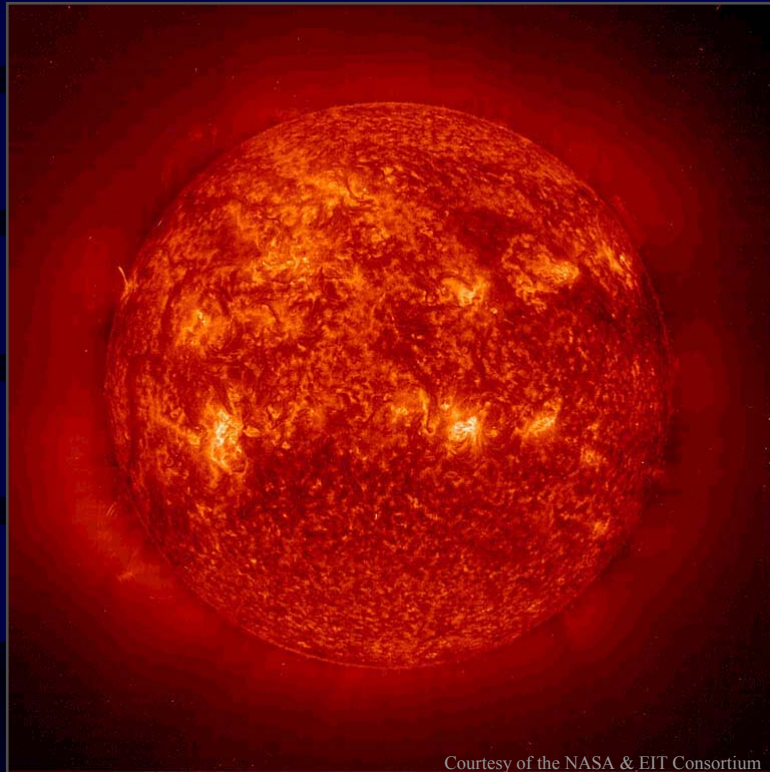


Status of the Acumentrics SOFC Program

Dr. Norman Bessette
SECA Annual Workshop
Boston, MA.
May 11, 2004

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



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

Alliance Investments



Northeast Utilities

ChevronTexaco

Connecticut Innovations

NiSource

Sumitomo

General Dynamics

Morgan Stanley

ChevronTexaco



**Northeast
Utilities System**



**Sumitomo
Corporation**

GENERAL DYNAMICS
Communication Systems

NiSource



**Connecticut
Clean Energy Fund**

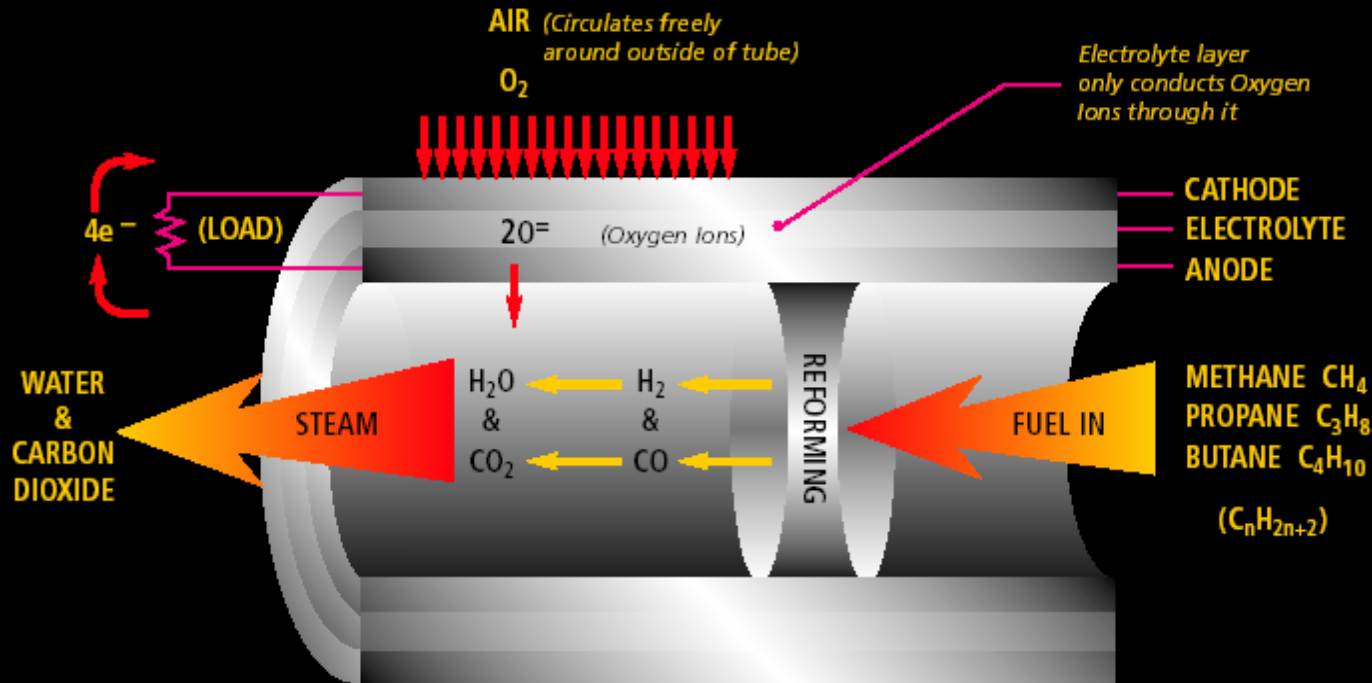


**MASSACHUSETTS
TECHNOLOGY
COLLABORATIVE**

How Acumentrics Fuel Cells Work

