Status of the Acumentrics SOFC Program

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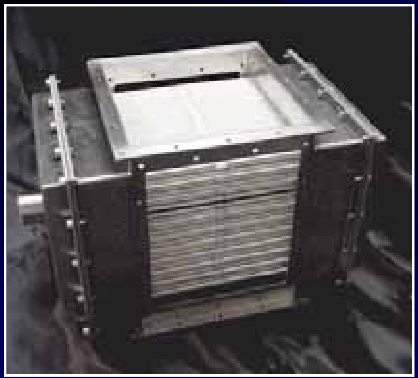
Acumentrics Corporation

- *~ 55 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

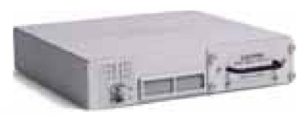


Acumentrics

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 2kW UPS

Full on-line UPS

For Cable/Broadband

Operates on line pressure natural gas

Fuel internally reformed by partial oxidation

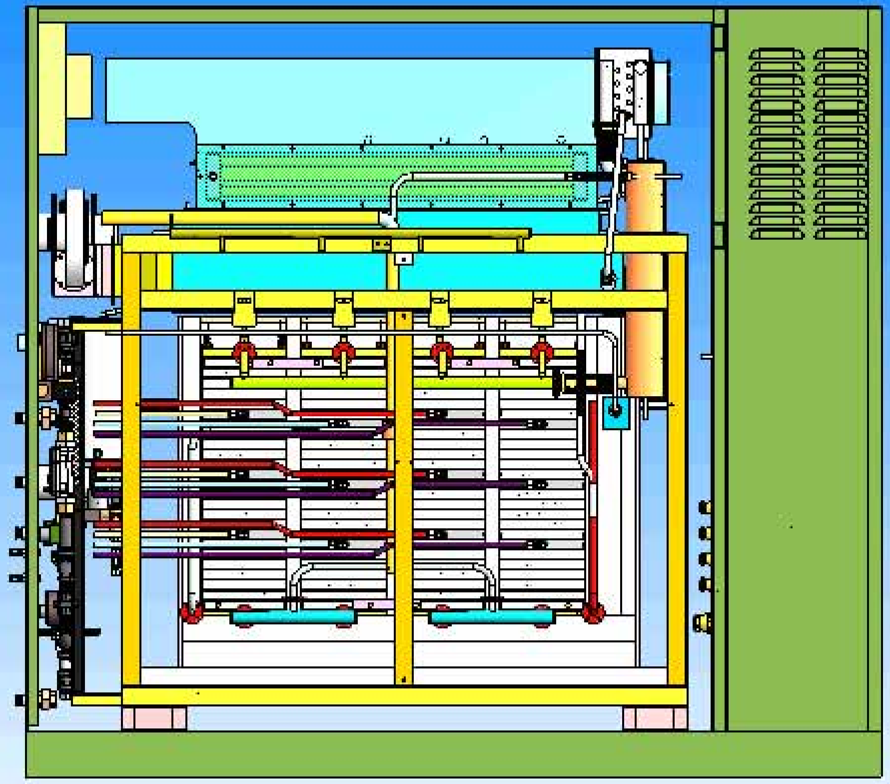
System Efficiency capable of mid 30% range

5kW Auxiliary Power Unit

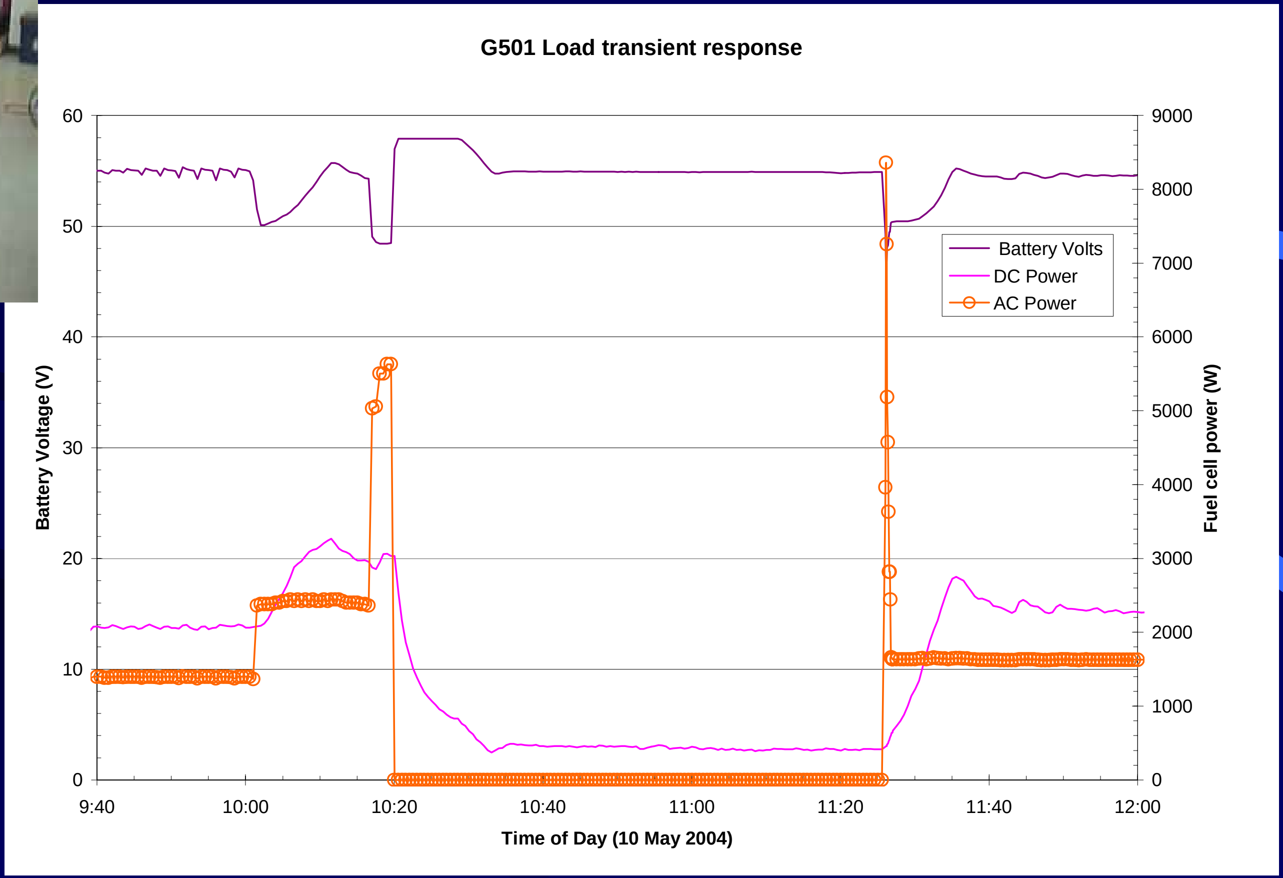
2002
Anode supported
Tubular SOFC Systems

