DMFC Power Supply for All-Day True-Wireless Mobile Computing

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PolyFuel, Inc.

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Project ID# FCP 39

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Overview

Timeline

Start Date: Sept, 2004

End Date: Sept, 2007

Project is ~ 45% complete

Budget

Original Plan:	$6.34 million
DOE share:	$3.00 million
PolyFuel share:	$3.34 million
FY05 Funding:	$1.08 million
FY06 Funding:	$ 0

Barriers Addressed

Volumetric Power Density:	> 30 W/l
Gravimetric Power Density:	> 30 W/kg
Energy Density:	> 500 W·h/l
Cost:	< $5/Watt
Lifetime:	> 1000 hours

Objectives

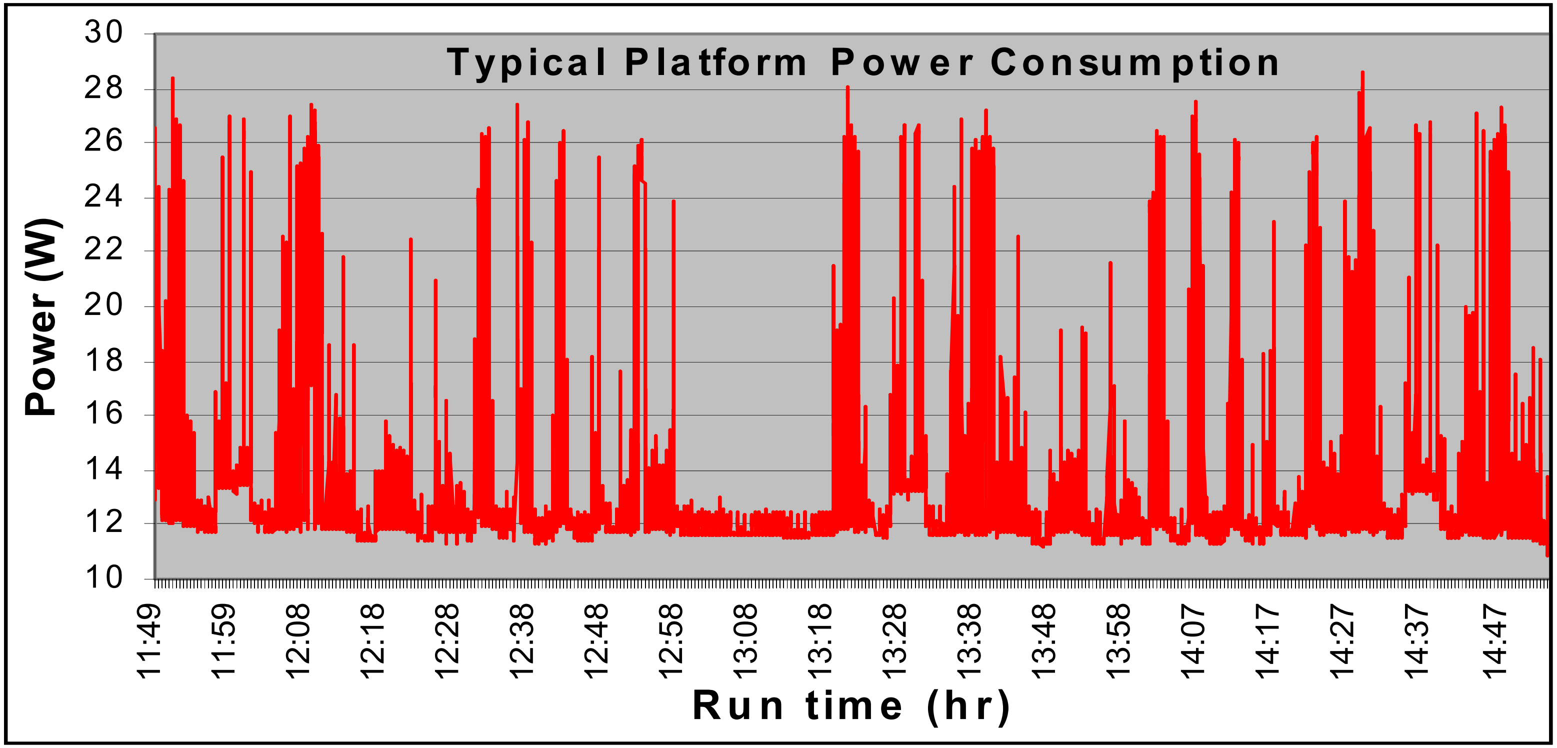
- To build a DMFC laptop power supply with a significant advantage over Li-ion batteries
- To fully integrate this power supply into a laptop computer
- A radical departure from conventional active systems is required to realize competitive power density
- Focus is on dramatically improving volumetric power density

