Water Transport Exploratory Studies

Office of Hydrogen, Fuel Cells, and Infrastructure Technologies 2007 kickoff meeting

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DOE Forrestal Building

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Los Alamos National Lab

The Institute for Hydrogen and Fuel Cell Research

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Objectives

- **Develop understanding of water transport in PEM Fuel Cells** (non-design-specific)
- Evaluate structural and surface properties of materials affecting water transport and performance
- Develop (enable) new components and operating methods
- Accurately model water transport within the fuel cell
- Develop a better understanding of the effects of freeze/thaw cycles and operation
- Present and publish results

Technical Targets/Barriers

Characteristic	Units	2003 Status	2005 Status	2010	2015
Energy efficiency[b] @ 25% of rated power	%	59	59	60	60
Energy efficiency @ rated power	%	50	50	50	50
Power density	W/L	440	500[c]	650	650
Specific power	W/kg	420	470[c]	650	650
Cost[d]	$\$/kW_e$	200	110[e]	45	30

N. Vanderborgh, 1994 "...... it's all about water management ..."

Start up and shut down energy[f] from -20°C ambient temp from +20°C ambient temp	MJ MJ	na na	7.5 na	5 1	5 1
Unassisted start from[j]	°C	na	-20	-40	-40

Technical Targets: Membranes			
Characteristic	**Units**	**2004 Status**	**2010**
Inlet water vapor partial pressure	kPa (absolute)	50	≤1.5

Approach

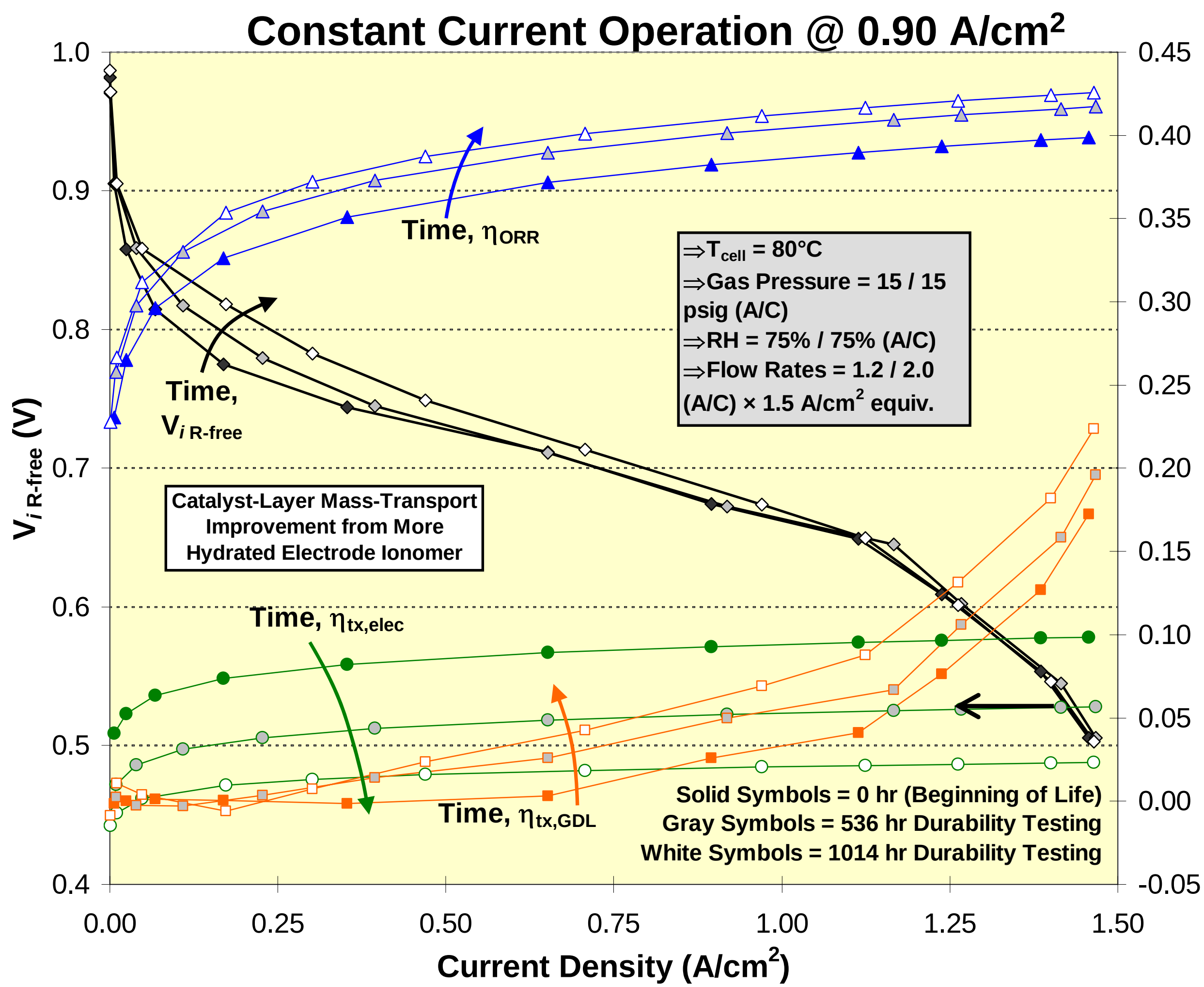
- **Develop understanding of water transport**
  - Experimental measurement and testing
  - Characterization
  - Modeling
- Evaluate structural and surface properties of materials affecting water transport and performance
  - Measure/model structural and surface properties of material components
  - Determine how material properties of GDL, MPL, catalyst layers & interfaces affect water transport (and performance)
  - Determine properties change during operation (degradation effects)
- Develop (enable) new components and operating methods
  - Prevent flooding (high power operation)
  - Prevent dehumidification (low RH operation - transportation)
- Develop a better understanding of the effects of freeze/thaw cycles and operation
  - Help guide mitigation strategies.

