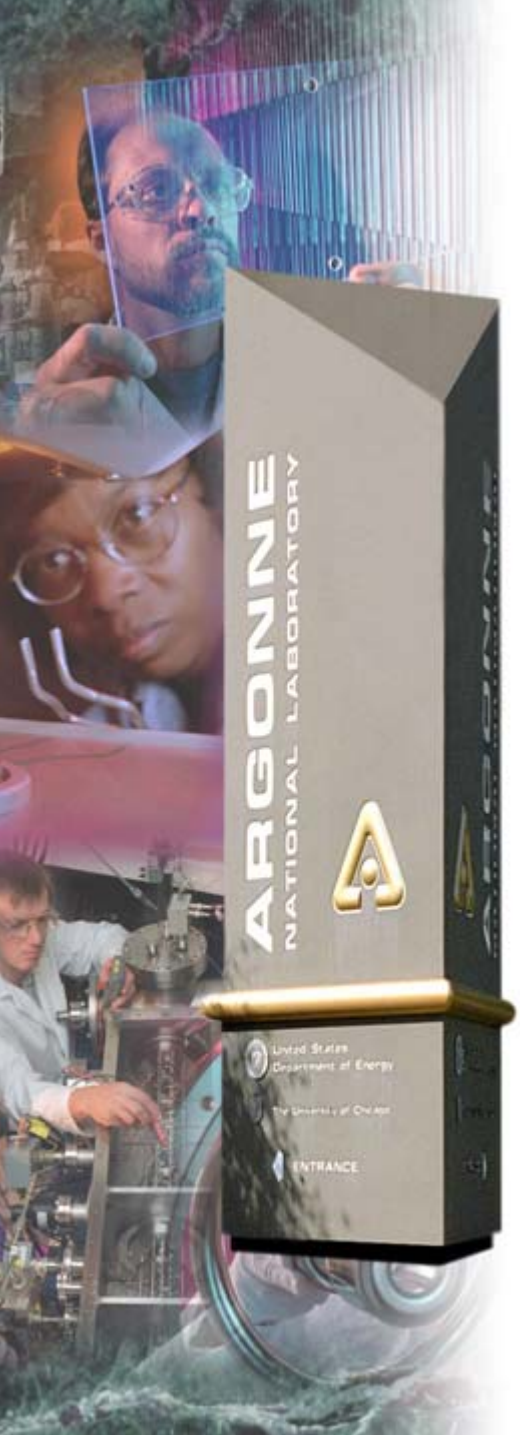

Hydrogen, Fuel Cells and Infrastructure Technologies Program

Fuel Cell Testing at ANL: Procedures, Activities, and Hydrogen Safety

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FreedomCAR & Fuel Partnership

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Overview and Objectives

- **Timeline**
  - Facility Planning: 1996
  - Facility Commissioned: 1999
  - End: Open - this is an ongoing activity to test/validate/document fuel cell performance as the technology continues to evolve and improve

- **Budget**
  - FY04: $300K
  - FY05: $300K

- **Objectives**
  - To provide DOE with an independent assessment of DOE contract deliverables
  - To benchmark performance of the state-of-the-art fuel cell technology

Technical Targets for Hydrogen Fueled PEM Fuel Cell Stacks

Characteristics	Units	2005	2010	2015
Stack Efficiency @ 25% of rated power	%	65	65	65
Stack Efficiency @ rated power	%	55	55	55
Stack Power Density	W/L	1500	2000	2000
Stack Specific Power	W/kg	1500	2000	2000
Cost	$/kW$_e$	65	30	20
Transient response (time from 10% to 90% of rated power)	Sec	2	1	1
Cold start-up time to maximum power				
@ -20°C ambient temperature	Sec	60	30	30
@ 20°C ambient temperature	Sec	30	15	15
Precious Metal Loading	g/kW	2.7	0.3	0.2
Durability with thermal cycling	Hours	2000	5000	5000
Survivability	°C	-30	-40	-40

Standards and Procedures

- **Testing Standards**
  - ASME PTC50-2000: Fuel Cell Power Systems Performance
    - *Provides guidance for the evaluation of fuel cell power systems to determine power output and efficiency*
  - SAE J2578 and J2616 standards
    - *Recommended Practices for General Fuel Cell Vehicle Safety and Performance Test Procedures for the Fuel Processor Subsystem of Automotive Fuel Cell System*
- **Energy Efficiency @ 25% of rated power and rated power**
  - Operate stack at power level for at least one hour and measure fuel consumption
  - This test excludes parasitic power consumption
- **Power Density / Specific Power / Cost**
  - Verify rated power, measure weight and volume