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

Generator Configuration

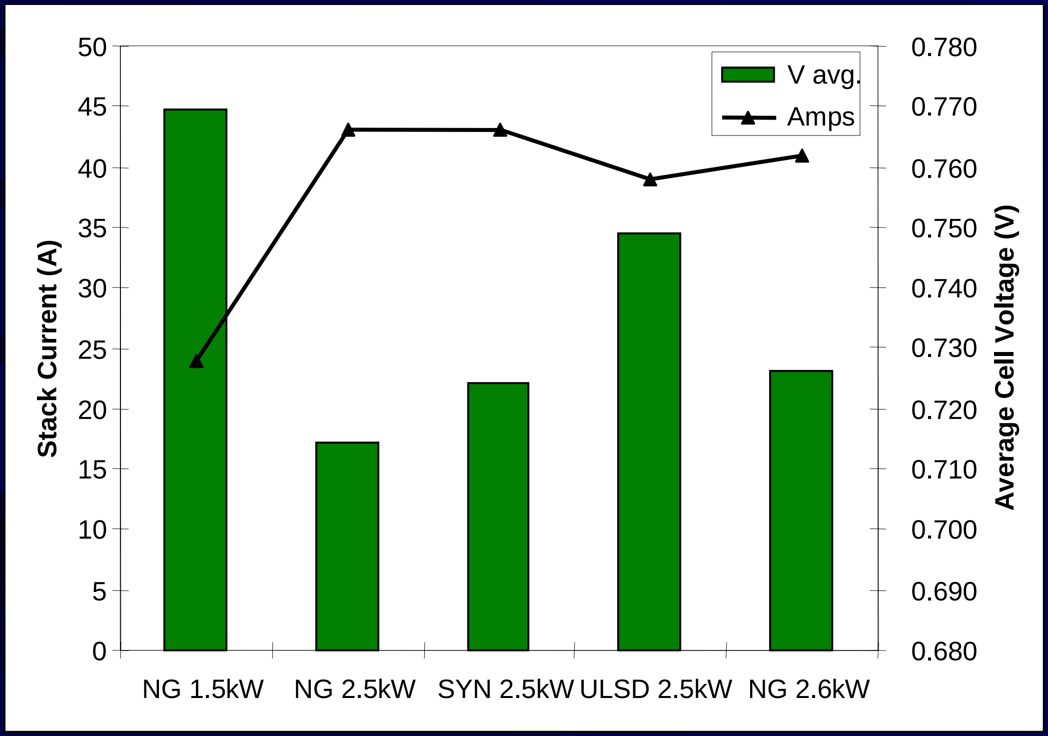


5kW Stationary CHP Unit



5kW Diesel Fueled Acumentrics SOFC

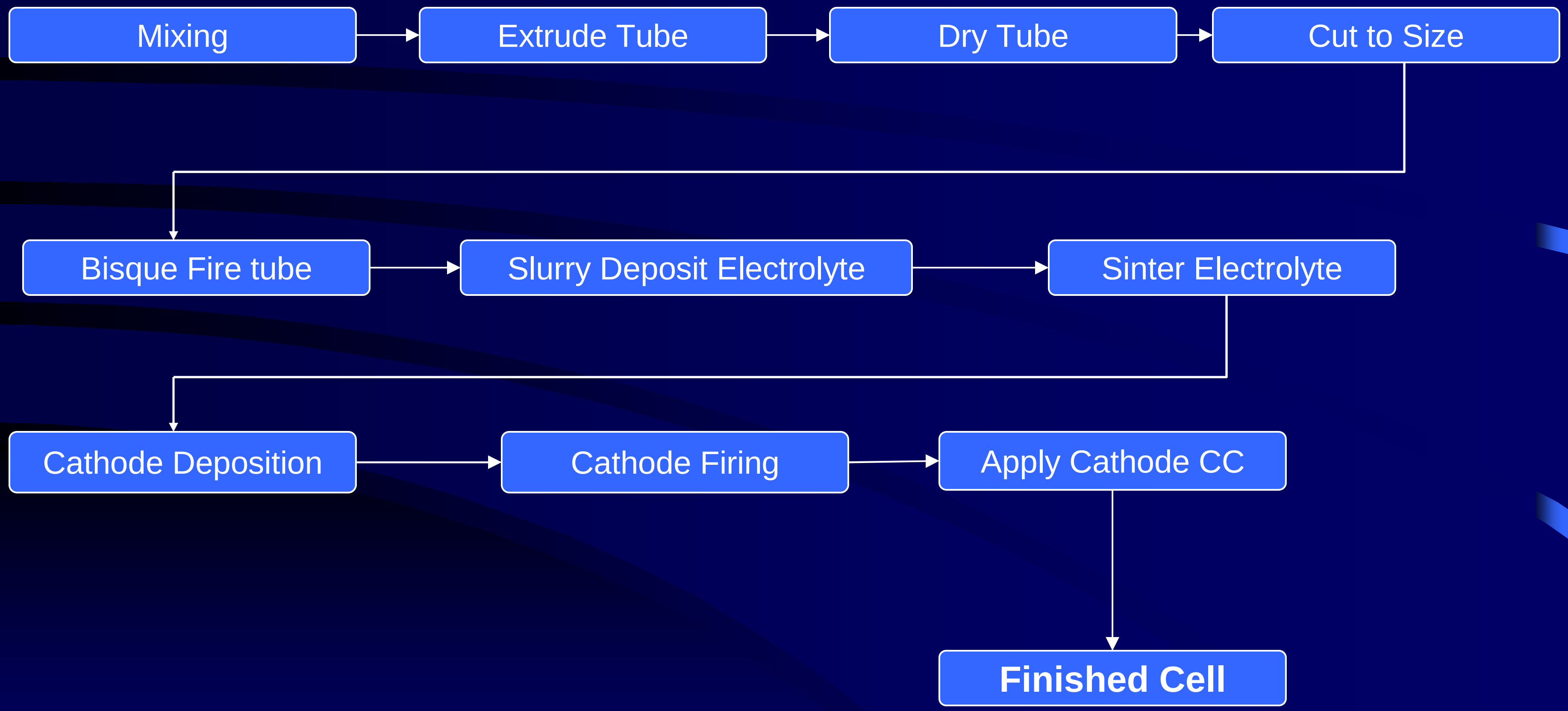
Diesel Fueled SOFC Performance



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 Process



Cell Manufacture

Anode Tube Extrusion

Anode Tube Extrusion

Anode Tube Bisque Firing

Anode Tube Bisque Firing

Electrolyte Deposition

Cathode Coating Operation

Fabrication Process Developments

Bisque Firing Update – Would like to:

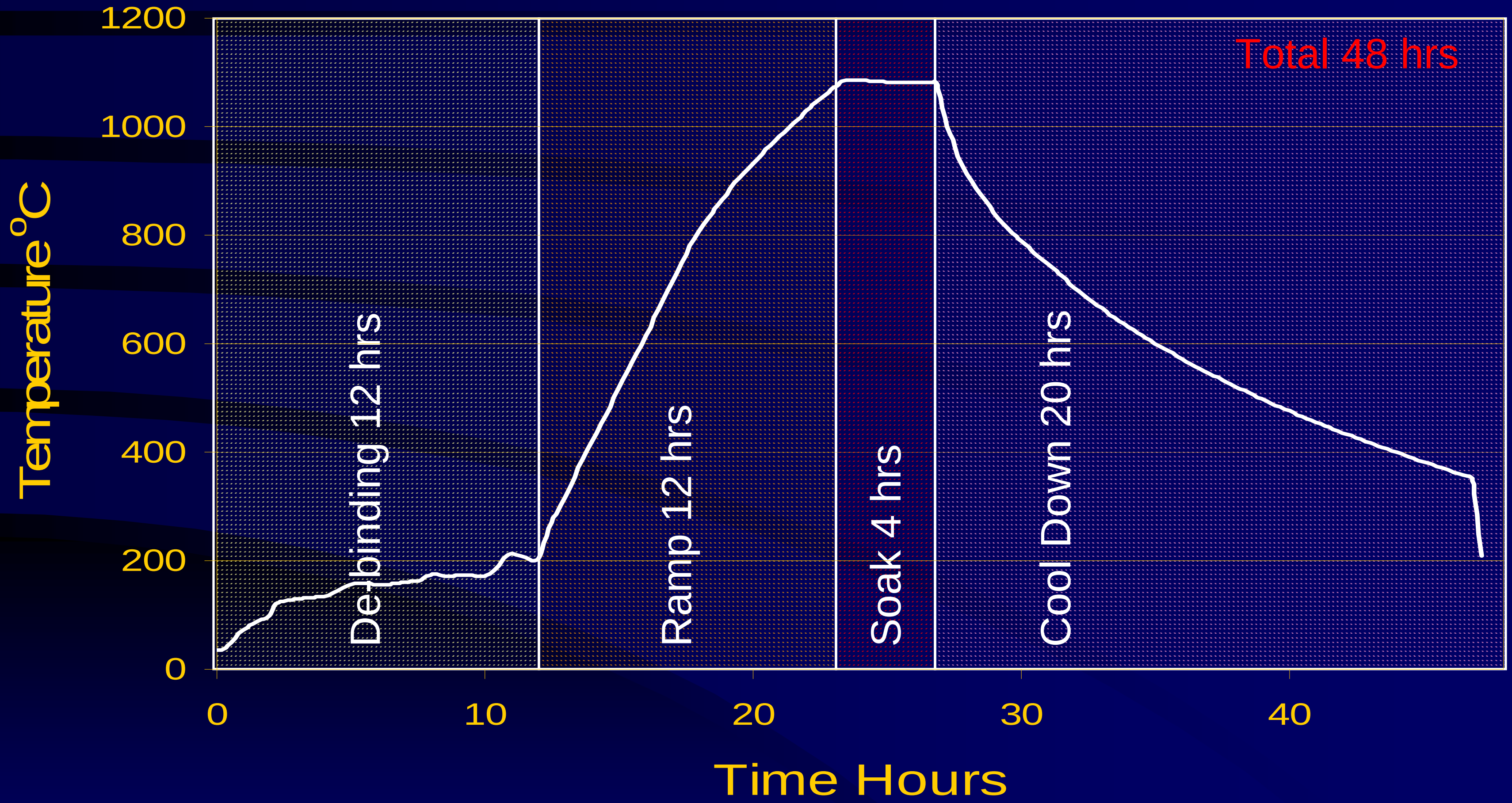
- Move from batch to continuous firing
- Use the same furniture throughout process
- Incorporate microwave drying into the bisque firing stage

To Achieve These goals:

- Microwave energy is being investigated to reduce debinding times
- A belt furnace is being investigated to reduce ramp and cool down times
- By combining the two processes, it is considered that a rapid continuous bisque firing process can be achieved
- The kiln furniture utilized must however be suitable in both environments!