Solid Oxide Fuel Cell

SOLID STATE (Ceramic) CONSTRUCTION



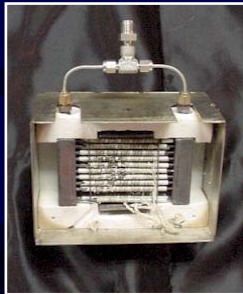
Acumentrics Fuel Cell Evolution

2000 – 2001
Electrolyte supported
Tubular SOFC Systems

10 Watts

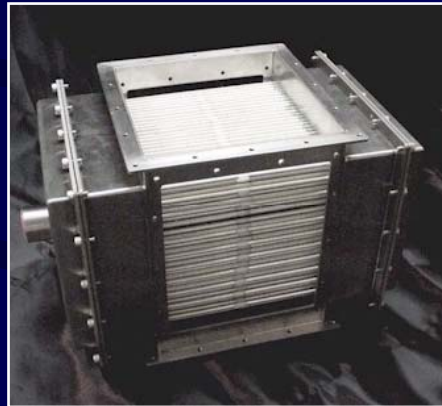


25 Watts



Q3
2000

200 Watts



Q1
2001

700 Watts



Q3
2001

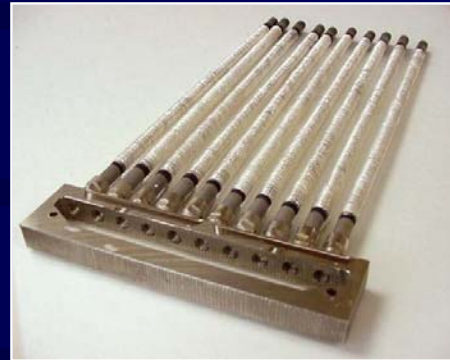
Acumentrics Fuel Cell Evolution

2002 – 2003

Anode supported

Tubular SOFC Systems

Stackable Manifold design



5 Watt
Tubes
Q2 2002

Stack Design Attributes

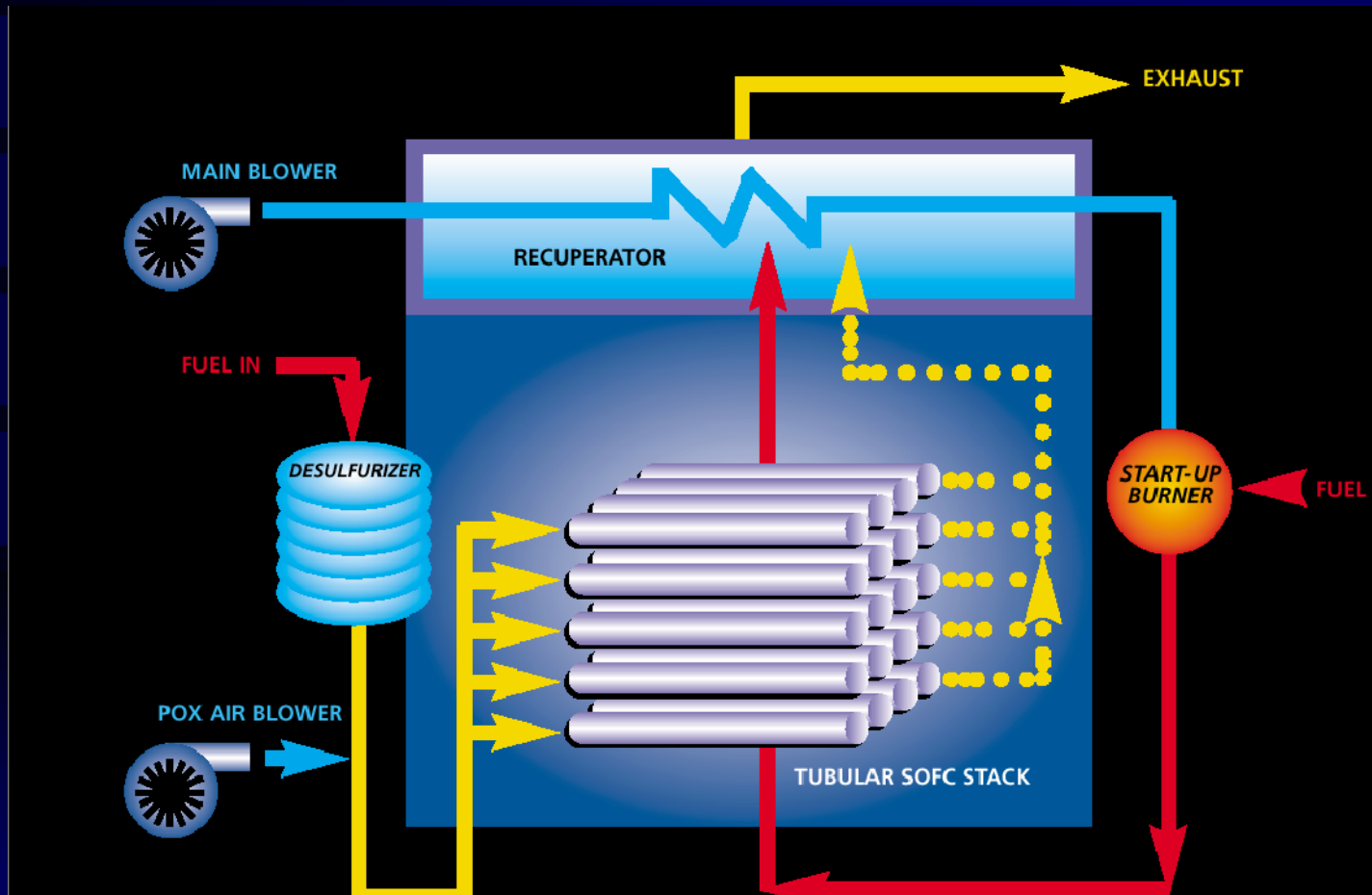
- Anode support tubes
- Brazed seals
- Stackable design
- Welded electric connections
- Low thermal mass
- Withstands heat expansion