Prior Work

- Prior relevant work includes (LANL):
  - Modeling of mass transport losses
  - Freeze/thaw
  - GDL characterization (durability)

- More team relevant prior work
  - Modeling
  - Electro-osmotic drag measurements
  - MEA / GDL manufacturing (etc.)
  - Characterization
  - Neutron imaging

MEA Overpotential Losses
(Modeling to delineate degradation losses)



- Increase in cathode GDL mass-transport Overpotential
  - Hydrophobicity loss
- Increase in ORR overpotential
  - S.A. decrease
- Decrease in cathode electrode mass transport overpotential
- Decrease in HFR

Changes in mass-transport (→ water management)

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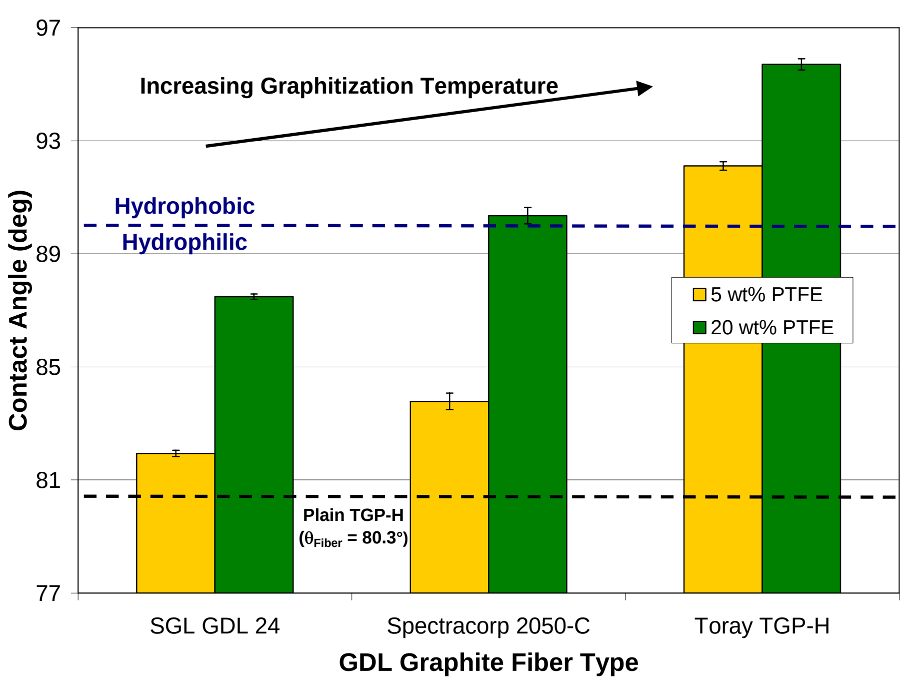
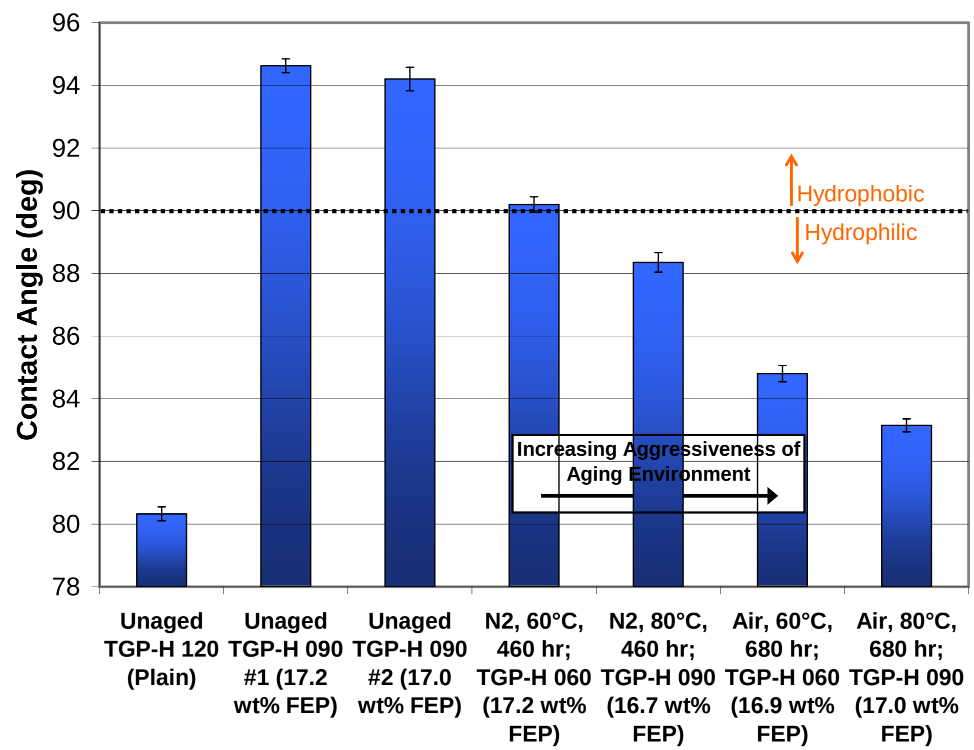
GDL Fiber Chemistry and Contact Angle