Requirements Definition

- Operating Life: 1000 hours or 125 refueling cycles
- Cost: Less than $100 per unit at 100,000 per year
- Ambient Temperature: +5 °C to +40 °C
- Orientation Independent
  - Must run while tilted or inverted
- Fuel cell system volume: 250 cc
- Methanol cartridge volume: 120 cc
- Fuel: pure or nearly pure methanol
- Maximum noise level: 40 dbA at 0.5 meter

Requirements Definition

- Average Power Level: 15 Watts
- Peak Power Level: 40 Watts
- Voltage: 8.0 - 12.6 Volts, with 10.8 Volt nominal
- Requires Fuel Cell – Battery hybrid design



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General Approach

- The best system will involve co-optimization of membrane properties and system strategy
- PolyFuel is approaching the problem from both sides

System/Cell

"What membrane properties are required by the cell/system?"

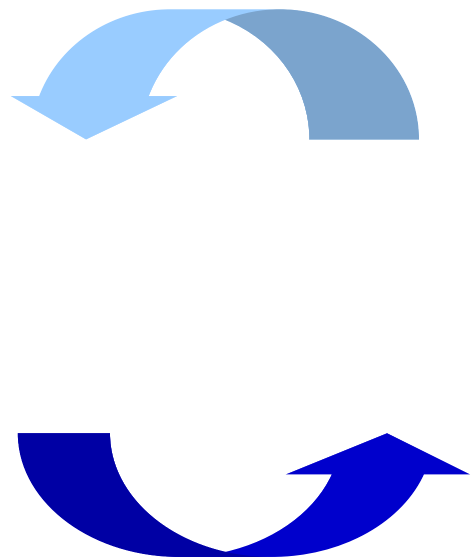
Operating Strategy

Electrical Architecture

Water management

Thermal Management

Packaging



Membrane

"What conditions are required by the membrane?"

Conductivity

MeOH crossover

Diffusivity

Mechanical Strength

Bonding

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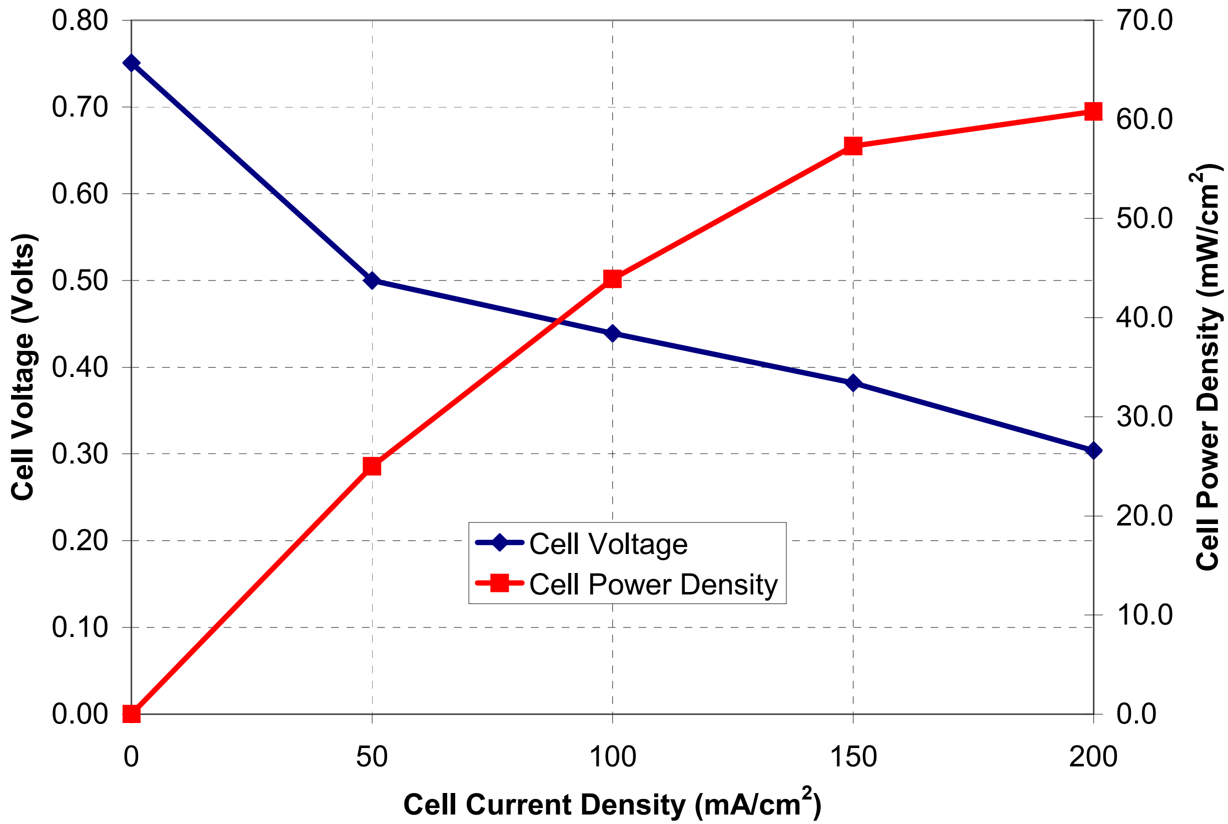
System Approach

