DOE Hydrogen Program

CIRRUS

Subfreezing Start/Stop Protocol for an Advanced Metallic Open-Flowfield Fuel Cell Stack

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Project ID #
FC32

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Overview

Timeline

- 3 year program
- Actual start: 7/1/2007
- Planned end: 6/30/2010

Barriers

- Barriers addressed
  - (D) Water Transport within the Stack
  - (G) Start-up and Shut-down Time and Energy/Transient Operation

Budget

- Total project funding
  - $4.970 Million (DOE)
  - $2.160 Million (Nuvera)
- FY07 funding = $619K
- FY08 funding = $1,881K

Partners

- W. L. Gore & Associates
- SGL Technologies
- University of Delaware
- Los Alamos National Lab

Objectives

The **objective** of the CIRRUS Program is to demonstrate a PEM fuel cell stack meeting DOE 2010 cold start targets:

Table 3.4.3 Technical Targets: 80-kW$_e$ (net) Transportation Fuel Cell Stacks Operating on Direct Hydrogen [a]					
Characteristic	Units	2003 Status	2005 Status	2010	2015
Cold start-up time to 50% of rated power					
@ –20ºC ambient temperature	seconds	2	20	30	30
@ +20ºC ambient temperature	seconds	<1	<10	5	5
Start up and shut down energy [I]					
from -20°C ambient temp	MJ	N/A	7.5	5	5
from +20°C ambient temp	MJ	N/A	N/A	1	1
Unassisted start from low temperature [J]	ºC	N/A	-20	-40	-40

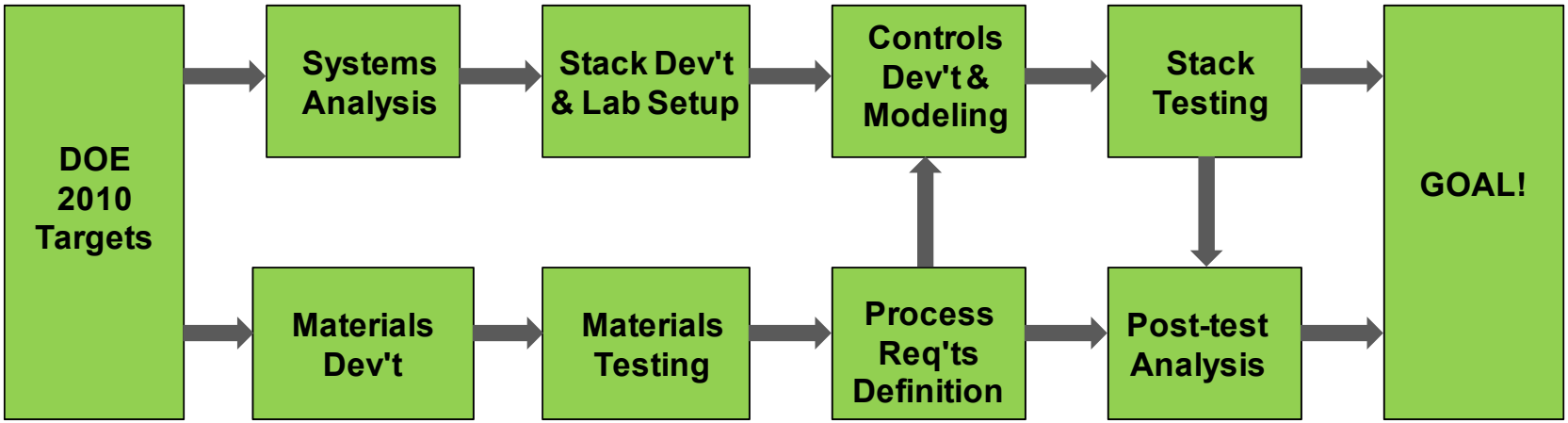
Specific **FY08 goals** include:

- Achieving -20C cold start target respecting the energy budget
- Identifying electrochemical material freeze cycle aging modes

FY08 Milestones

- ***Achievement of -20C startup goal***
  - ***Reference Stack Technology***
  - ***Conditioned gas temperatures (environmental chamber)***
  - ***Optimized procedure using dynamic model***
  - ***System-compatible strategy***
  - ***>50% rated power in 30 seconds***
  - ***Auxiliary energy use < 5 MJ***
- ***Identification of freeze/thaw decay/failure modes***
  - ***Detailed post-test analyses of freeze cycled MEAs and GDM***
  - ***MEA stress evaluation from -40C to 65C at variable RH***
- ***Articulation of 2010 Technology***
  - ***Performance specifications & design attributes***
  - ***Freeze start performance forecast***