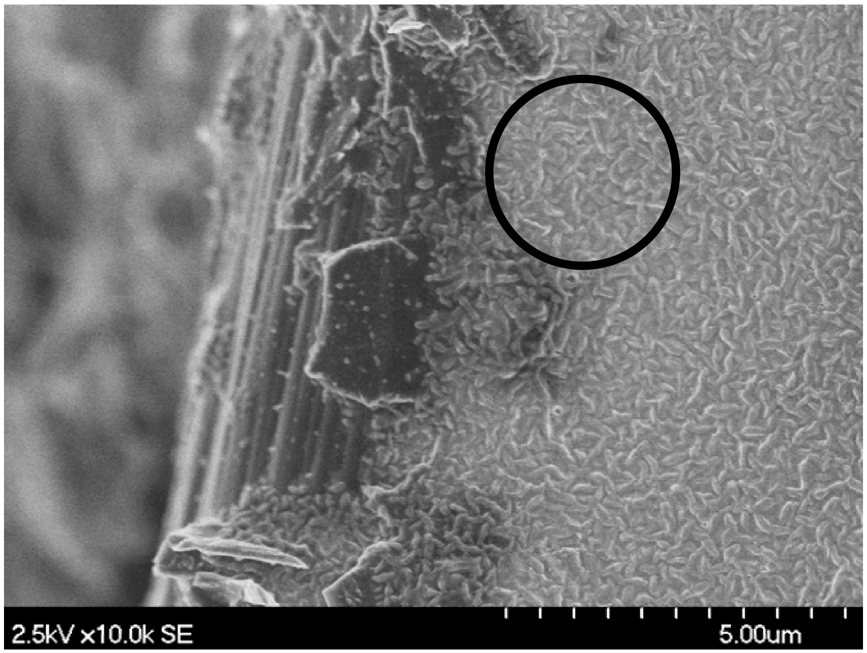




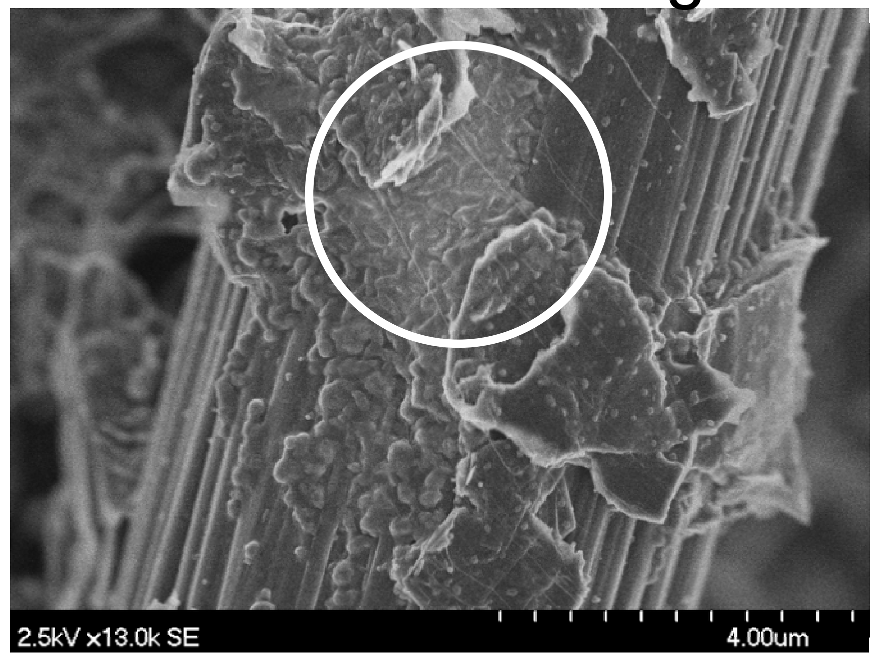
- Fiber graphitization can increase single-fiber contact angle ~ 10°
- Both graphitization T and PTFE loading can change the liquid-water wetting regime of the GDL substrate.