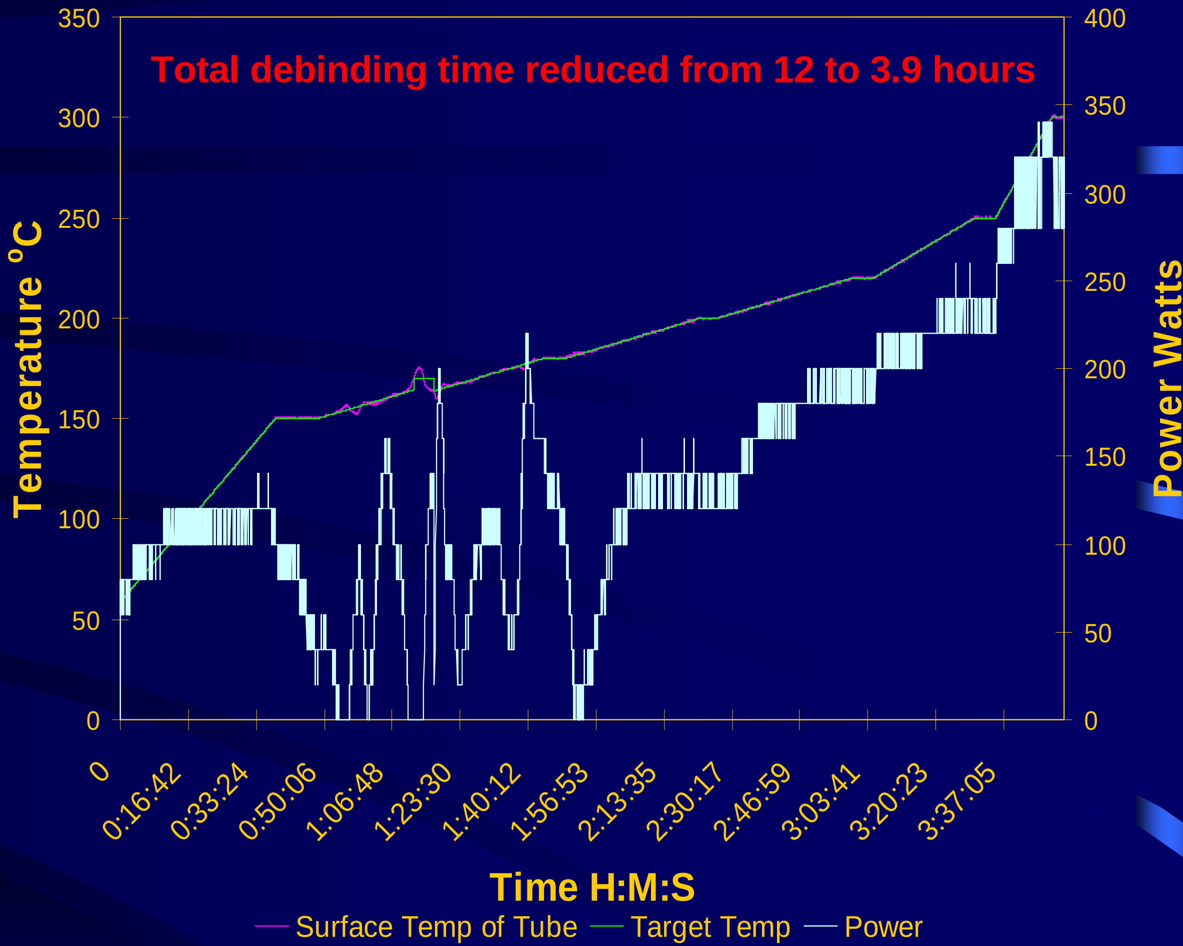
Fabrication Process Developments

Profile of current bisque fire – Batch process



Fabrication Process Developments

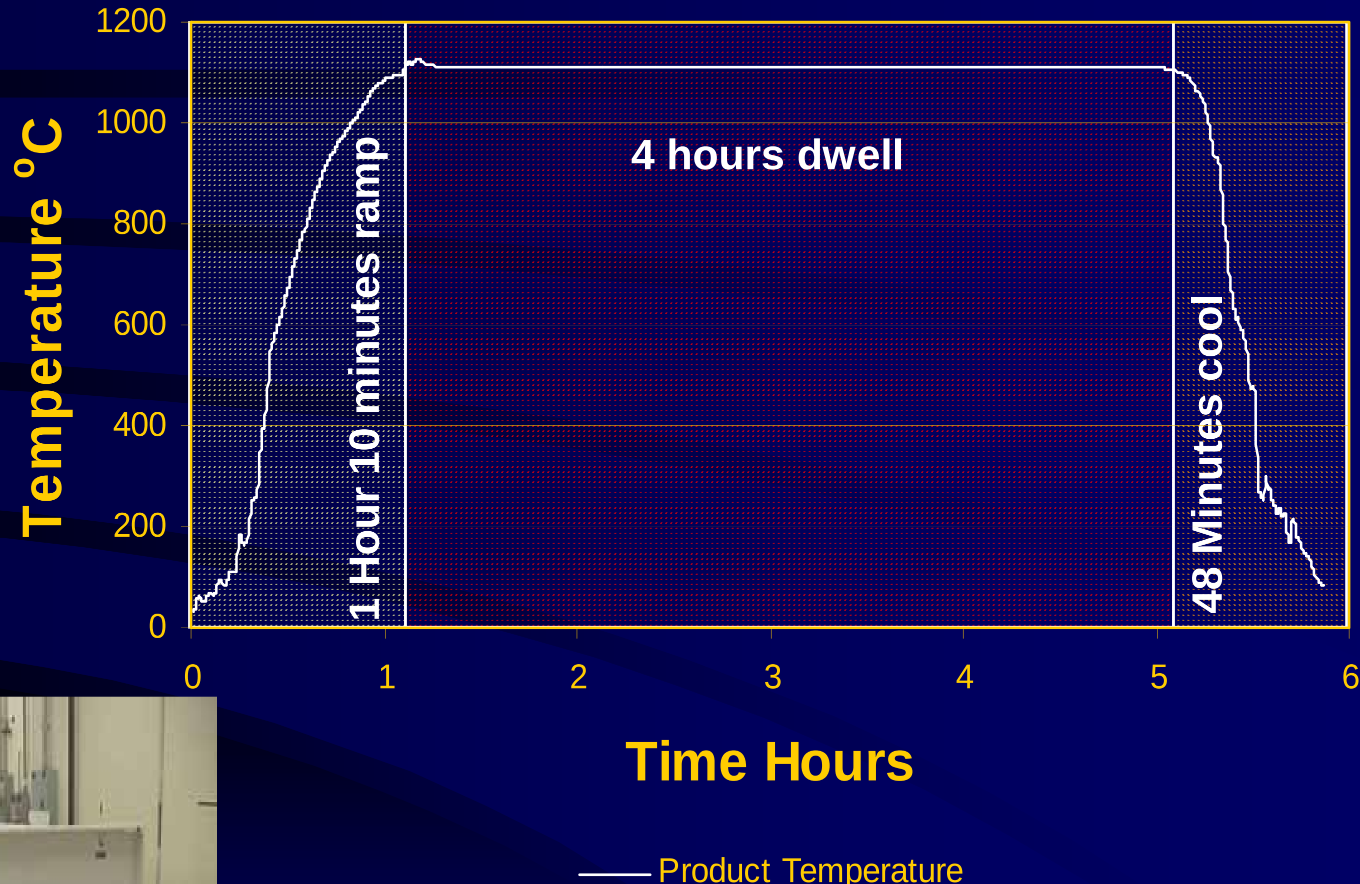
Microwave debinding



Light from optical pyrometer shines directly upon the part that is being debinded to allow constant temperature feedback and therefore adjustment of microwave energy giving optimum debinding time and conditions