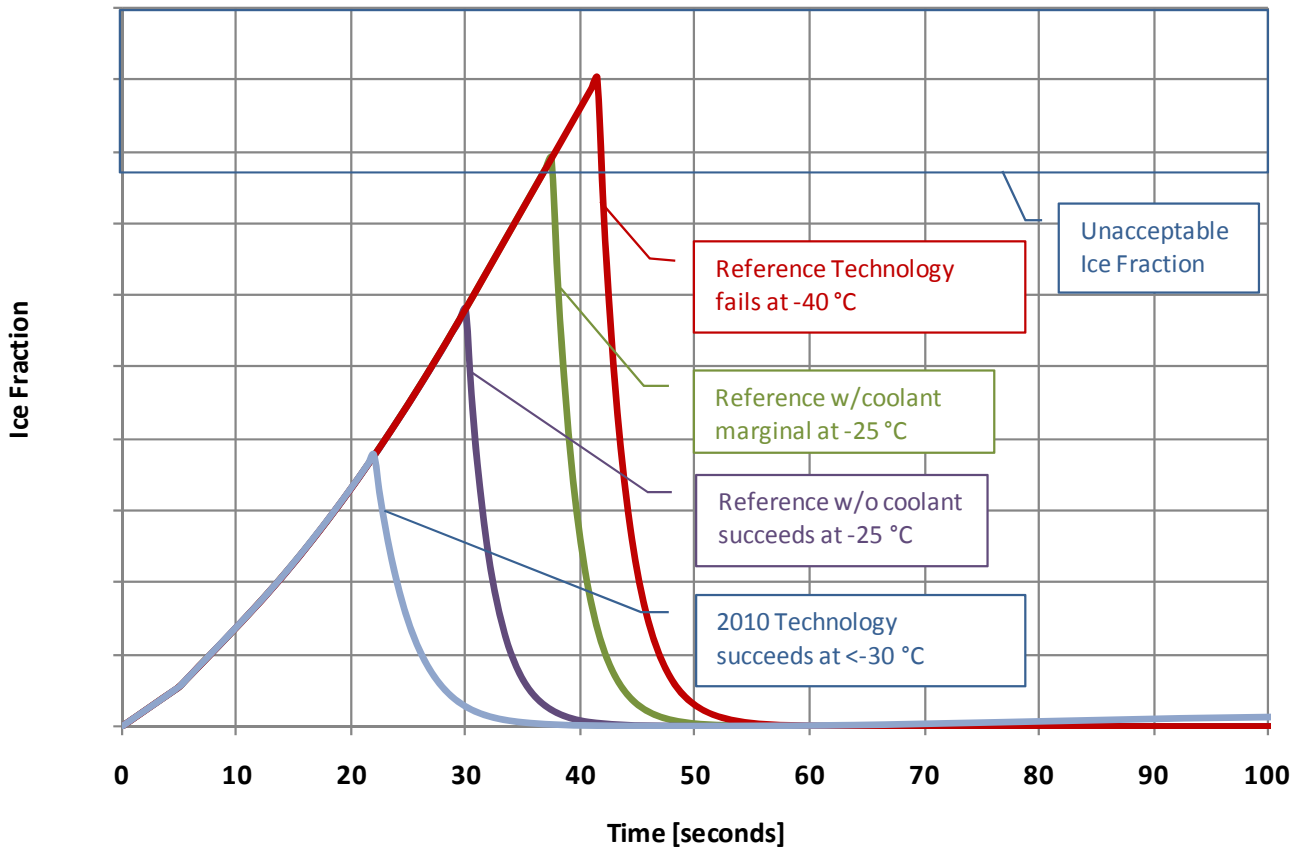
Approach



Program allows for one iteration:

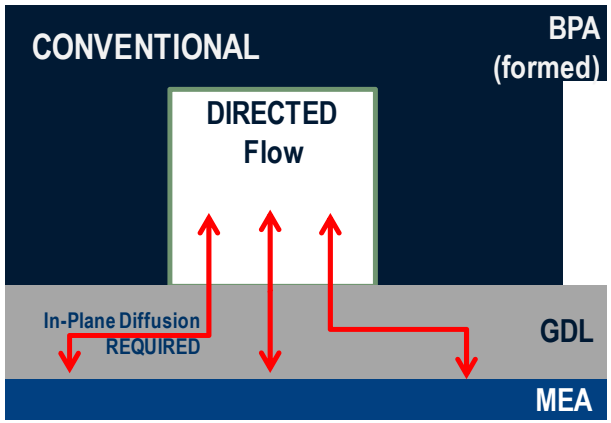
Reference Technology: Q3/2007 -- Q1/2009
2010 Technology: Q2/2009 -- Q2/2010

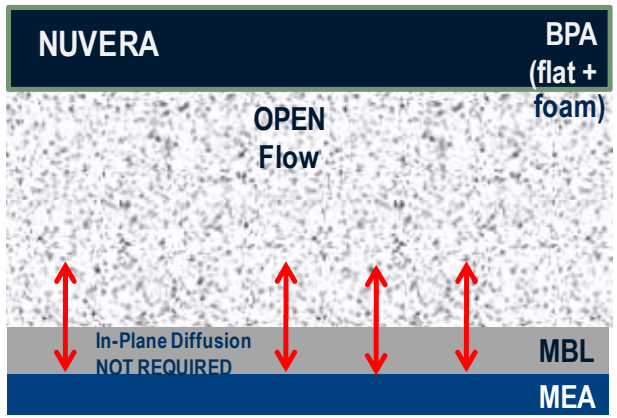
Systems Analysis



Progress in stack thermal mass reduction is essential for meeting freeze start targets