High Power Anode Tubes

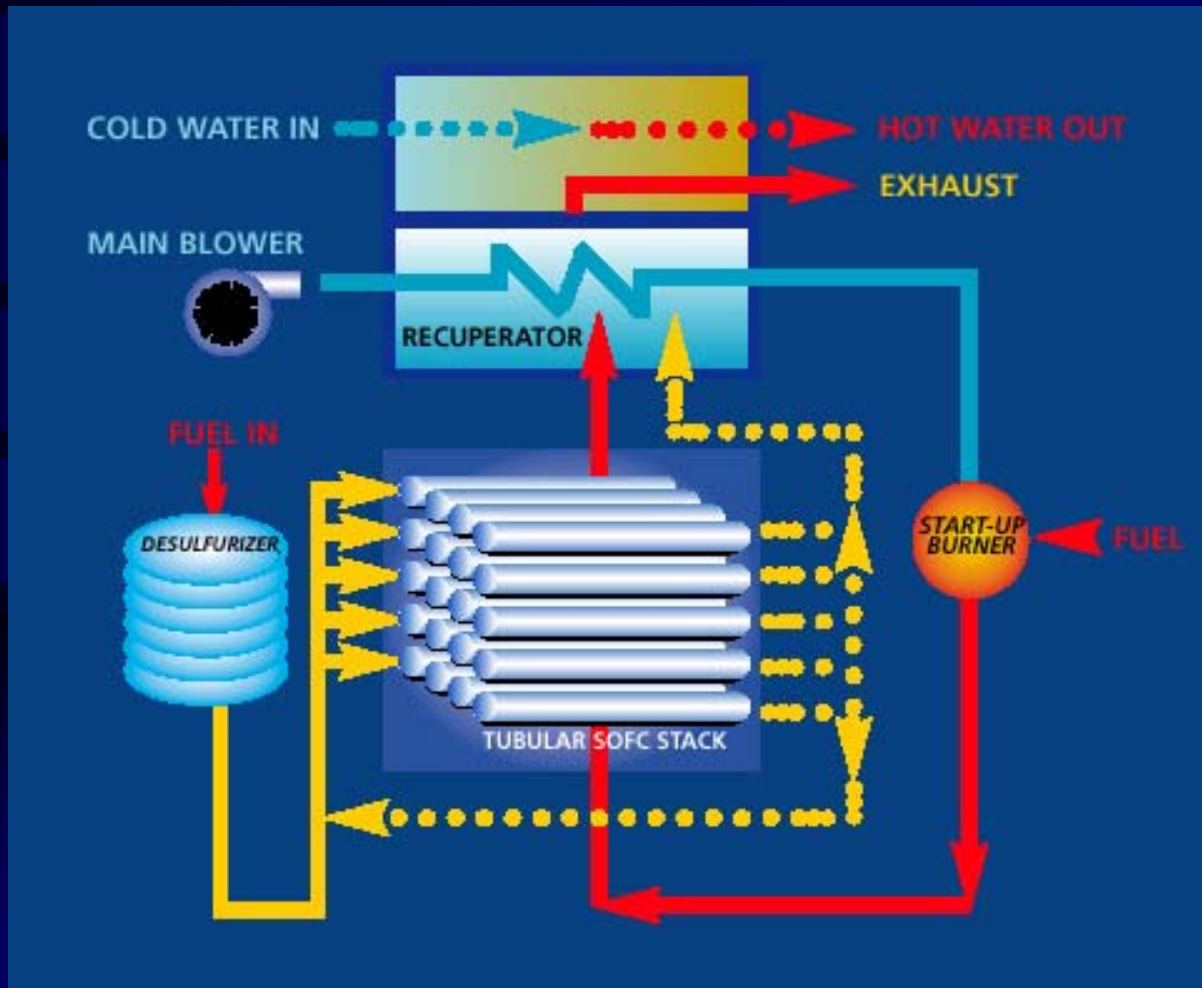
20 Watt
Tubes
Q3 2003



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



Acumentrics Fuel Cell Evolution

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

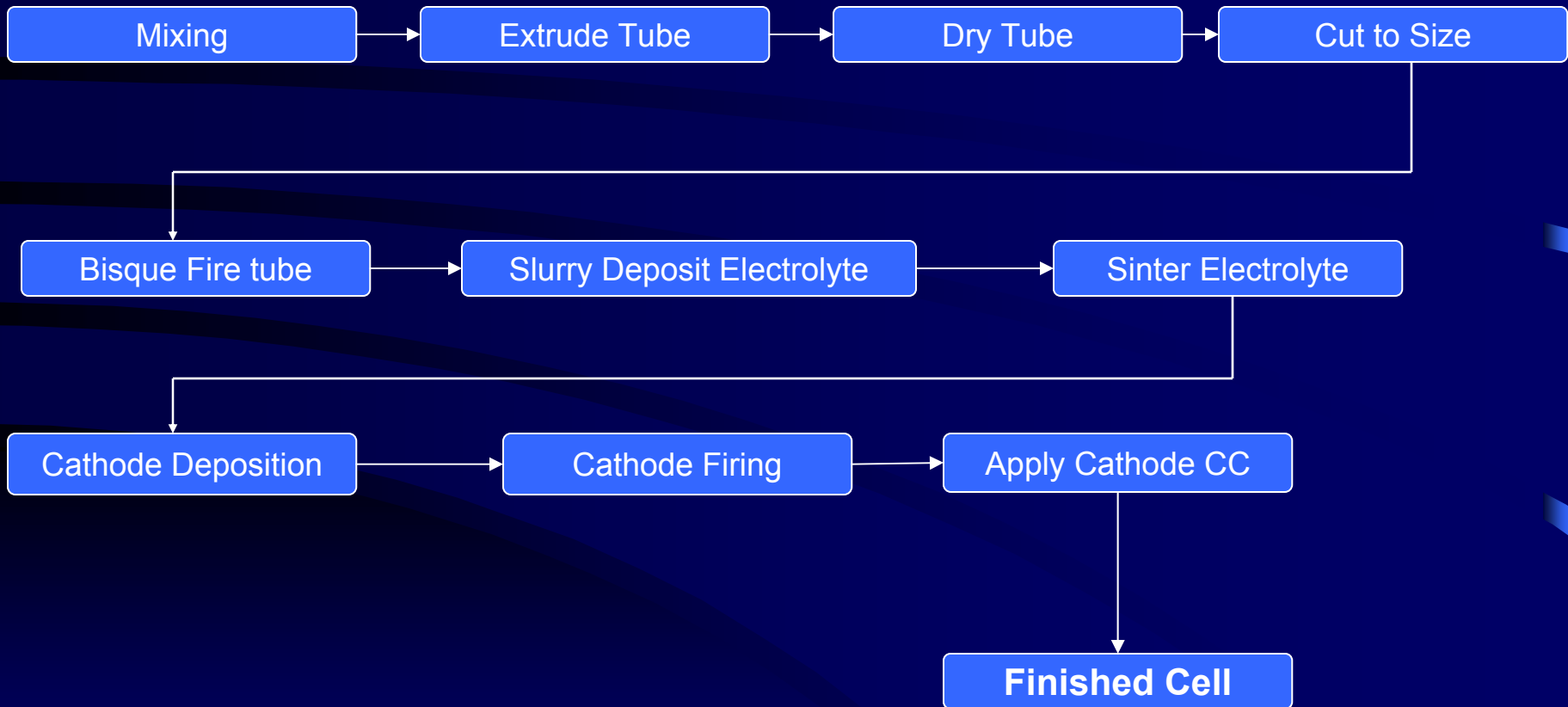
Product Objectives

- 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.