Standards and Procedures (2)

- **Transient Response**
  - Operate stack at 10% of rated power until operating conditions are stable
  - Perform a 10% to 90% rated power jump; the time between the reactant change and load change is the response time (time to meet the demand)
  - Operate stack at 90% of rated power until operating conditions are stable
  - Perform a 90% to 10% rated power jump; the time between the reactant change and load change is the response time
- **Bare stacks can readily meet the transient performance targets. System performance is yet to be verified**

Standards and Procedures (3)

- **Cold start-up time to maximum power (planned)**
  - Cold Start #1: (less realistic, but cheaper to implement)
    - ***Cool stack/system down to target temperature and soak for at least 8 hours***
    - ***Remove cooling system and start stack (Allow it to heat itself and surroundings)***
  - Cold start #2: (more realistic, but expensive to implement)
    - ***Cool stack/system down to target temperature and soak for at least 8 hours***
    - ***Start system while still maintaining the cold ambient temperature***
  - Measure start-up energy

Standards and Procedures (4)

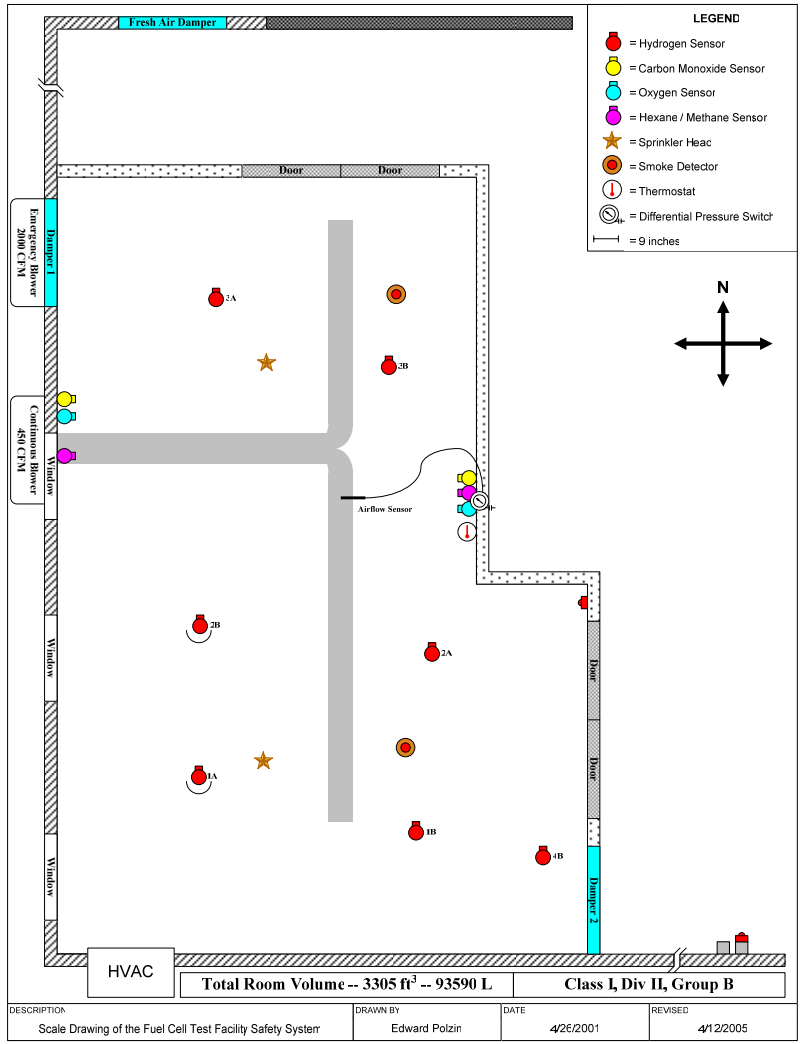
- **Durability (planned)**
  - Benchmark stack performance as delivered
  - Run a meaningful transportation duty cycle repeatedly for a suitable period of time
  - Re-evaluate stack performance after the cycling period and the repeat the duty cycles

- **Survivability (planned)**
  - Benchmark stack performance as delivered
  - Cool stack/system down to target temperature and soak for at least 8 hours
  - Increase temperature to normal operating point and re-evaluate stack performance

Facility Safety Systems in Fuel Cell Test Facility (FCTF)

- **Two Levels of Alarm: Warning and Danger**
  - Warning – Testing is suspended and fuel supply is shut off
  - Danger – Same as warning with the addition of fire department notification, emergency ventilation system activated, facility power removed from non-critical instruments
- **Continuous room ventilation takes care of most small hydrogen leaks**
- **Stacks are checked for leaks with static pressure tests before introducing reactants**