- Goal is to eliminate as many balance of plant components as possible
  - High parasitic loads cause large increase in device volume
  - Every 1 Watt of parasitic load is worth 10 cc of system volume
  - High pressure, inefficient, and noisy air pump is eliminated
- System must operate on pure or nearly pure alcohol fuel
  - Water necessary for anode reaction is pulled directly through the membrane from the cathode
  - Need to condense and re-circulate product water is eliminated
- New membrane must have more capability
  - Higher diffusivity of water
  - Higher tolerance to methanol

Polymer Membrane Improvements

- Improvements made in polymer stability in high concentrations of methanol
  - No measurable organic material after 7 day soak in 20M methanol at 60 °C
- 40% improvements in fully hydrated proton conductivity
  - 40 mS/cm after soaking in 60 °C water
- Enhanced water transport properties to allow sufficient water to back diffuse from the cathode to the anode
- Small increase in water uptake and membrane swelling
  - 35 wt% water uptake at 100 °C
  - 20% X-Y dimensional change in 8M methanol at 60 °C

Cell Performance at Beginning of Life



Conditions

Anode: 100% MeOH

Stoichiometry ~ 1.1

Cathode: ambient dry air

Temperature: 50 C

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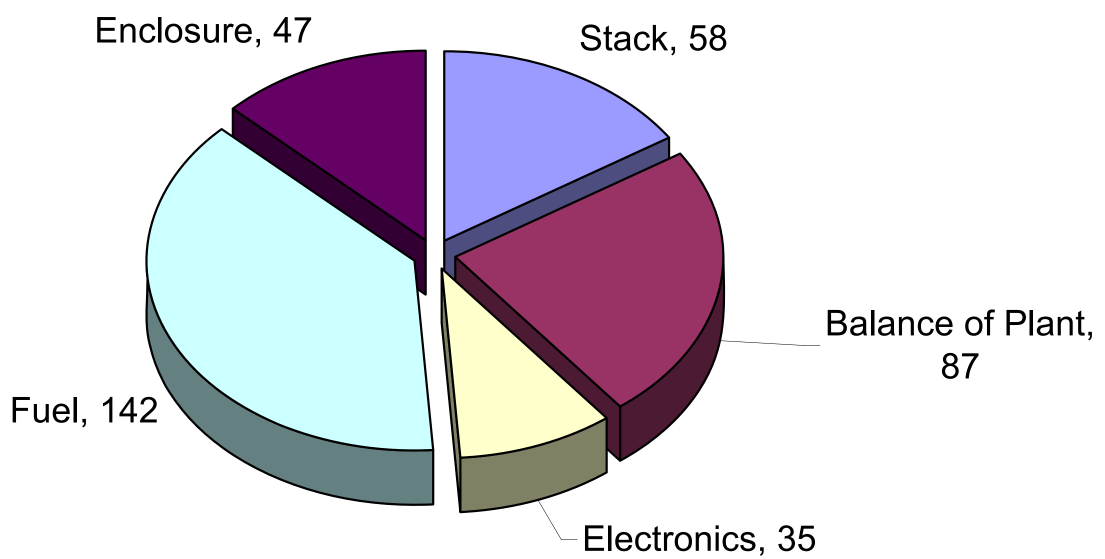
System Component Breakdown