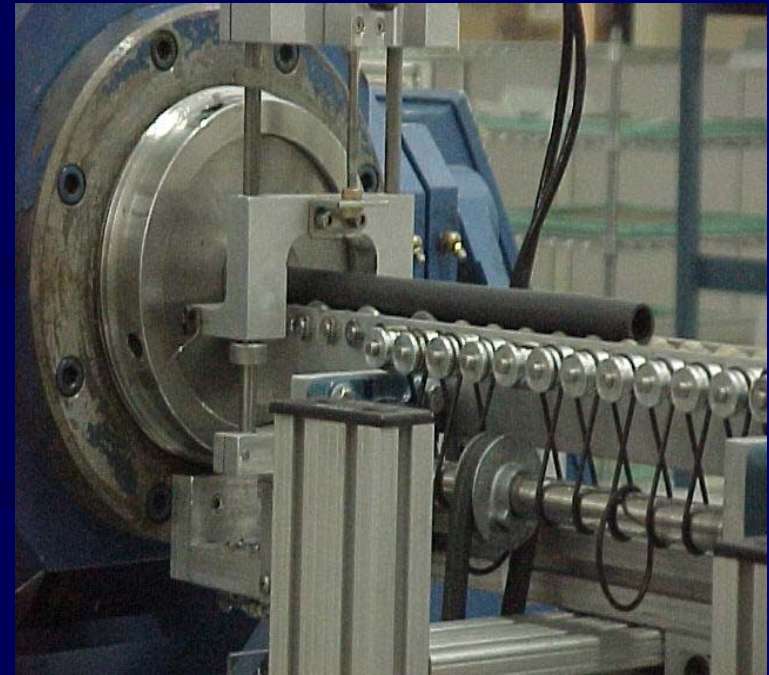
Cell Production

- 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



Anode Tube Extrusion



Anode Tube Bisque Firing



Electrolyte Deposition



Cathode Coating Operation



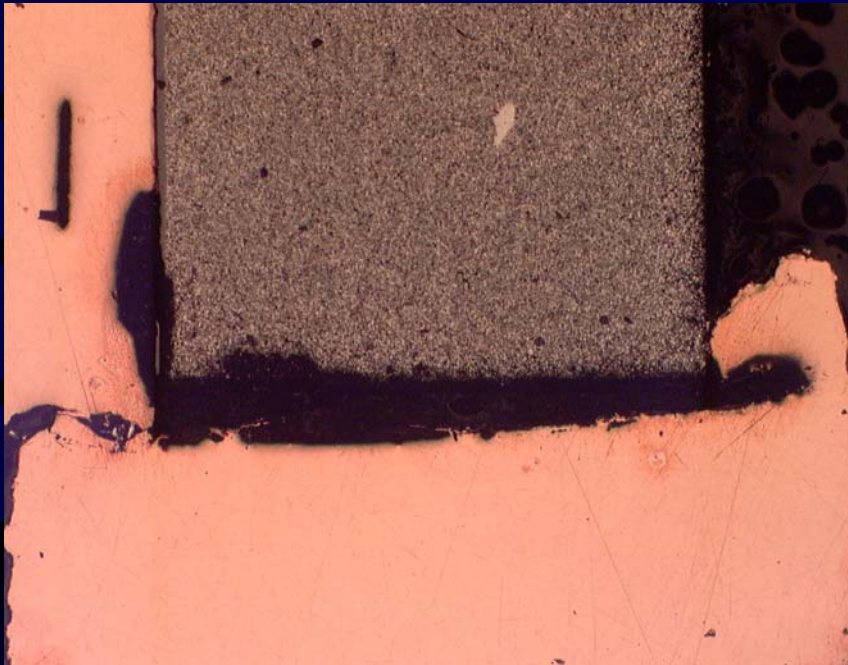
Brazing Apparatus



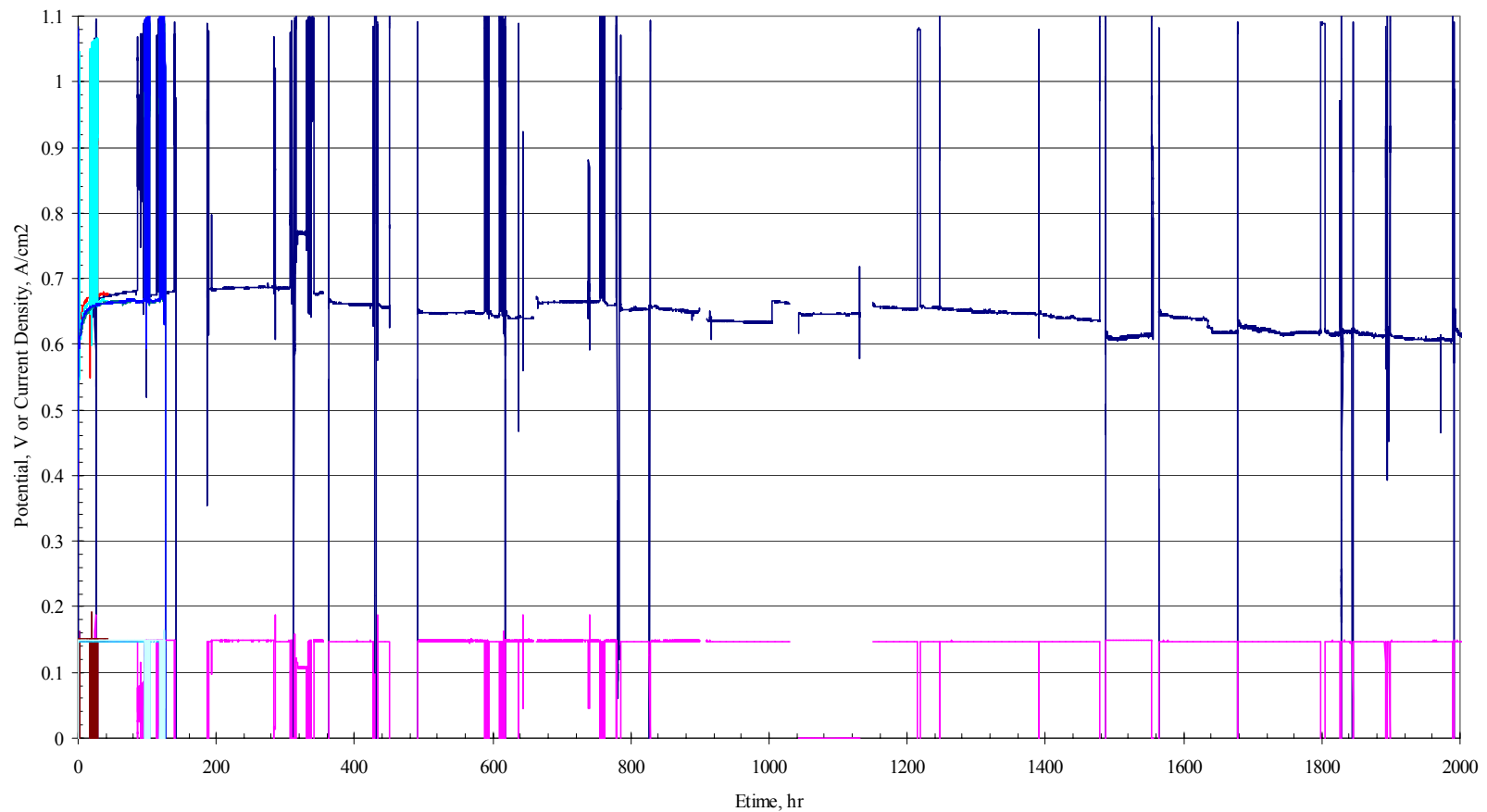