Before/After SEM Comparison of PTFE Microstructure of GDL

Fresh



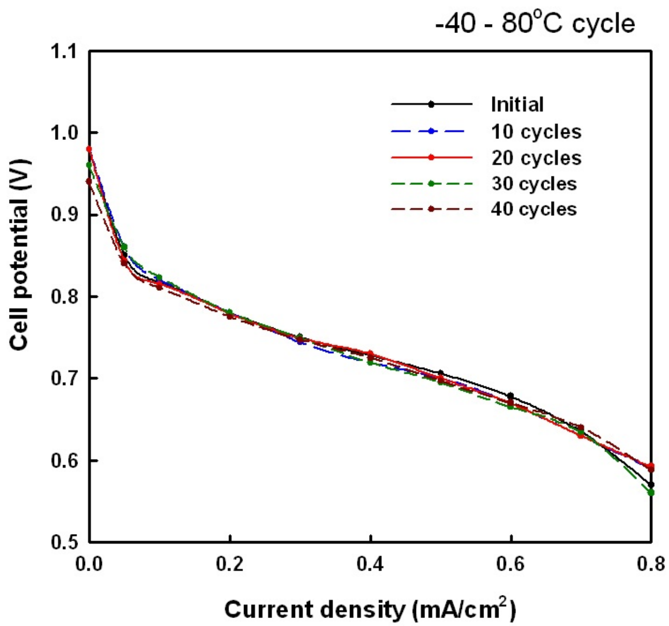
After Testing

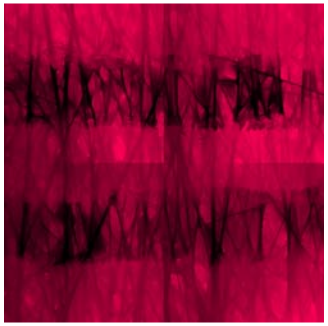


- Loss of definition delineating the individual PTFE particles
  - (typically shaped like and ellipsoid and 200-500 nm diameter).
- Features could be associated with changes in liquid water transport characteristics or carbon fiber surface changes.
- Features are also affected by sintering time and temperature.