Stack Development





Nuvera SYSTEM Advantages	Size	Efficiency	Durability	Freeze	Cost
Higher catalyst utilization	✓	✓	✓		✓
Elimination of mass transfer limit	✓			✓	✓
Reduced cell pressure drop		✓		✓	✓
Reduced stress on MEA			✓		
Enhanced cell stability			✓	✓	
Reduced electrical resistance	✓	✓	✓		✓

Open flowfield is hypothesized as favored for meeting PEMFC freeze start requirements

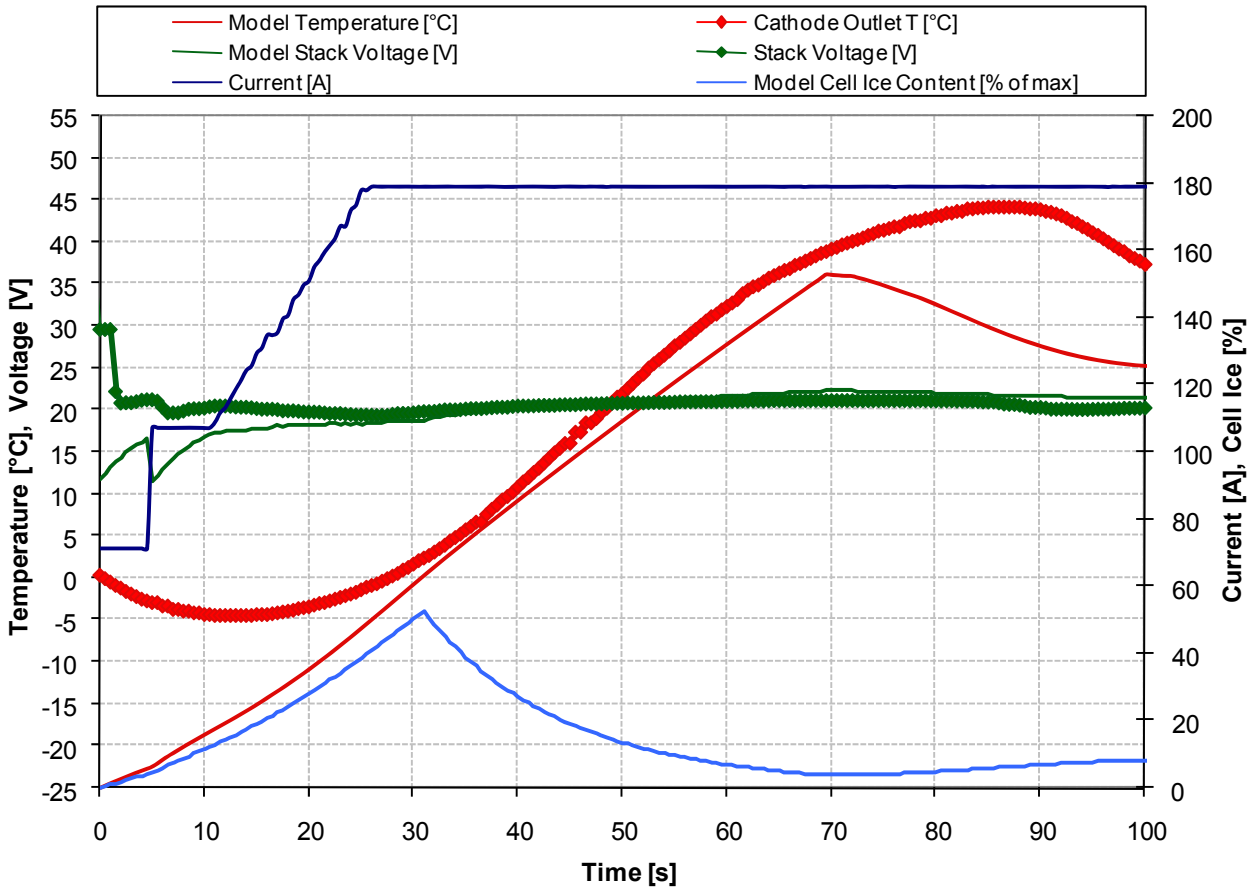
Laboratory Setup

- Reference technology
- 32 cells, 360 cm^2 AA/cell
- Commercial freezer

- 30 kWe Greenlight station
- Fully automated
- Adding env'l chamber Q3 08

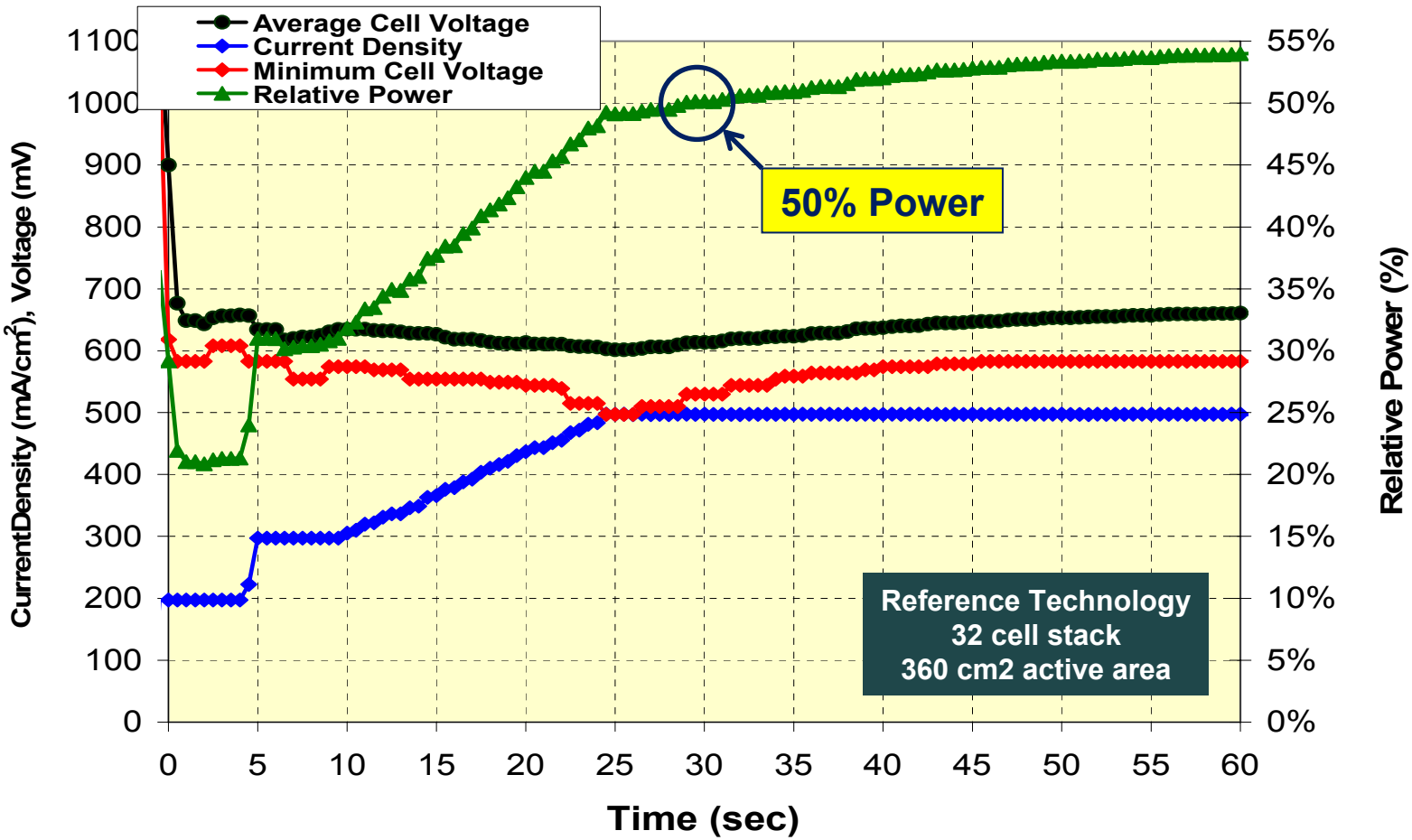
Primary testing infrastructure has been fully commissioned, with 36 freeze tests to date