Brazing Apparatus operating



Comparison of poorly brazed and well-brazed Joint



Low Cost Braze-Life Graph



Brazing

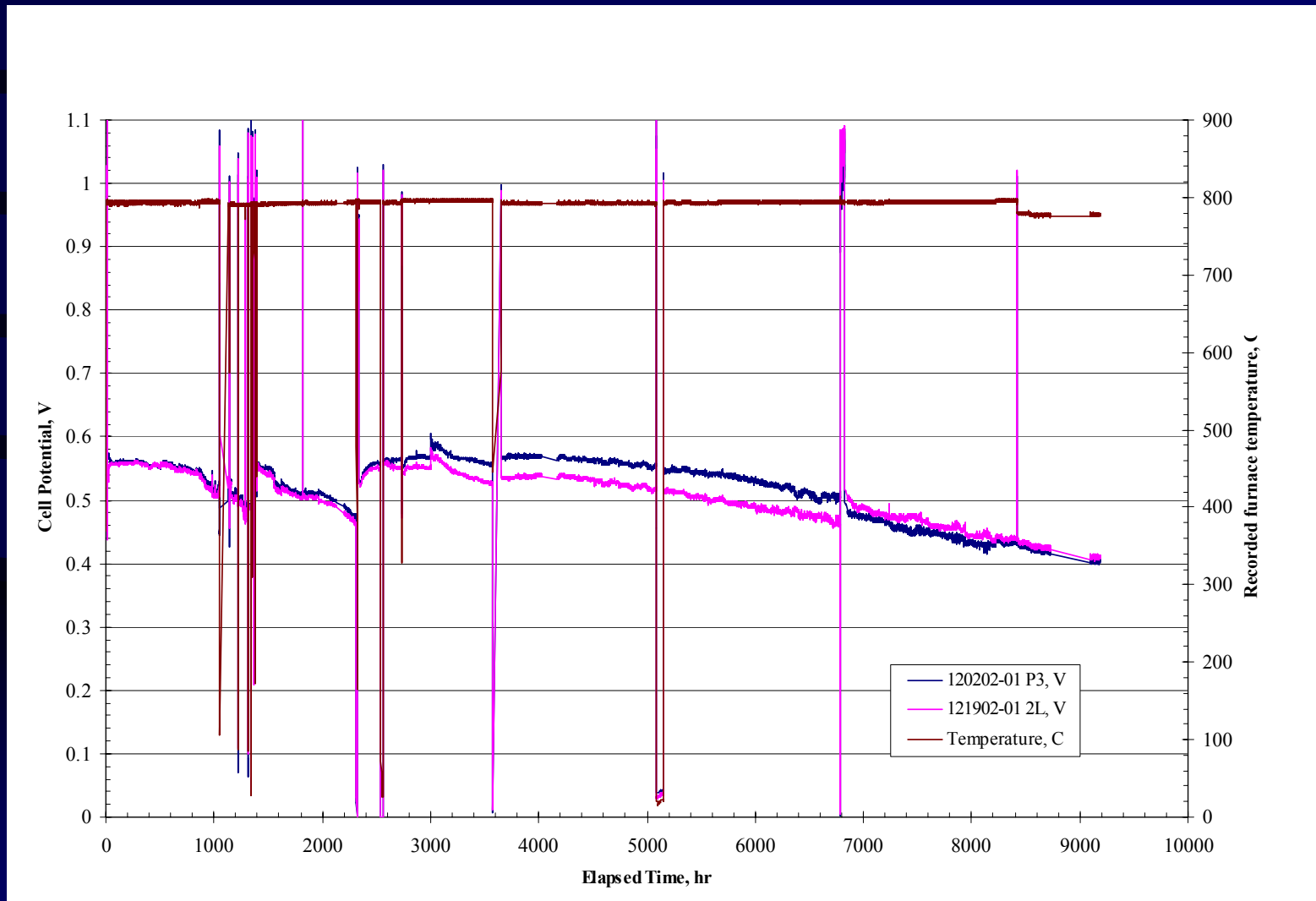
New Braze Materials have been validated reducing cost from over \$1400/kW to less than \$1/kW.

New Braze Cap manufacturing process has reduced cost from ~\$6/cell to ~\$0.50/cell