Fabrication Process Developments

Belt furnace bisque fire

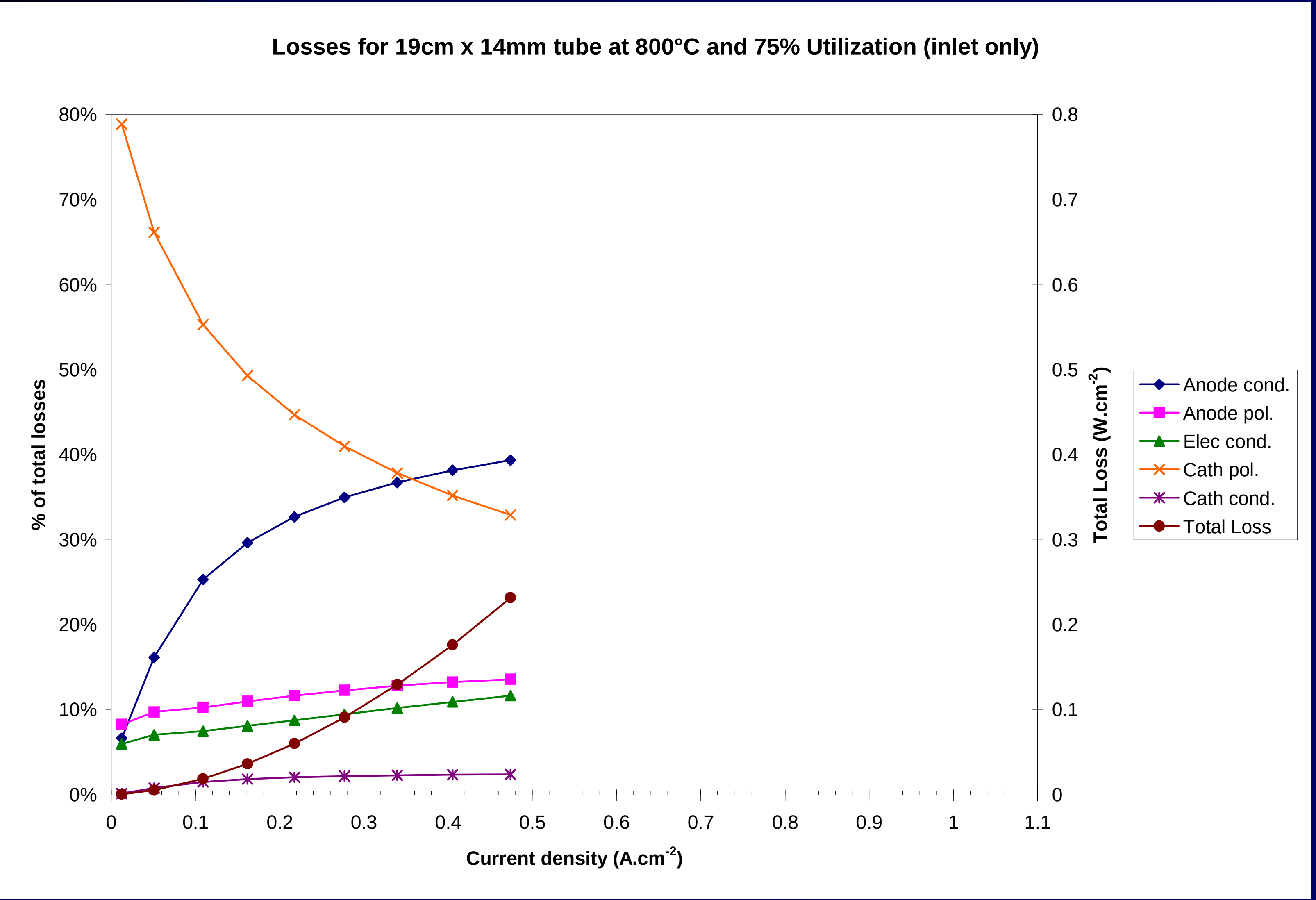


Belt furnace ramp soak and cool down reduced current processing time from 36 hours to approximately 6 hours

Cell Technology

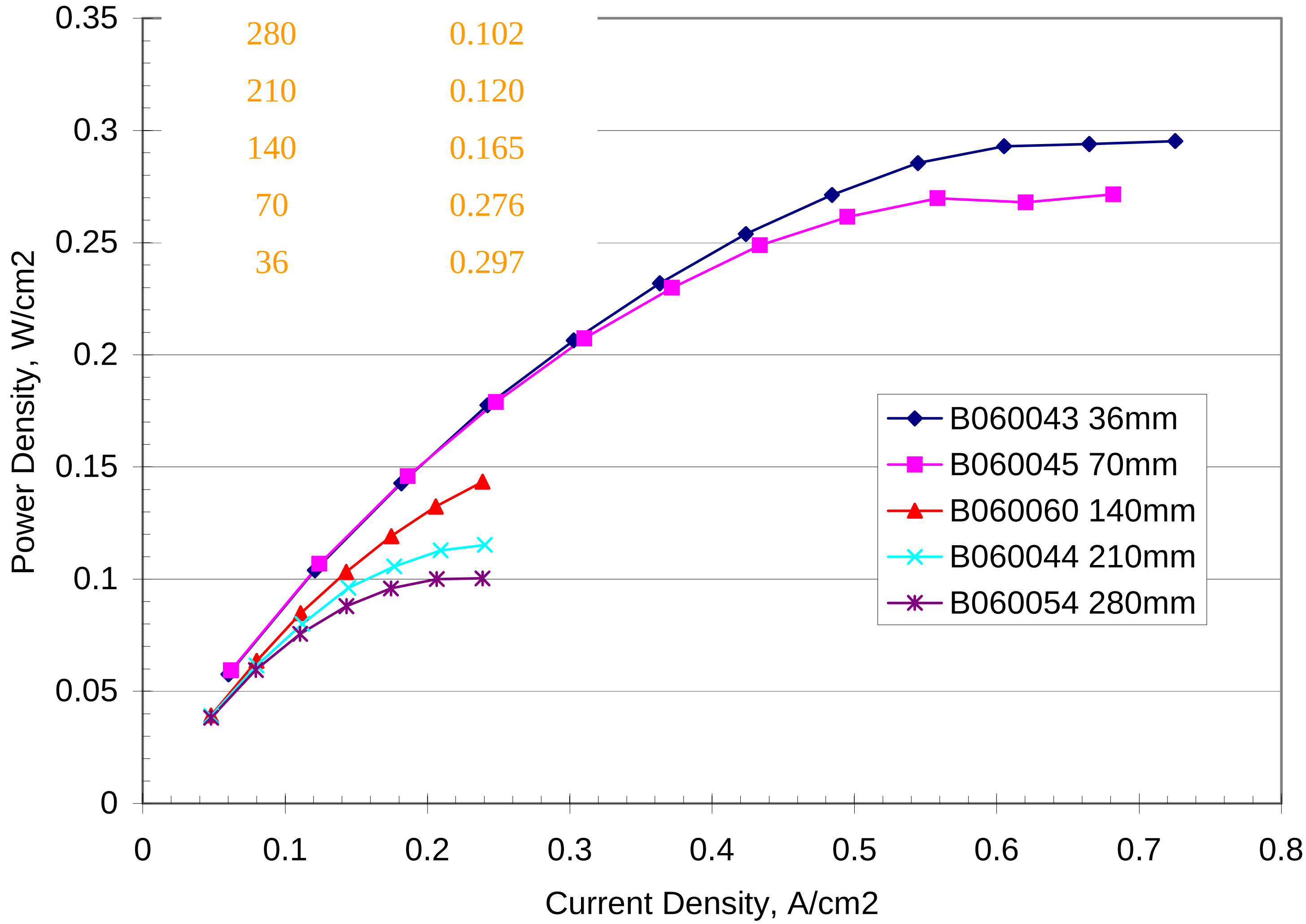
- Work has focused on improving the power per cell.
- Power improvements have been realized by increasing the number of power take-offs as well as improving the conductivity along the cell length.
- Improvements of 80-100% have been realized and are being implemented into generator designs.