Controls Development & Modeling



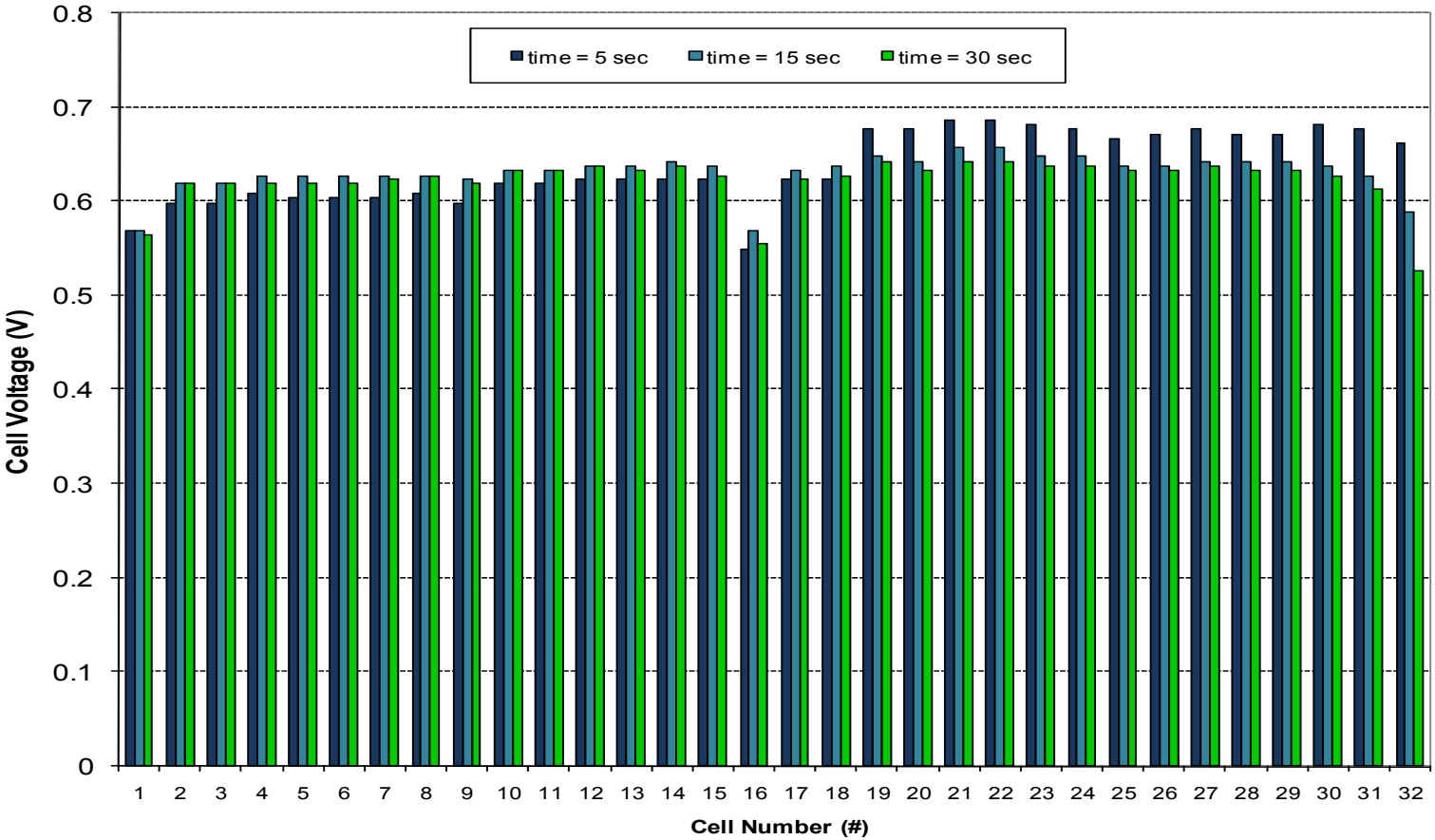
Dynamic modeling offers important guidance for selection of operating protocols

Stack Testing



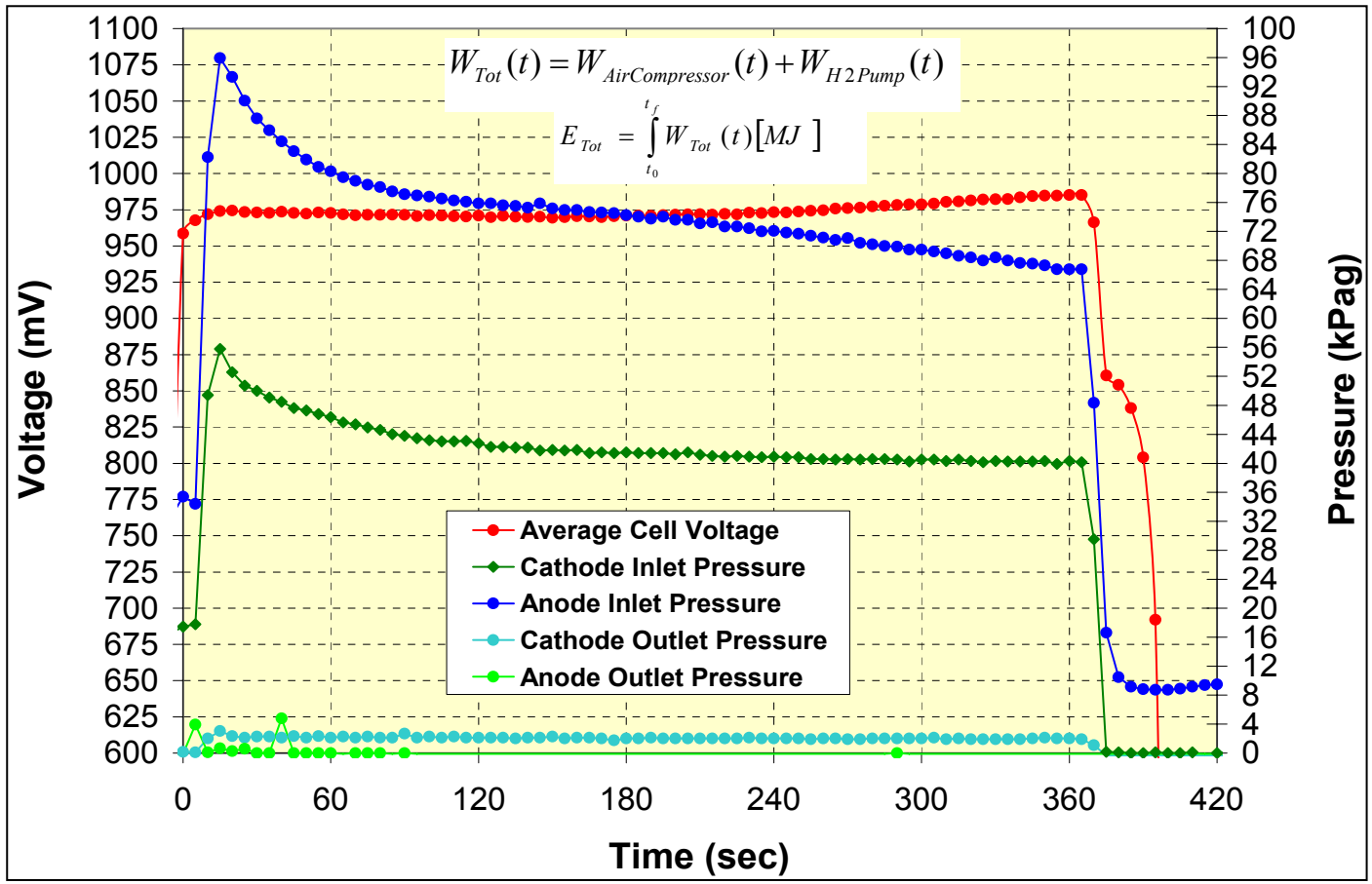
Startup target of 50% rated power in 30 seconds has been achieved using Reference Technology