Warning	Danger
Hydrogen detected greater than 0.8% in air (20% of LFL)	Hydrogen detected greater than 1.6% in air (40% of LFL)
Emergency stop button pressed	Loss of continuous room ventilation
Loss of principle power	Smoke / Fire / Explosion (no emergency room ventilation activated)

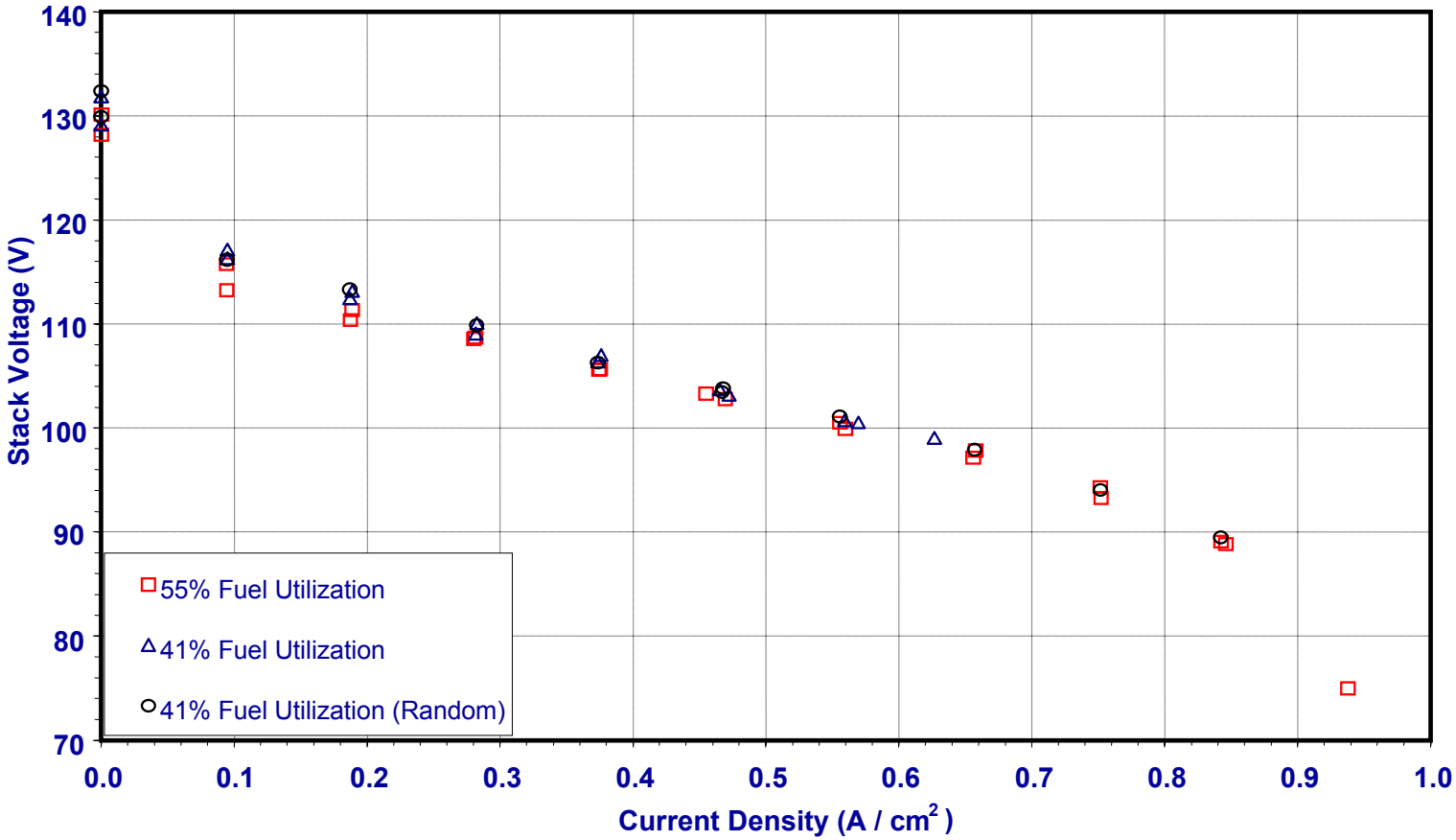


Evaluation Experience

- Bare stacks: 720 W_e to 72 kW_e
- Complete Systems: 10 kW_e to 50 kW_e
- Partial Systems: 200 kW_{th} reformer