Modeled losses for a cell

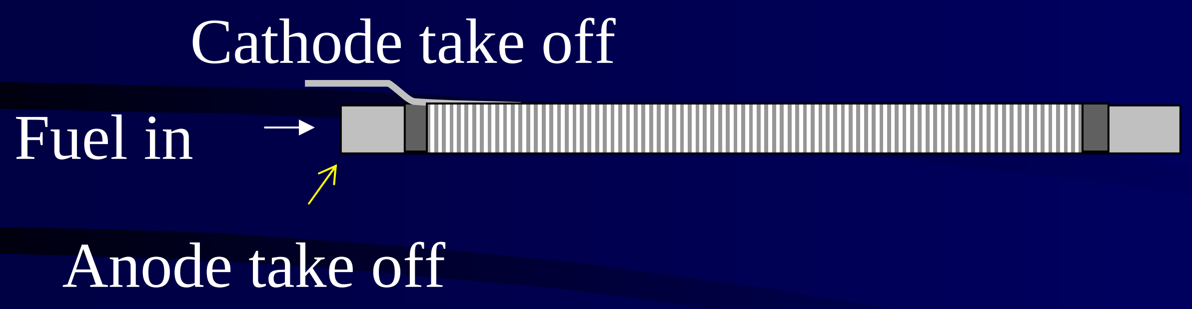


Power Density at 800ºC, 75%FU

Size, mm	Peak, W/cm²
280	0.102
210	0.120
140	0.165
70	0.276
36	0.297

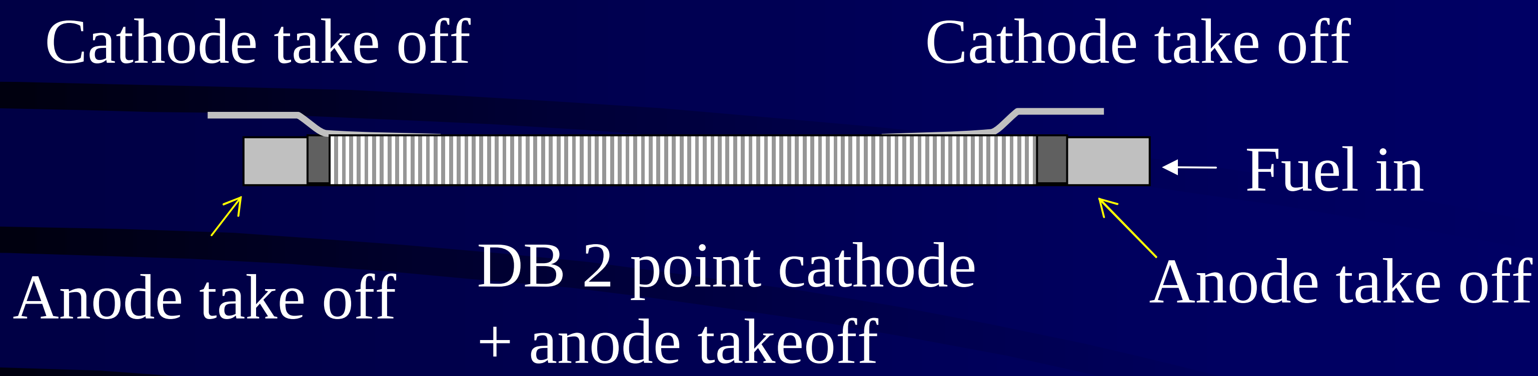


Standard Cell Performance



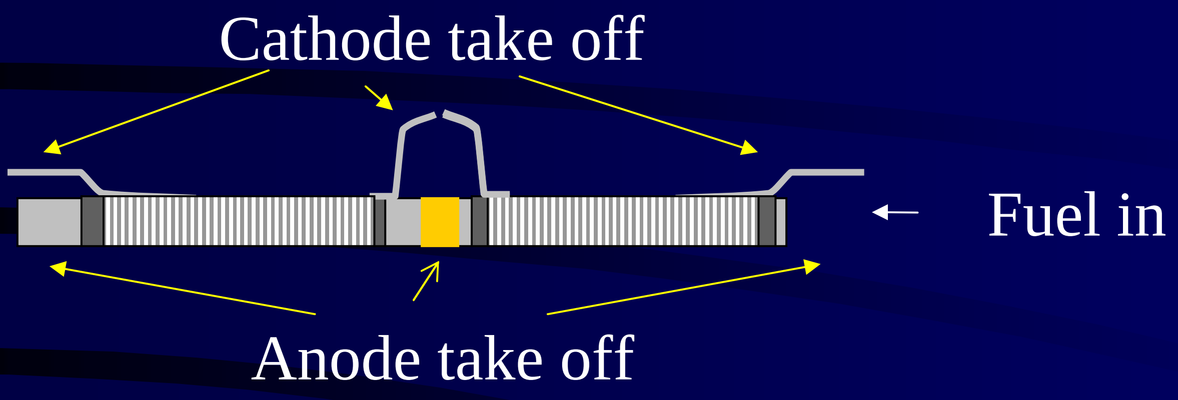
peak power density	
115	mW/cm2

2-takeoffs per cell 800C 75%FU



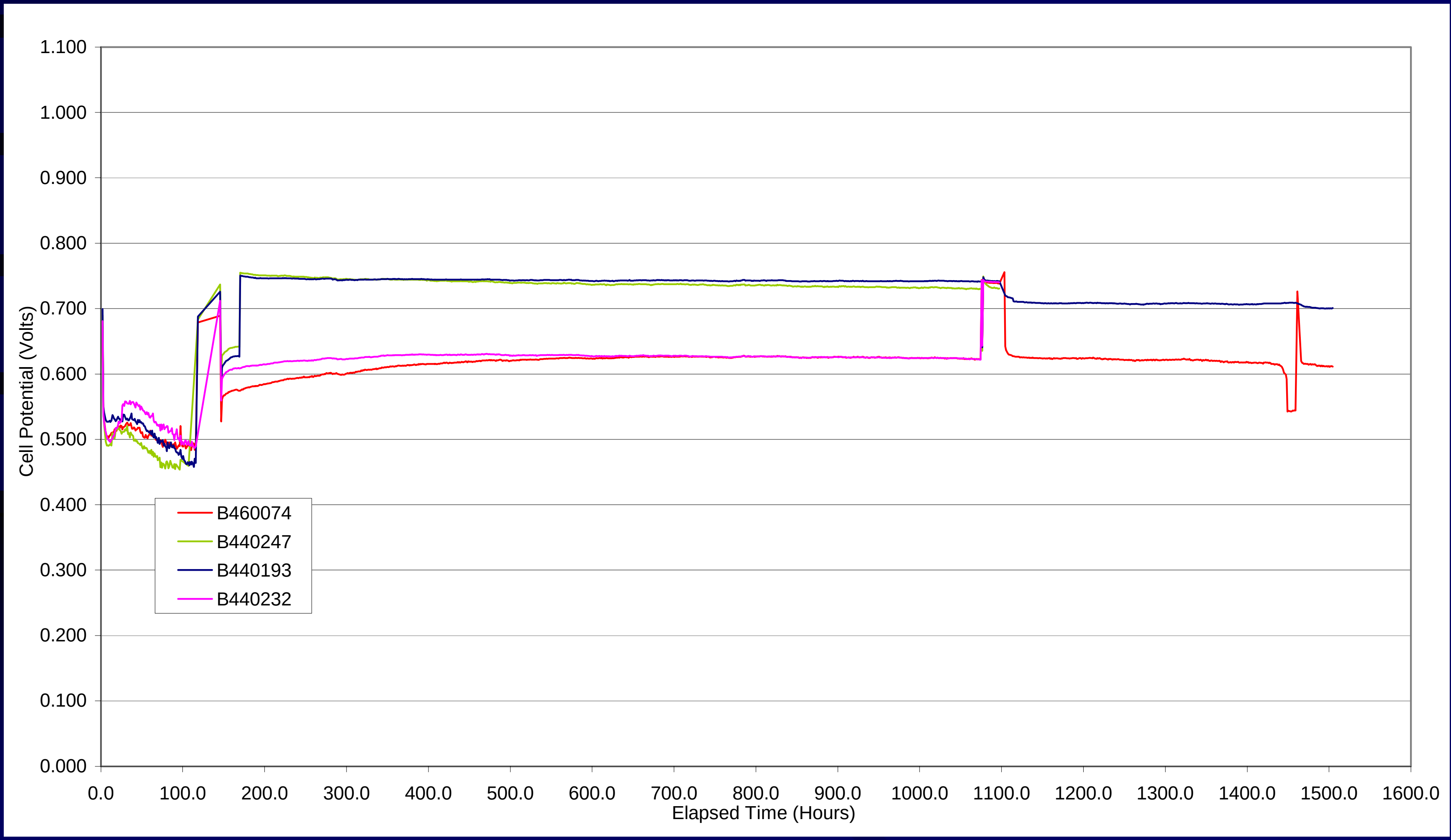
peak power density	
184	mW/cm2

3-takeoffs per cell 800C, 75%FU

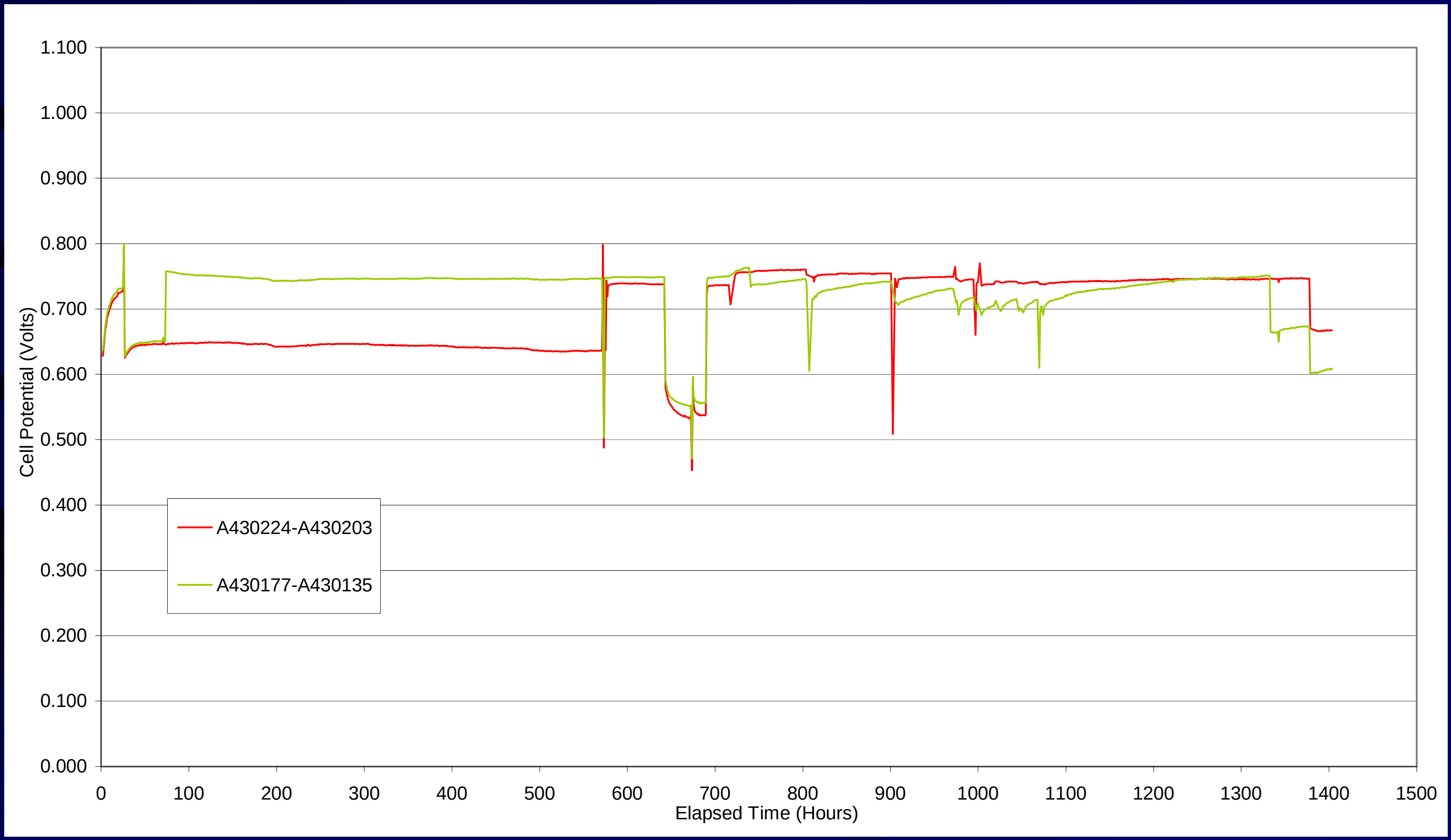


peak power density	