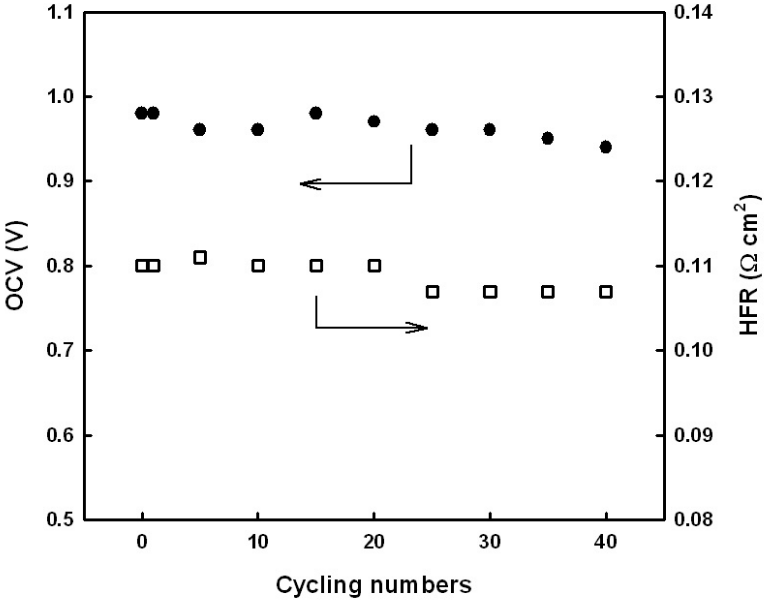
Freeze/Thaw cycling

GDL: carbon paper (SGL), Active area: 5 cm^2





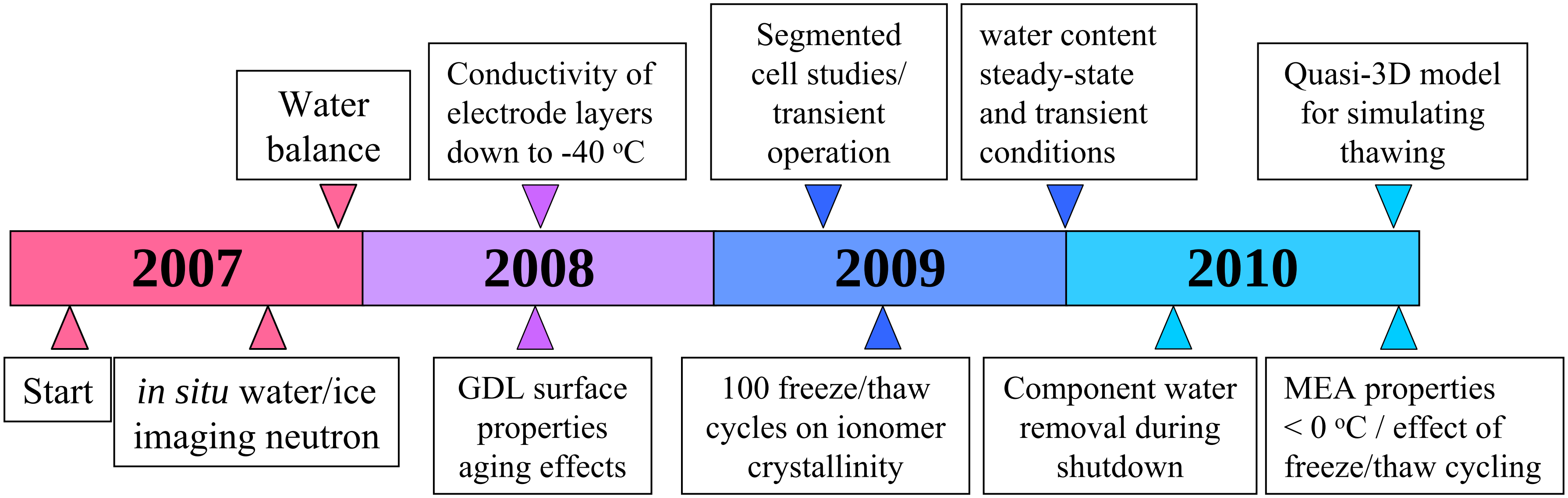
nfocal laser imaging
Mike Hickner
ndia National Lab



- No systematic degradation observed up to 45cycles
- Mechanical Failure @ 45 cycles
- Fiber breakage at land/channel edge is a potential failure mechanism
  - More tests required to investigate failure mechanisms

Water Transport Exploratory Studies

Project initiated in FY2007 for 4 years



	Go/No-Go
Qtr. 4	Demonstrate 1-D model validity in case studies. (Go/No Go Decision to Proceed to 3D based on Reasonable 1D Prediction)
Qtr. 6	Electro-osmotic drag coefficient measurements. Activity gradient cells vs. electrophoretic NMR measurements.
Qtr. 10	Demonstrate start up fuel cells from -20 °C. Only materials and conditions that meet this decision criterion (start up from –20 °C) will be explored in further studies.
Qtr. 10	z-direction imaging capability by neutrons. If not capable of performing tomography at this point, we will conclude the neutron imaging work.

Organizations / Partners

- Los Alamos National Lab
  - (Lead: experimental measurements, modeling)
- Sandia National Laboratory (modeling)
- Case Western Reserve University (characterization, modeling)
- W. L. Gore and Associates, Inc. (MEAs)
- SGL Carbon Group (GDLs, MPLs)
- Oak Ridge National Lab (characterization)
- National Institute of Standards and Technology (neutron imaging)