Cell Stability



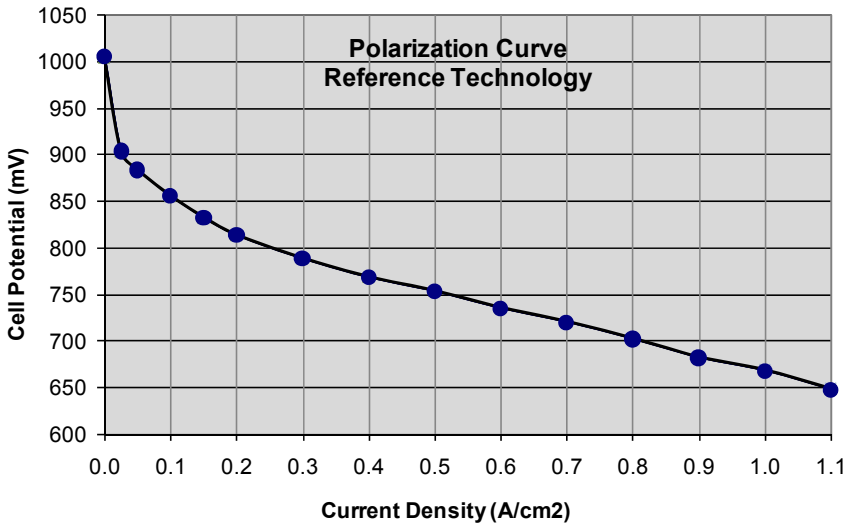
Cell stability through -20C start was acceptable -- depression of end cell voltages is evident

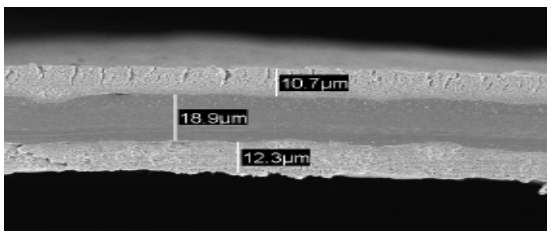
Energy Accounting



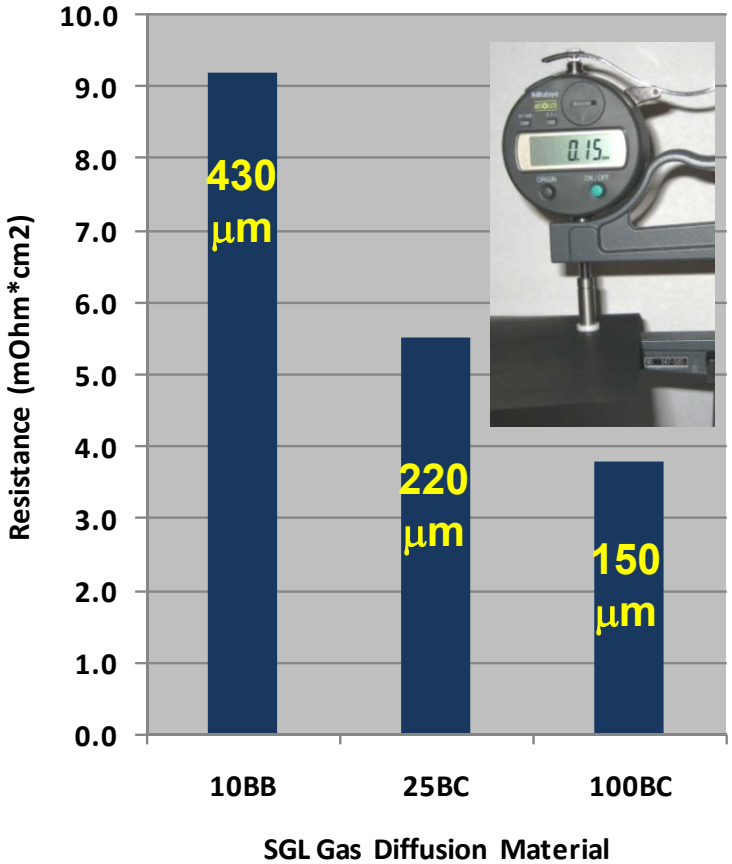
Estimated energy use over complete start/shutdown cycle = 5.6 MJ approaching DOE target (previously 26 MJ)