Target Volume Breakdown of Polyfuel Laptop Demonstration

Total System Volume: 370 cc

Energy Density: 325 Wh/Litre (15 W net, 8 hr runtime)

(Volumes in cm^3)



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DC-DC Converter Requirements

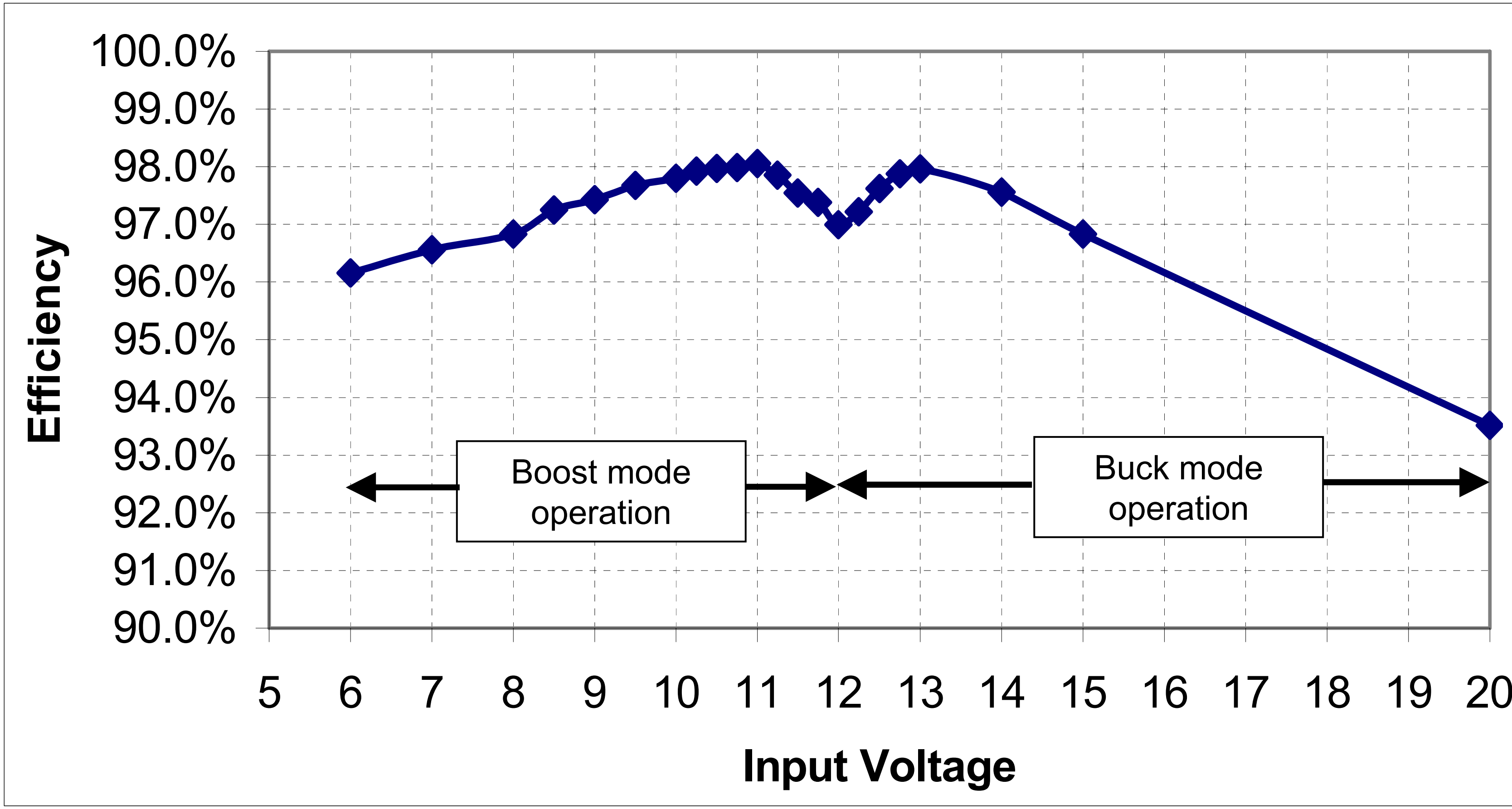
- DMFC cells have a sizable voltage droop between open circuit and full load
  - Open circuit voltage is about 0.85 Volts
  - Full load voltage drops to about 0.35 to 0.40 Volts
  - Fuel cell stack voltage will vary from 6 Volts to 20 Volts