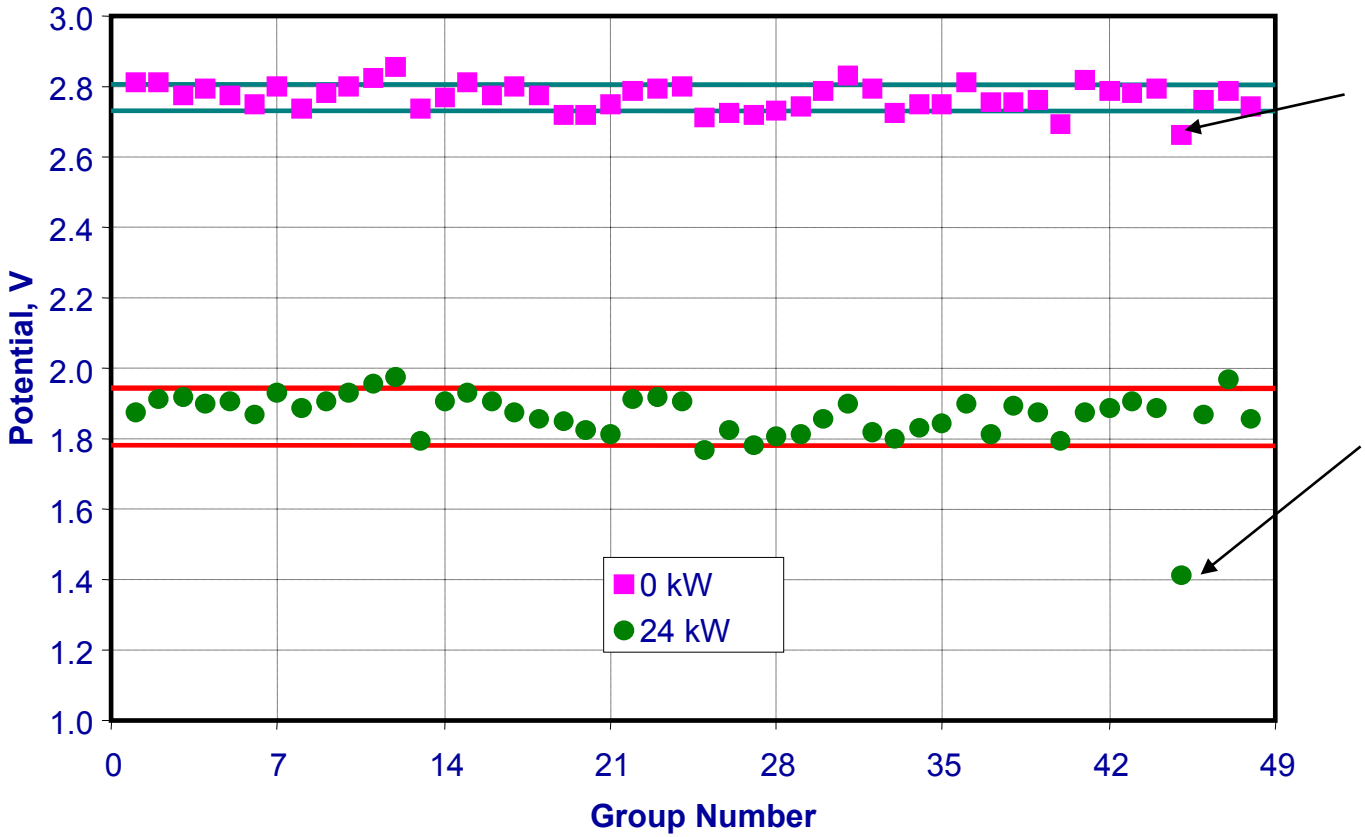
Evaluation Experience (2)

Polarization Results from a Stack Test using H_2



Evaluation Experience (3)

String Voltage Variation During Polarization Curve Experiment



- At OCV, voltage of group 45 is lowest
- As stack is loaded, outliers can be seen; for example, group 45
- Potential is more than 5 std. deviation units from average

Summary

- The FCTF provides data to sponsors for an unbiased gauge of technology development
- As test methods become standardized, the FCTF includes them in its testing protocols and methods
- FCTF is responsive to the needs of the sponsors, fuel cell developers, and end users within budgetary constraints
- FCTF is planning to obtain environmental chambers capable of testing full size systems from -40 to +50 °C
- FCTF is planning to upgrade it's current capabilities to provide fully-automated, 10 – 100 kW testing capabilities

- Acknowledgment

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