243	*mW/cm2*

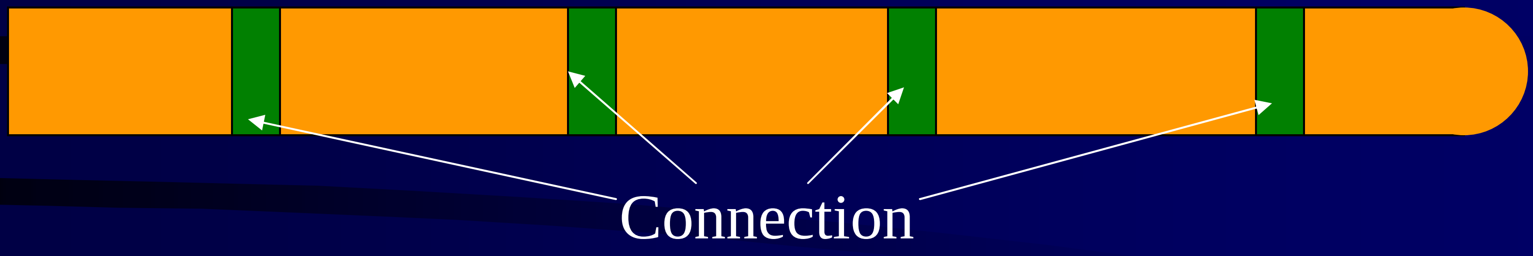
Life Graph for Double End Take-off Cells



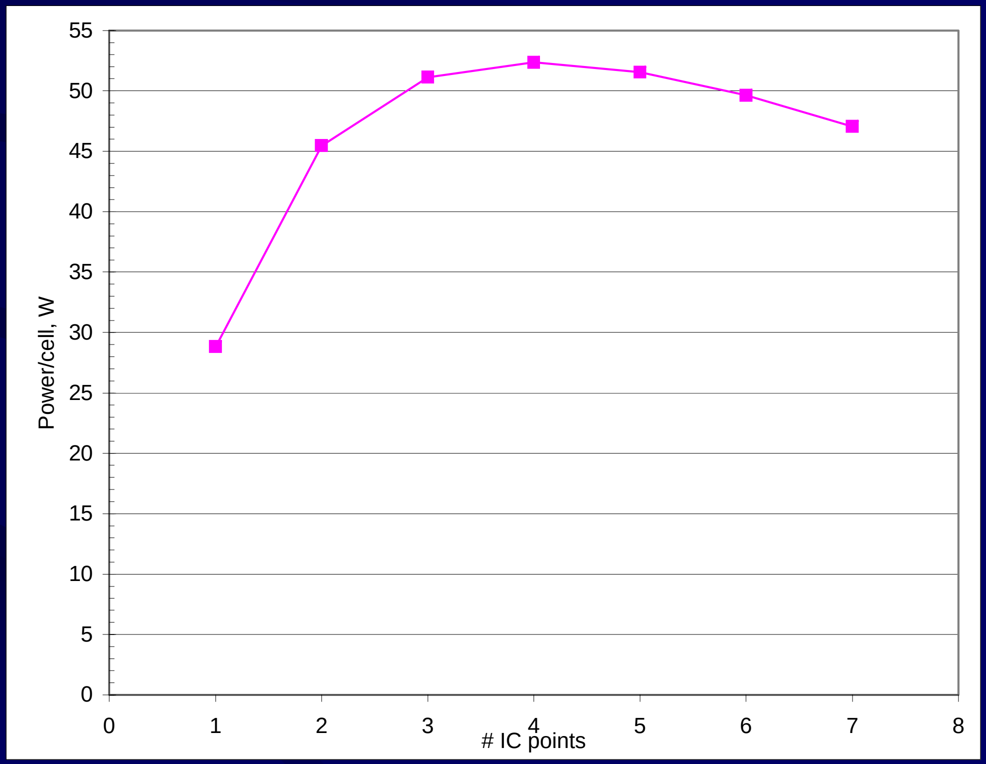
Lifegraph for the Triple takeoff



Multiple takeoff cell



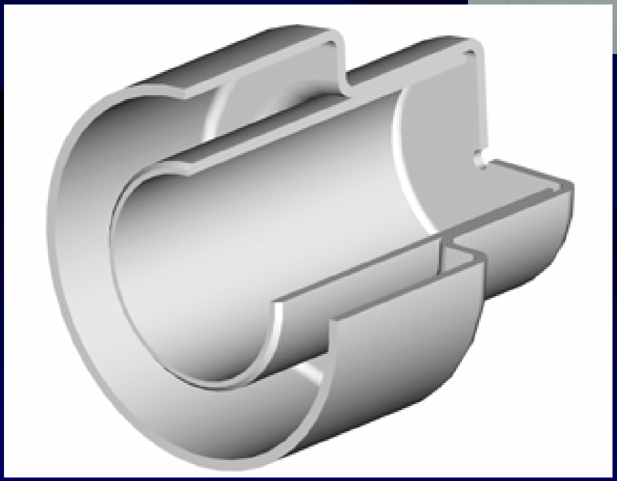
Operation at
275-315 mW/cm^2

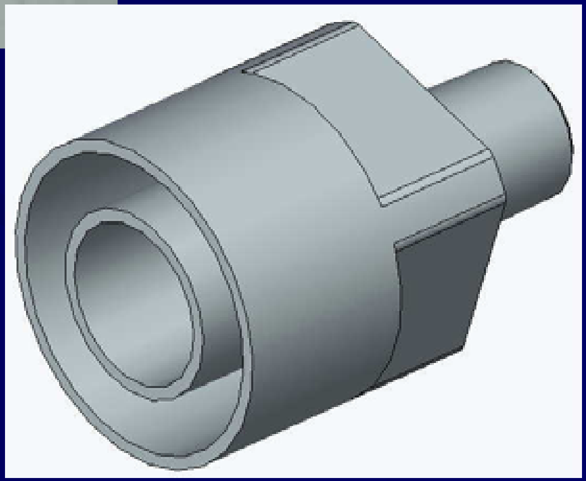


Generator Cost Reductions

- Work has focused on Four major areas:
  - Metal injected Molded (MIM) manifolds and braze caps
  - Stamped Braze Caps
  - Recuperators- metallic and ceramic
  - Fuel Recirculation Systems