Materials Development



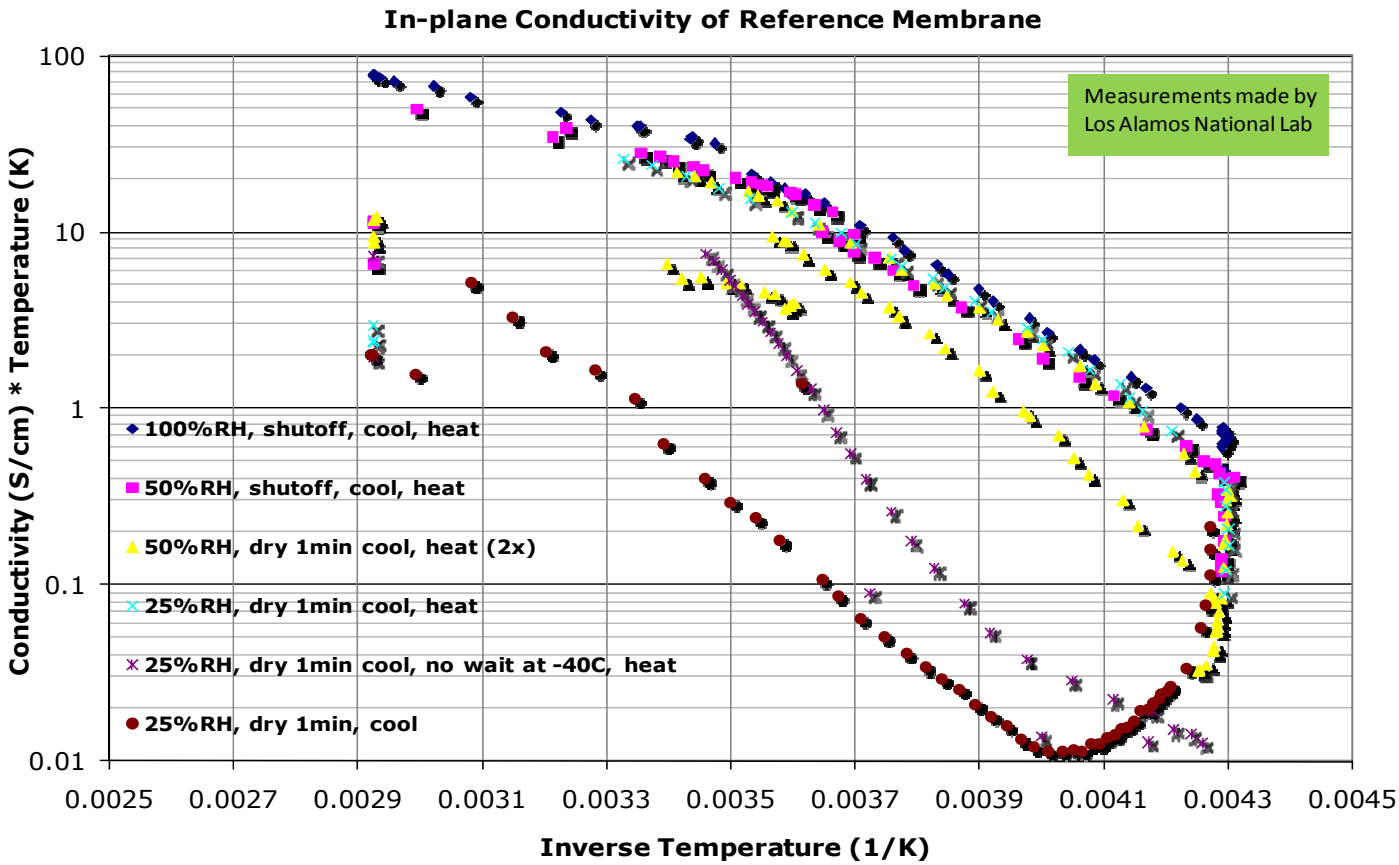


Reference MEA



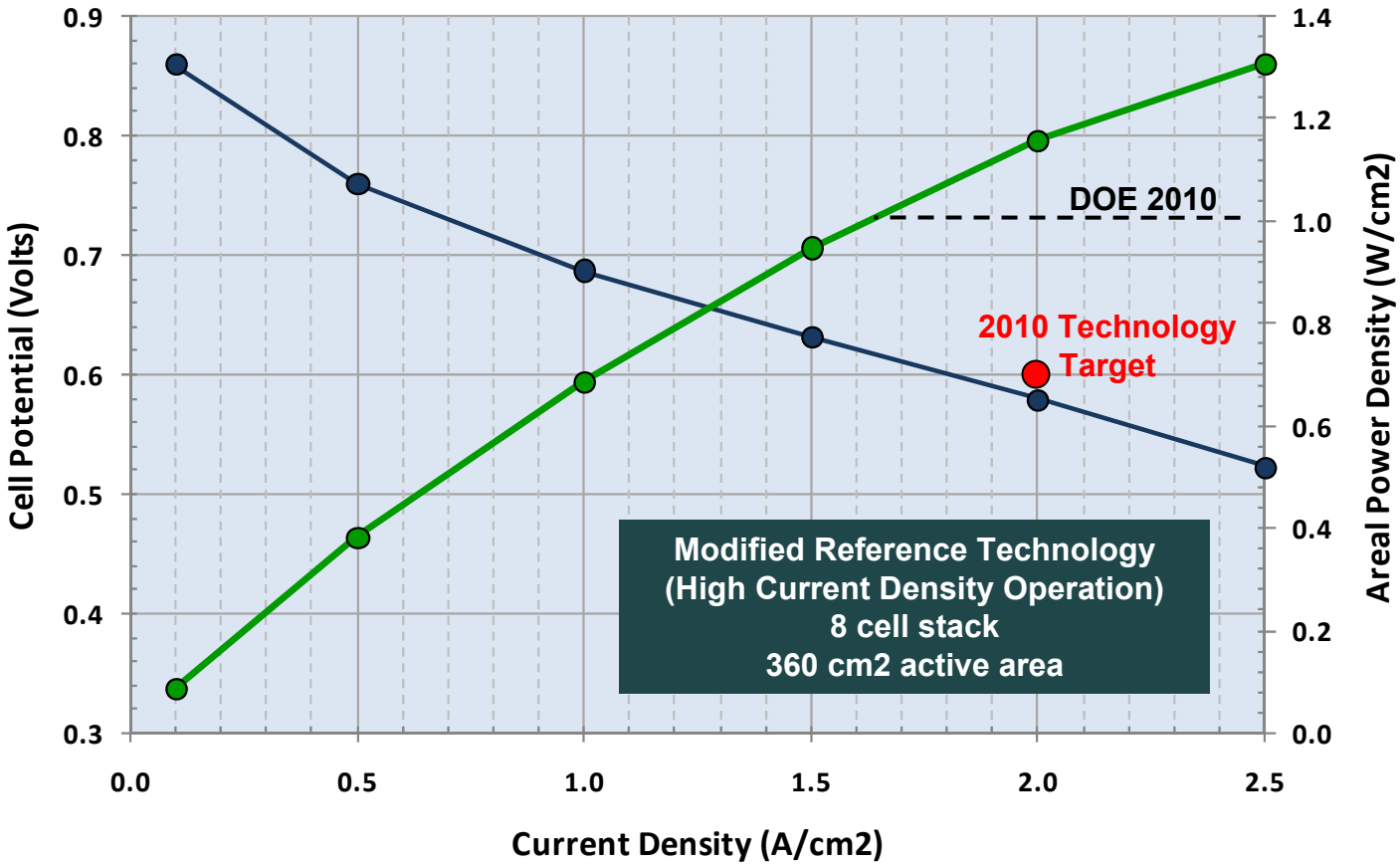
Program targeting higher durability MEAs & thinner diffusion layers

Materials Testing



Temperature dependence of Reference MEA conductivity under various shutdown approaches has been measured

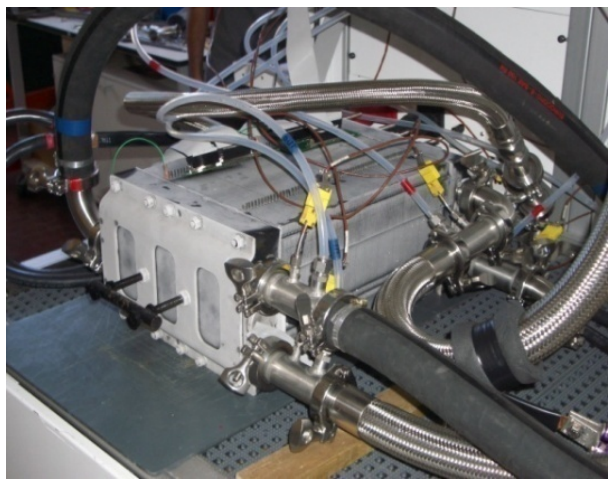
2010 Technology Preview



Key target for 2010 stack technology will be a Rating Current Density (RCD) of 2.0 A/cm2

Future Work

- Install and commission environmental chamber
- Develop 2d model to afford startup procedure optimization
- Analyze post-test material sets to understand decay modes
- Improve material sets (MEA durability, GDM thickness)
- Measure MEA stresses and refine process constraints
- Develop & validate 2010 Stack Technology



Summary

- **2010 startup goal of 50% rated power in 30 seconds has been achieved (32 cell, full format Reference Technology stack)**
- **Energy budget target of 5 MJ currently exceeded by 12%, will be met with further optimization**
- **Next generation 2010 material sets are in active development, to be informed by forthcoming post-test analyses**
- **2010 Technology, on account of higher performance and reduced thermal mass, will meet targets from start temperatures < -20C**

Technical Targets: 80-kWe (net) Transportation Fuel Cell Stacks Operating on Direct Hydrogen			
Characteristic	**Units**	**Status 2005 (DOE)**	**Status CIRRUS FY08**
Cold start-up time to 50% of rated power	seconds	20	30
Startup and shutdown energy (from -20C ambient)	MJ	7.5	5.6
Unassisted start from low temperature	C	-20	-25