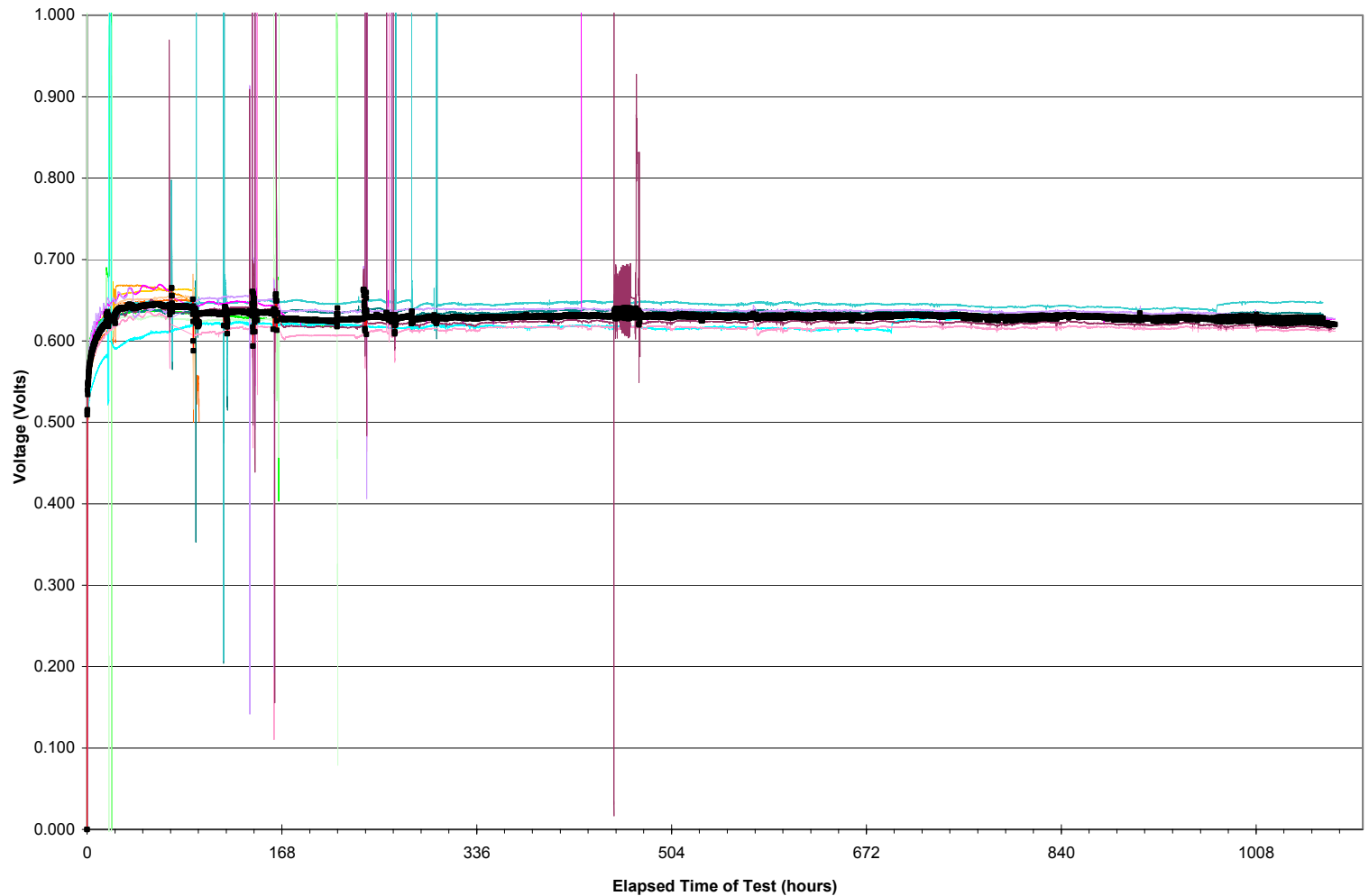
SECA Cell Testers



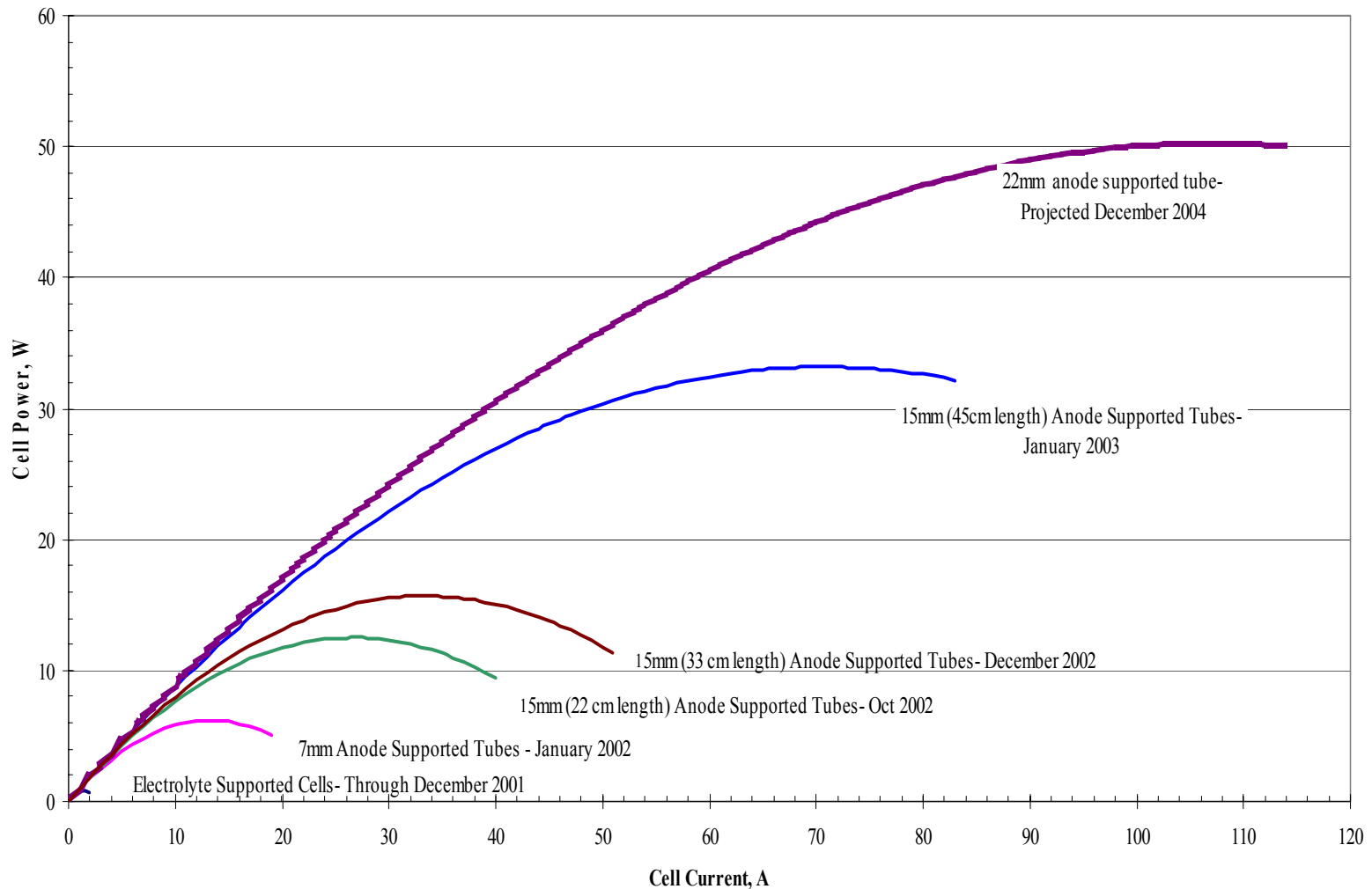
Two 7mm diameter cells on lifetest



Present 15mm History



Cell Power Trend



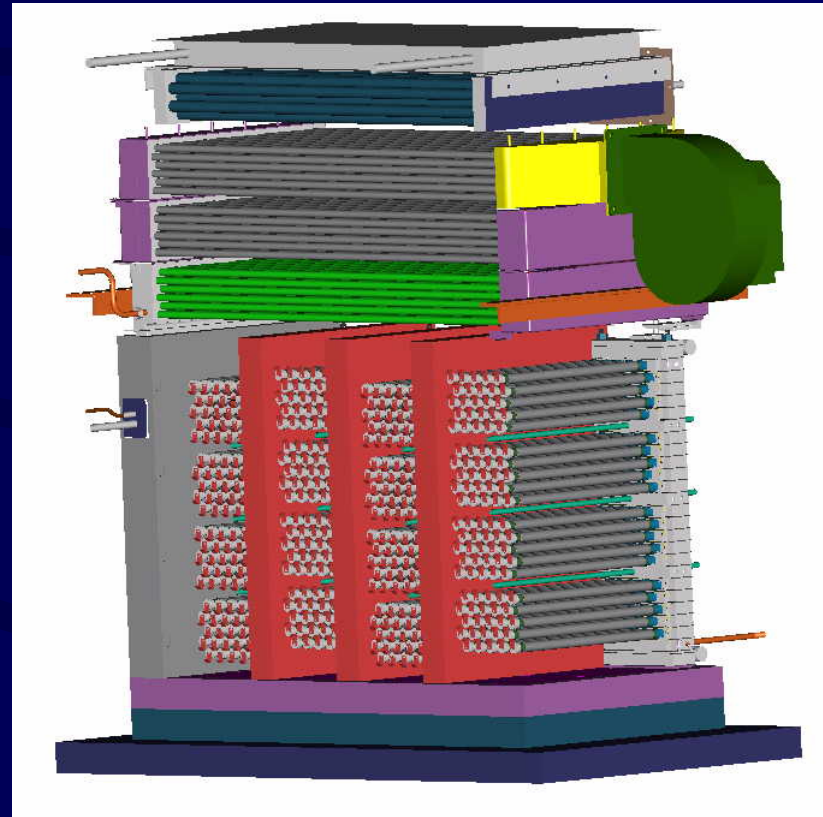
Cell Technology

- 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.

Acumentrics Generator Design

Anode supported
Tubular SOFC Systems

- Excellent start-up
- Excellent cycle capability
- Excellent load following
- No fuel pumps.
- Direct reformation