- Voltage regulation for laptop computer needs to be flat at about 13 Volts
- DC-DC converter will need to be buck-boost combination

- Very high efficiency is required to minimize waste throughout the system
  - Losses in conversion result in more fuel usage
  - Losses in conversion result in larger fuel cell stack
  - Target DC-DC converter efficiency > 95%

A 1% efficiency improvement = 1.2 cc system size reduction

DC-DC Converter Efficiency Over Full Input Range



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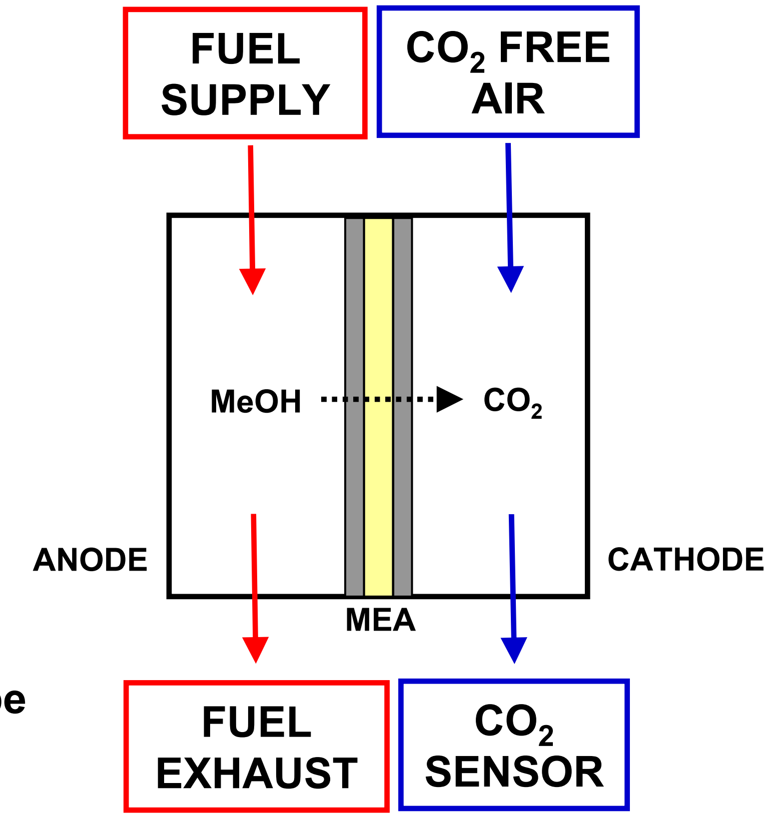
Tool Development – Real time Crossover Measurement

- **Real time crossover measurements have been developed to assess cell operation under operating conditions encountered while using high methanol concentrations**
- **Crossover methanol from the anode is oxidized to CO_2 at the cathode**
- **The CO_2 is measured using an infrared sensor in the oxidant exhaust**
- **Knowing the CO_2 concentration and the air flow rate, the methanol crossover rate can be easily computed**