MIM Cap Designs





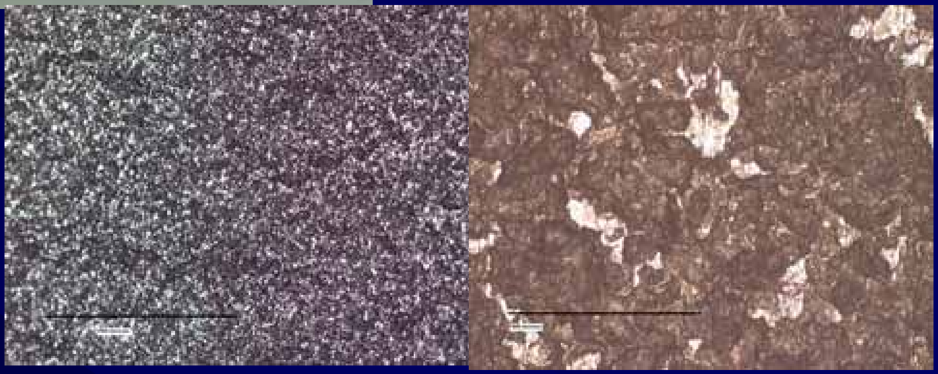
Deep Drawn Braze Caps

Manifold Development

- MIM has been demonstrated
- Issues first existed with firing of high temperature metals and required fixturing.
- Straightness and thread tolerance issues are being addressed
- Lower cost metals are being examined.

MIM Nickel Samples

50x



MIM Wrought

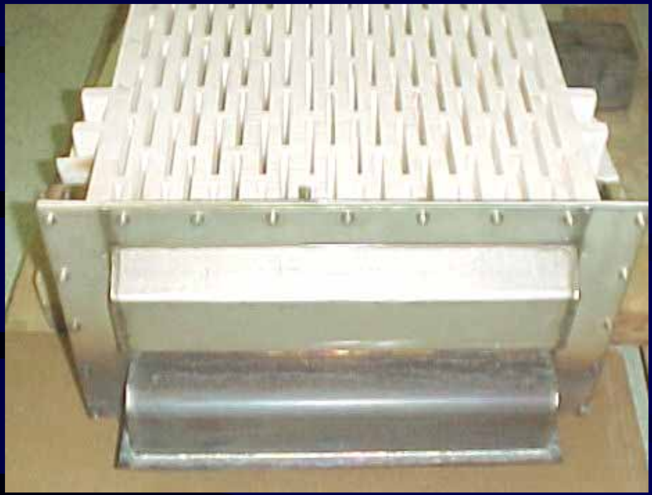
Finned Tube Recuperator

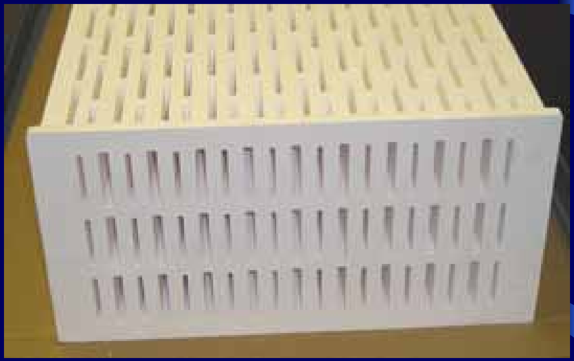
Counter Flow Recuperator

Metallic Recuperator Summary

		Cross Flow	Counterflow
Effectiveness		82	89
Volume	Cu. Ft.	2.23	0.73
Weight	Lbs	143	62
Air Side Dp	" w.c.	4.5	2.8
Exh Side Dp	" w.c.	0.2	1.4

Ceramic Recuperator





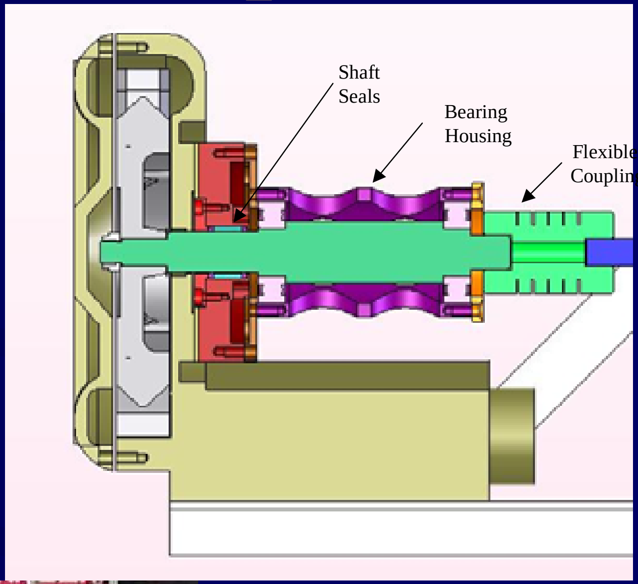
Ceramic Recuperator Summary

- Reduce leakage
- Determine effectiveness without leakage
- Prove thermal cycle ability
- Evaluate counterflow, alternate ceramic materials for improved effectiveness

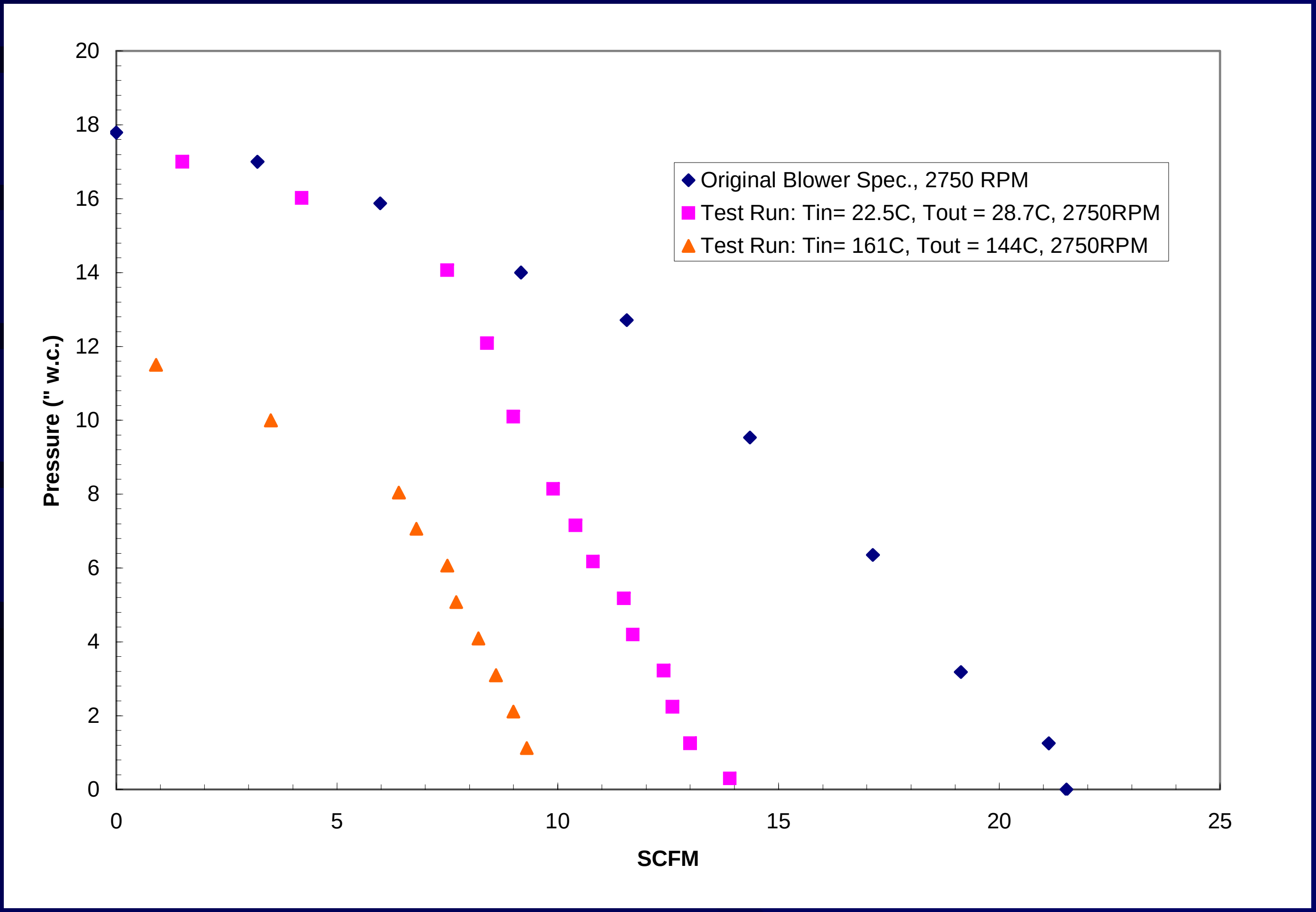
Recirculator Design

- Need to move to steam reforming for efficiency gains.
- Need a steam reform configuration that does not require high pressure gas
- Hot offgas recirculator is considered best long term option
- Hot Recirculator must operate near 800C
- Must have high temp seal and operate in fuel stream
- Must have high availability
- Must be capable of obtaining safety certification
- Medium Temperature Recirculator is being developed as near term alternative