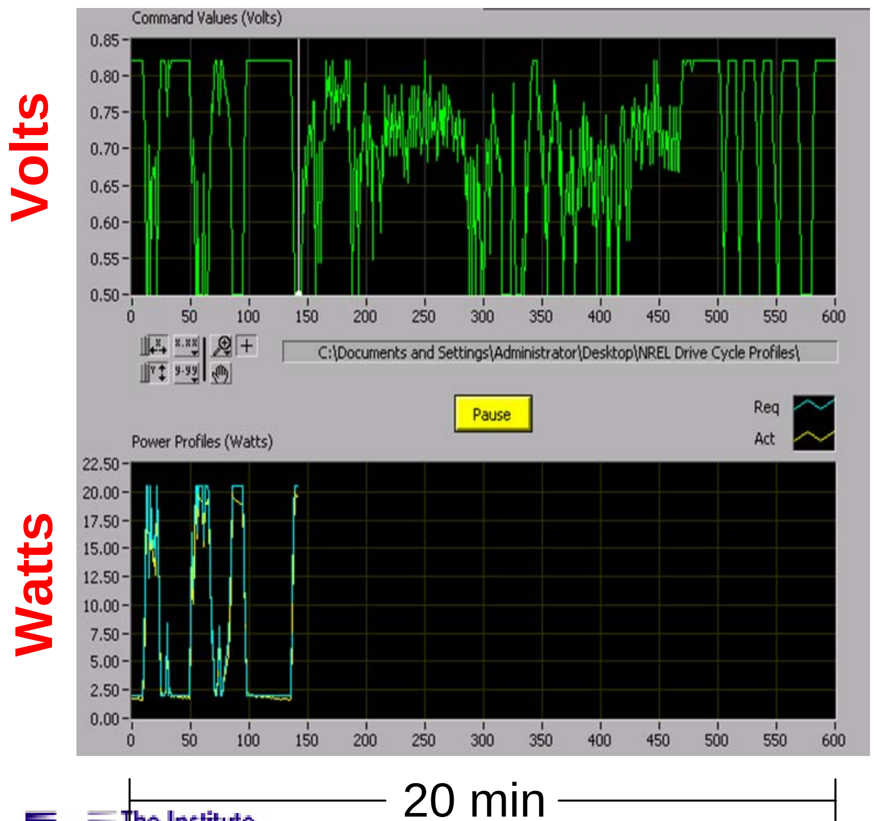
Budget

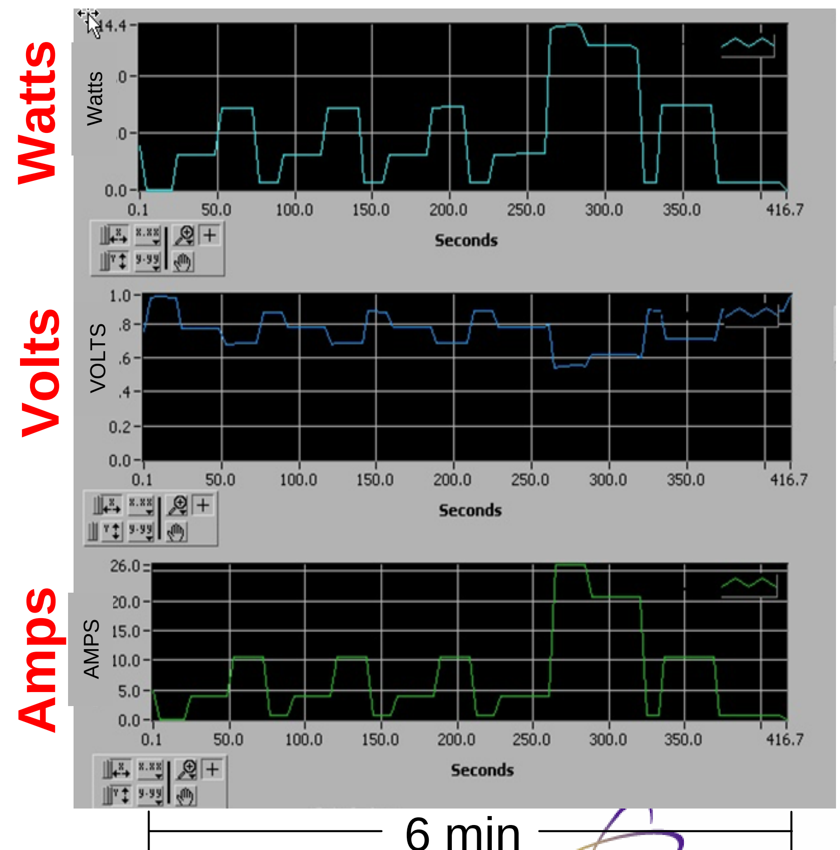
DOE Cost Share	Recipient Cost Share	TOTAL
$6,550,000	$290,811	$6,840,811
96%	4%	100%

	FY07
LANL	$1000k
Industrial Partners (Gore/SGL/CWRU)	$300k
Other National Labs (SNL/ORNL) (?)	$350k
FY07 Total	1650

Input / Needs

- Automotive OEM (FC Tech Team) definition of inlet RH as a function of power/time during operating drive cycles





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