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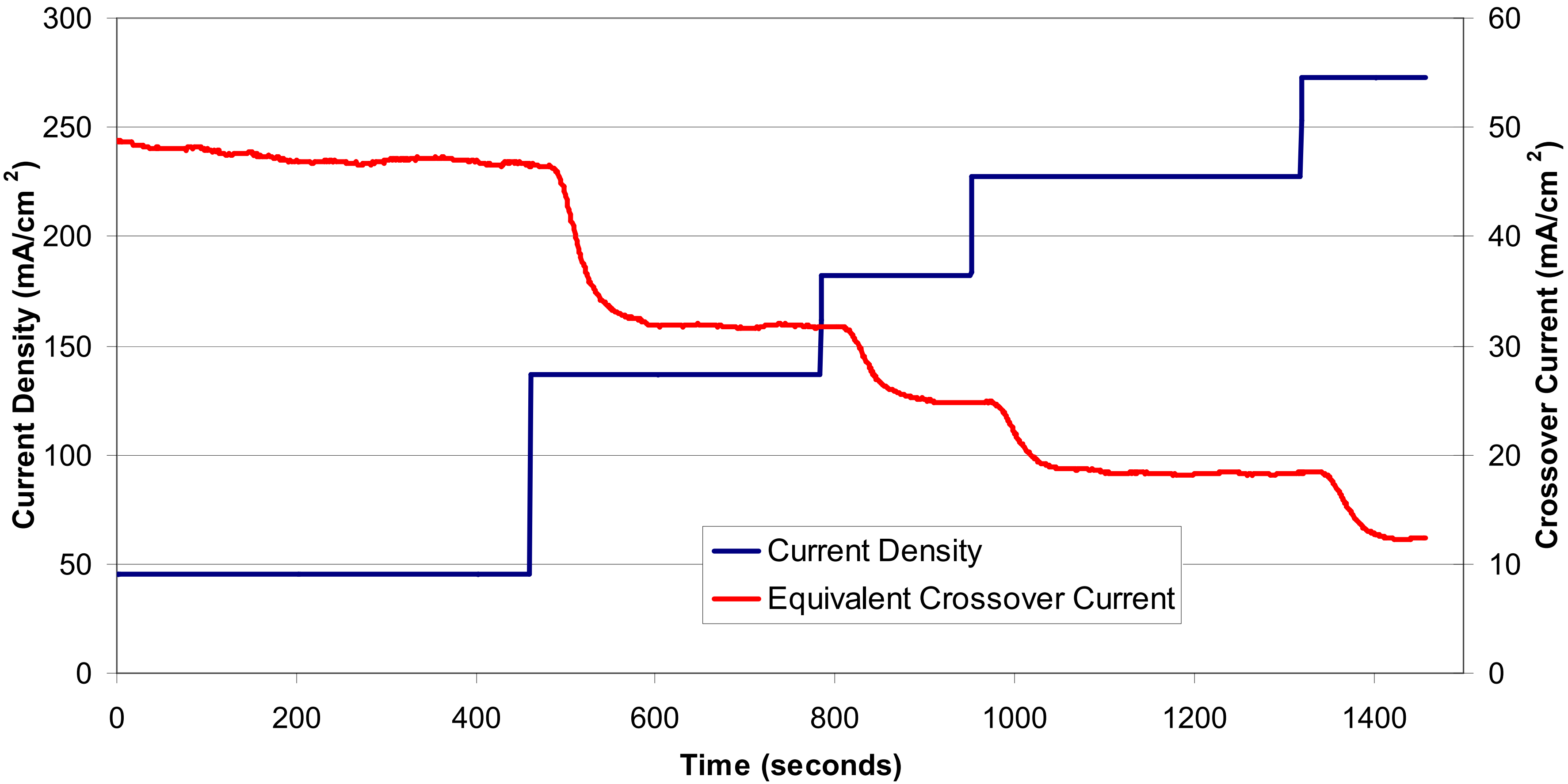
Tool Development – Real time Crossover Measurement