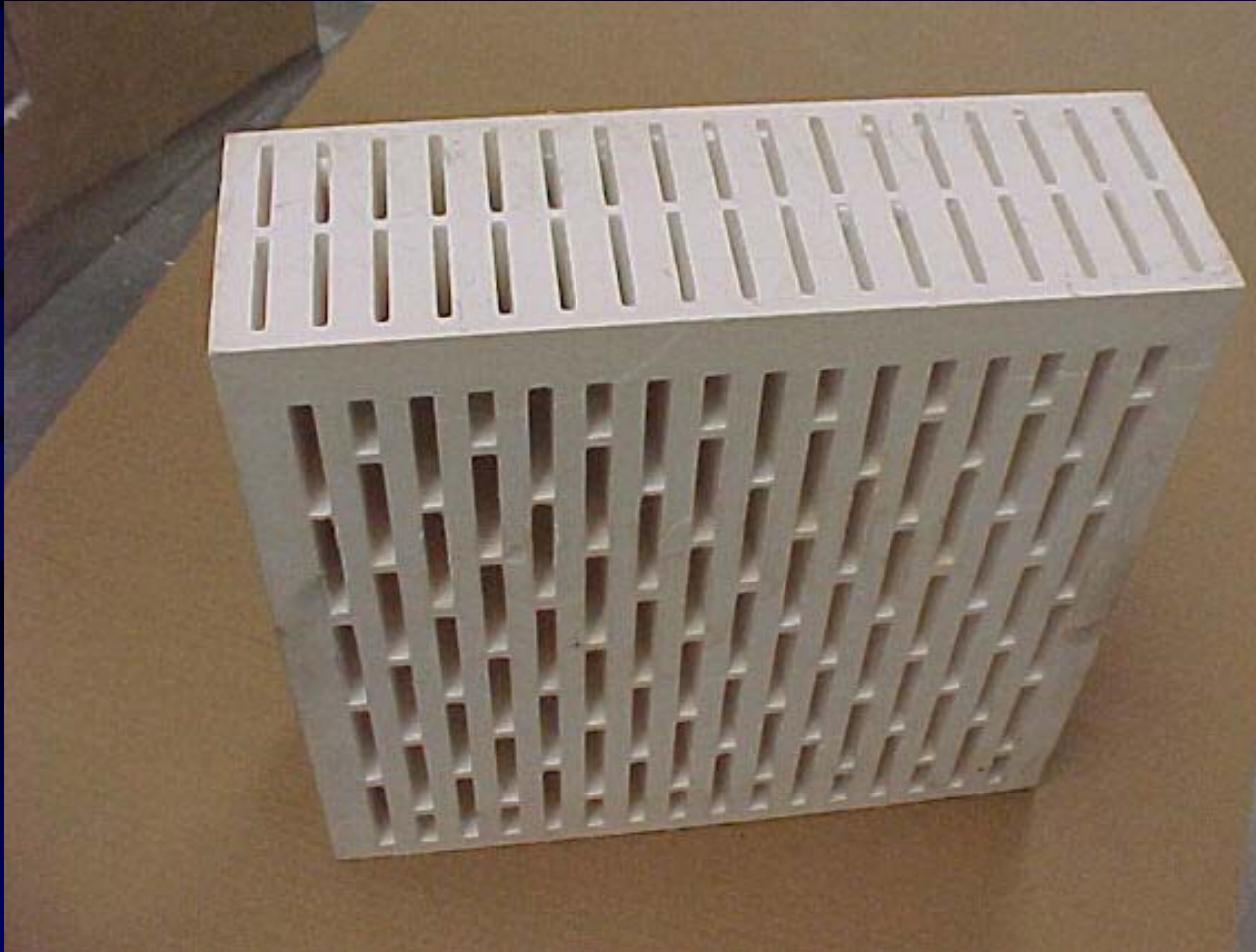
Generator Cost Reductions

- 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

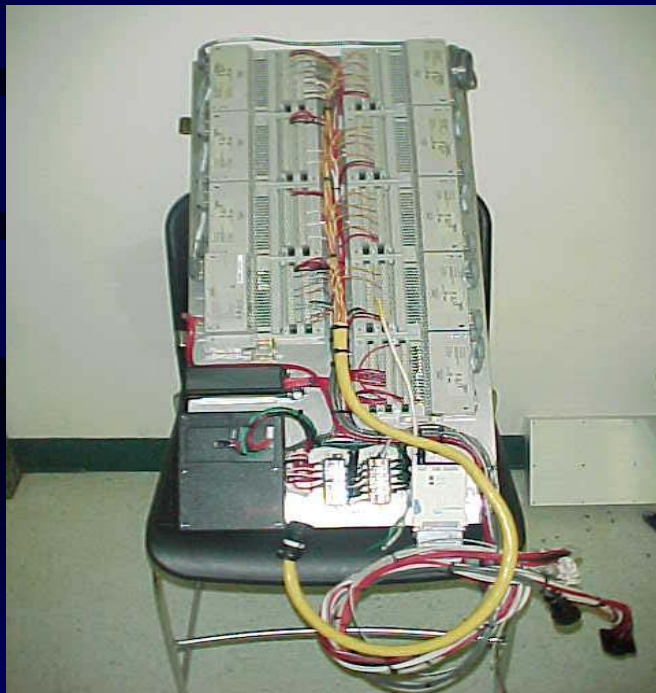


Control Electronics Evolution

- 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

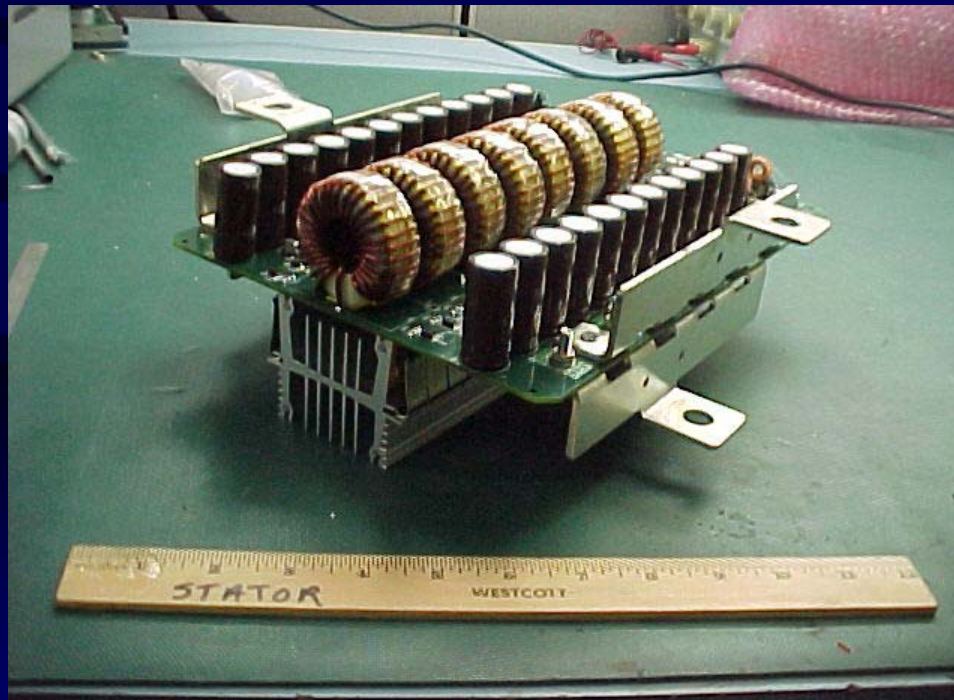
- Several small intelligent I/O boards.
- CAN bus communication.
- Eliminates substantial wiring and cost.
- Modular, incremental and applicable to a wide variety of systems.
- Redundancy and fault tolerance is easier and more cost effective to achieve.