Recirculator Test Setup



Recirculator Performance

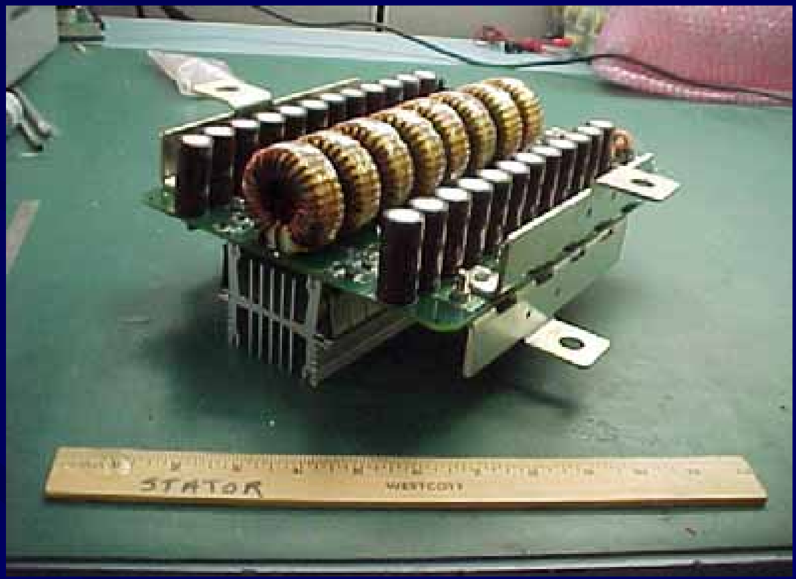


Future Recirculator Testing

- Offgas Recuperation
- Fuel & Offgas Flow Control
- Reformation Chemistry
- Fan Pressure Requirements
- Stack Performance

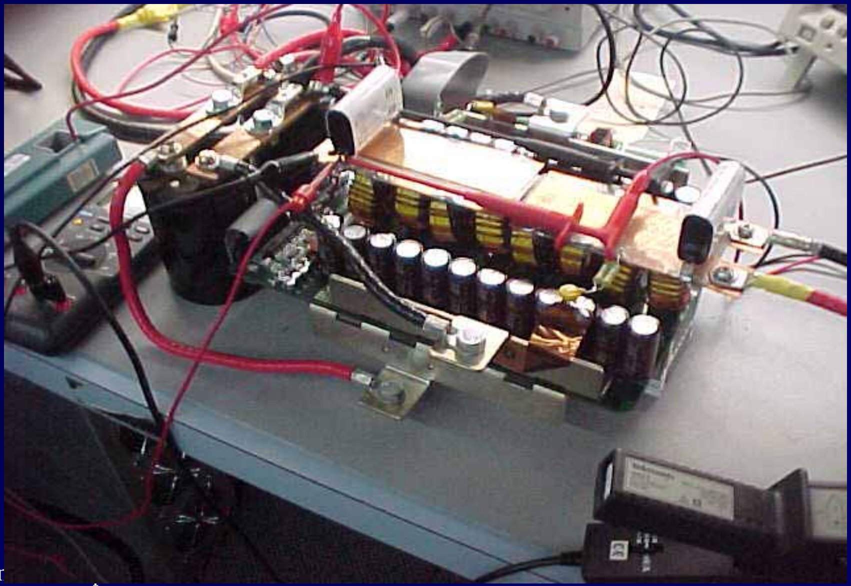
Fuel Cell Interface Converter, FC-IC

- Interfaces fuel cell to energy storage system
- Controls fuel cell output current
- Interleaved buck – boost topology
- 6kW building block

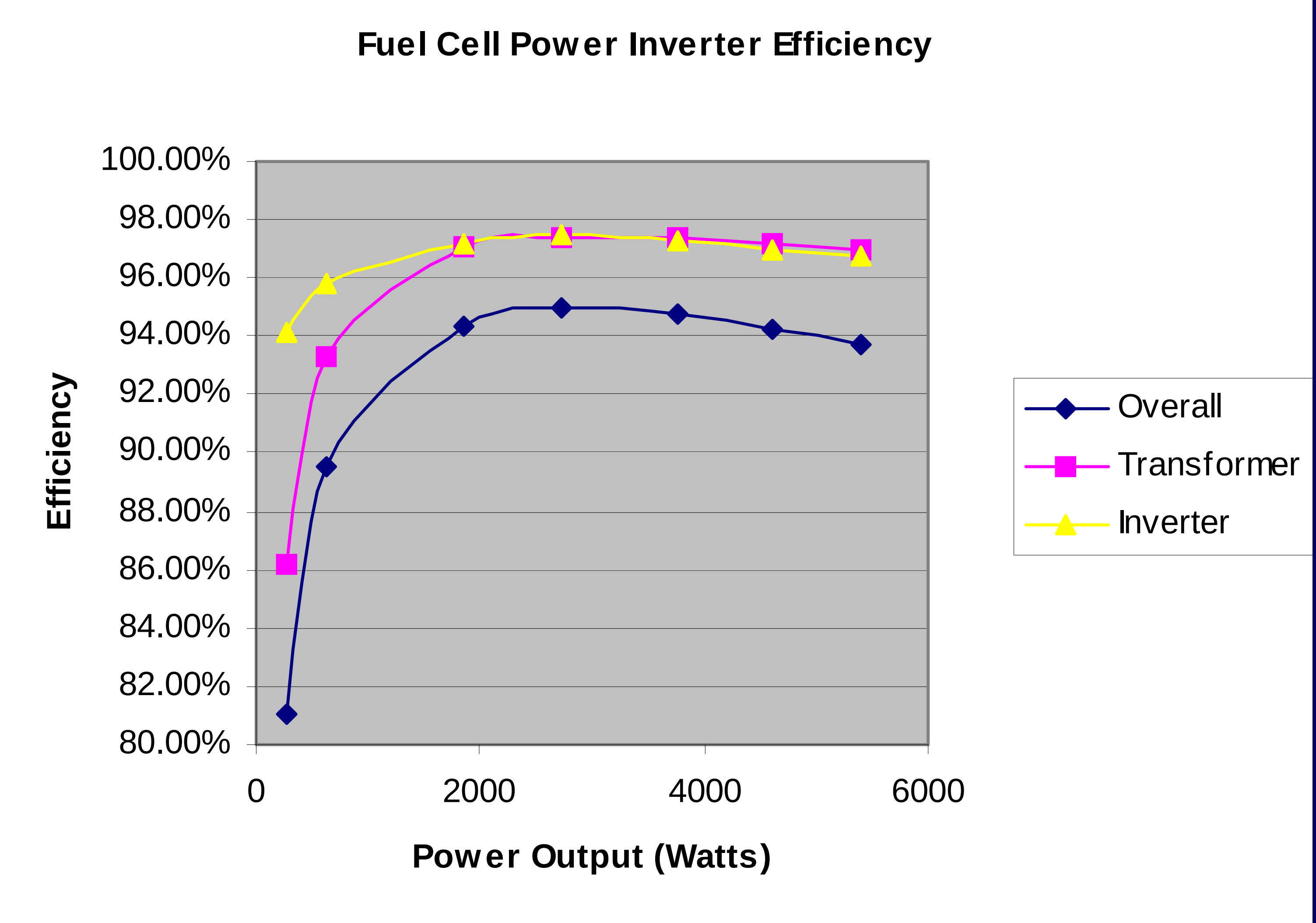


Low Voltage Inverter Development

- 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.



SECA Inverter Efficiency



Conclusions

- Demonstrated the capability to run on low sulfur diesel and syntroleum with the use of an external fuel processor.
- Demonstrated the capability to achieve twice the power density of the existing state of the art tube.
- Developed a path to triple the power of the state of the art tube.
- Proven the ability to reduce the tube firing process from 48 hours to less than 12.
- Continue to develop low cost generator components capable of achieving SECA cost targets.
- Continue to develop a low cost, high efficiency inverter capable of achieving SECA cost targets.

Acknowledgement

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