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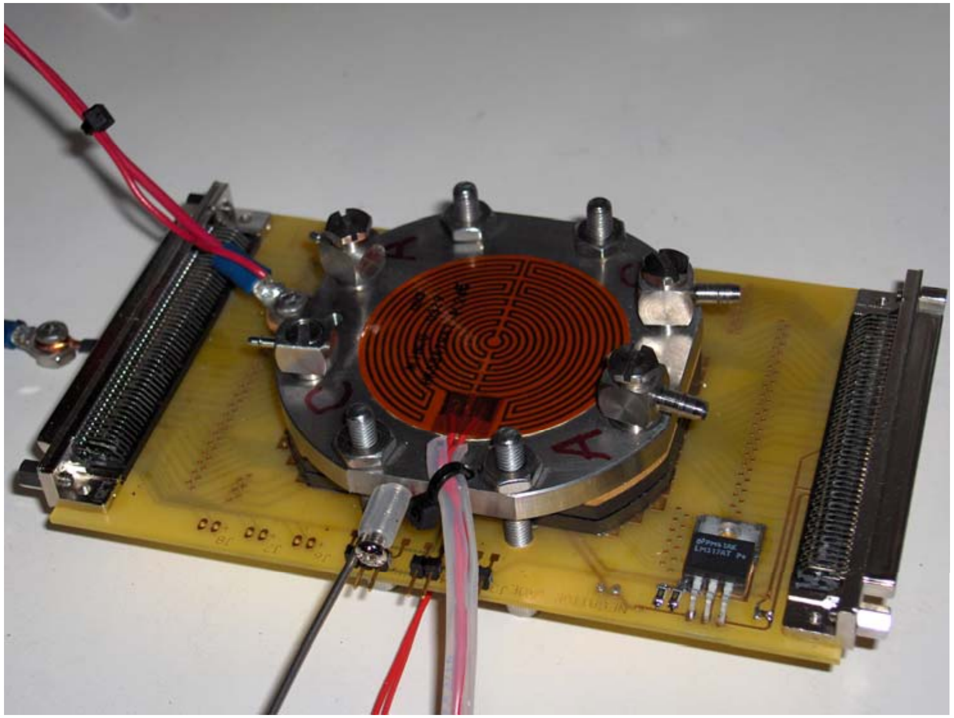
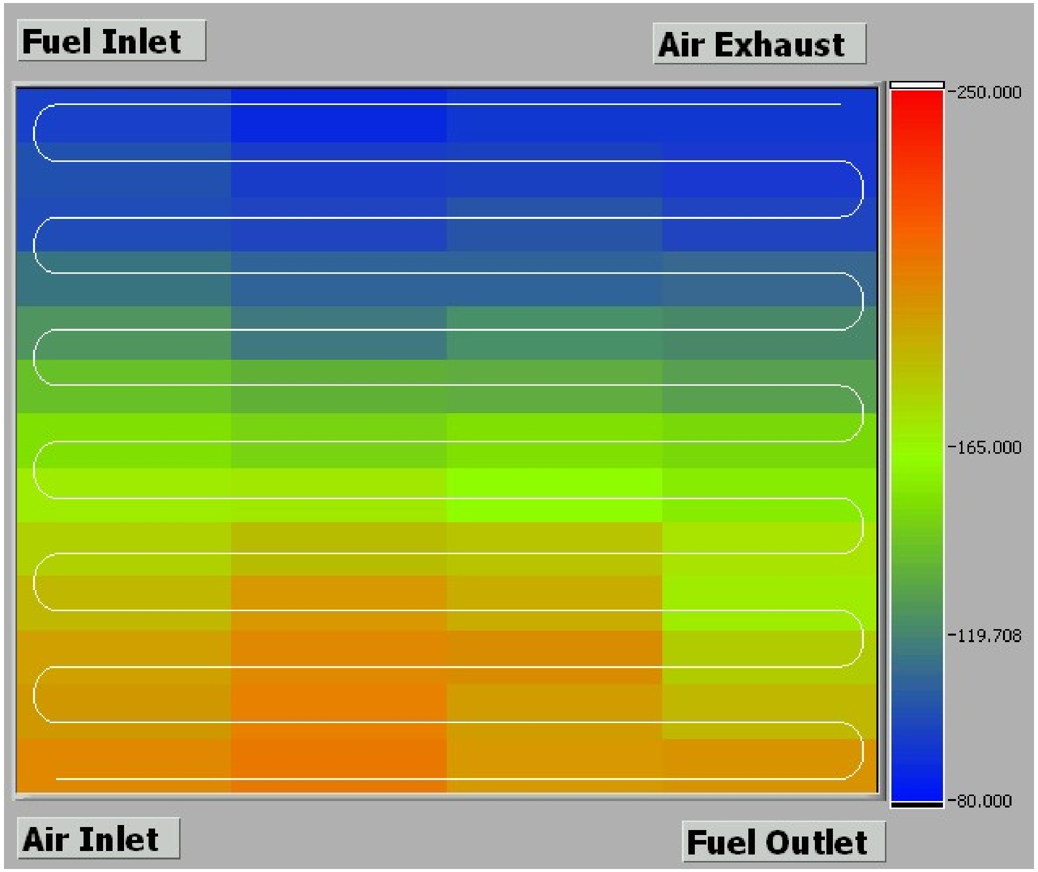
Tool Development – Current Mapping

- Simple tool developed to measure the current density distribution in an operating cell
- Cell elements of 0.5 cm^2 are measured using the tool to create a real time current density map
- Can be used to observe reactant distribution, catalyst corrosion, humidity, and temperature effects



Current Mapping Tool Output

- Color gradient displays current density distribution throughout the cell
- Red areas have high current density; blue areas have low current density
- Sample map at right has low air stoichiometry leading to high currents at the air inlet and low currents at the air exhaust



Future Work

- Establish cell lifetimes under new, harsher operating conditions
- Integrate all subsystems together into a highly compact package
- Design orientation insensitive fuel tank with high utilization
- Characterize full systems under simulated load conditions
    - Determine system operating life
    - Measure system noise levels
    - Measure system emissions