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

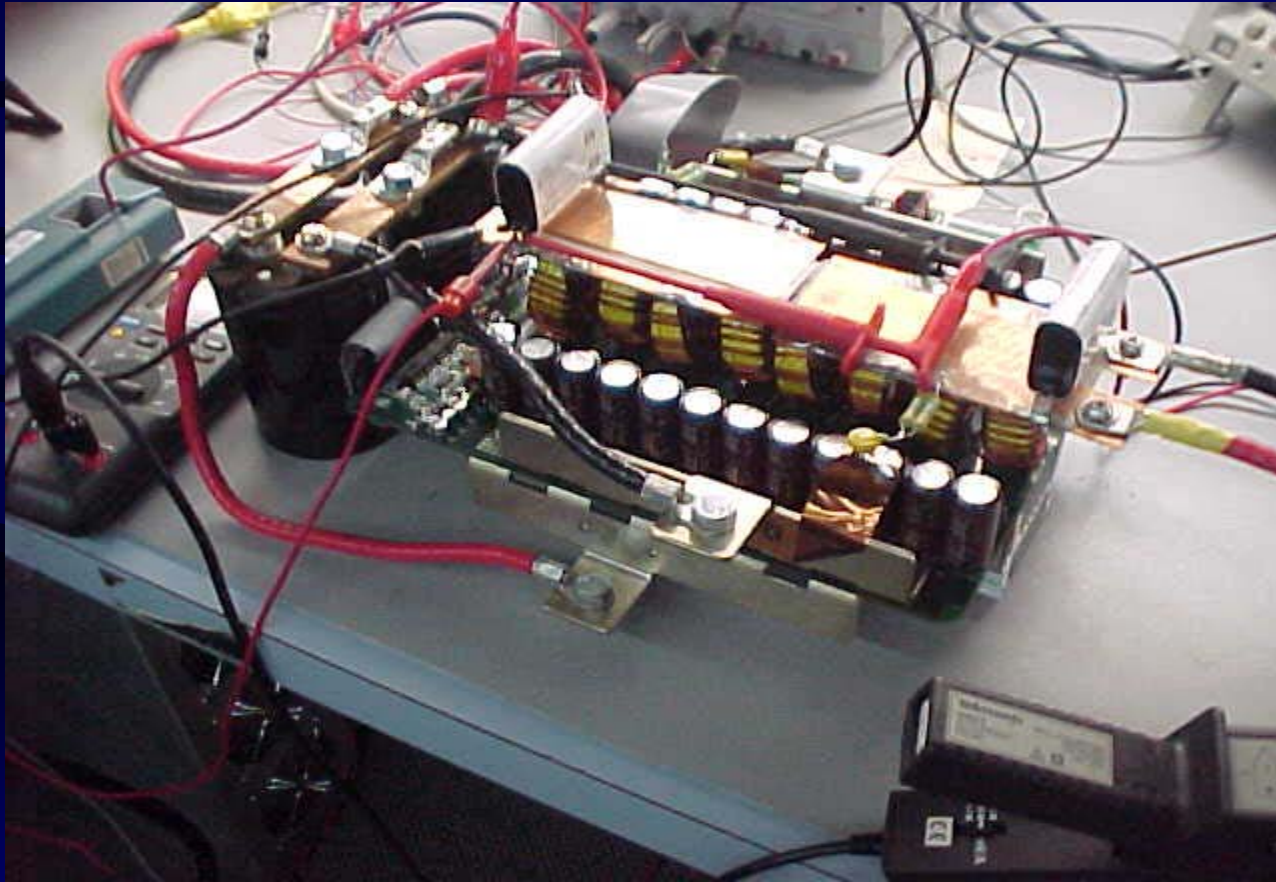
- Complete design, fabrication and test of a 98% efficient 48VDC power electronics front end.



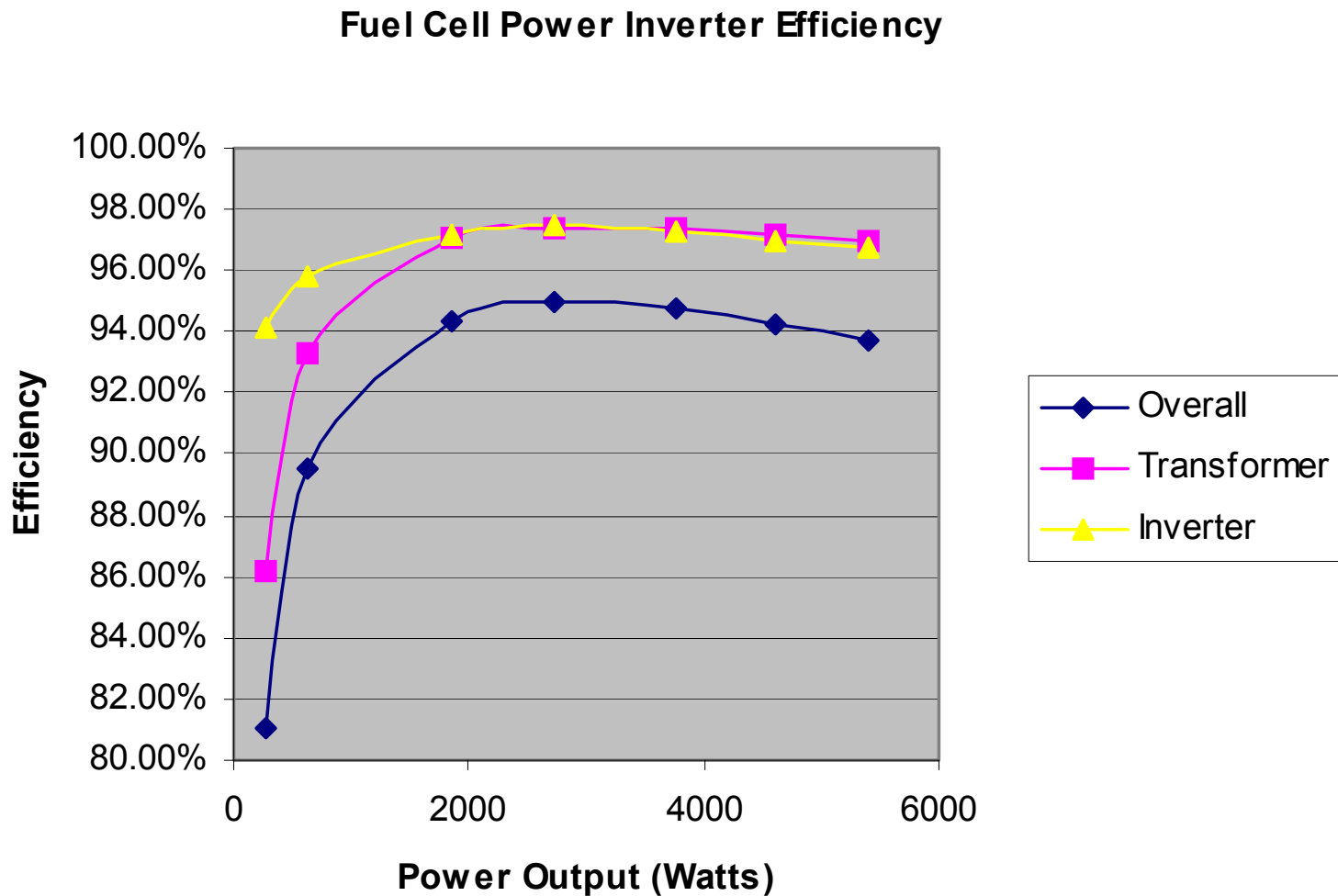
Low Voltage Inverter Development

- 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 low-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



Department of Energy-National Energy
Technology Laboratory

Don Collins, Project Manager