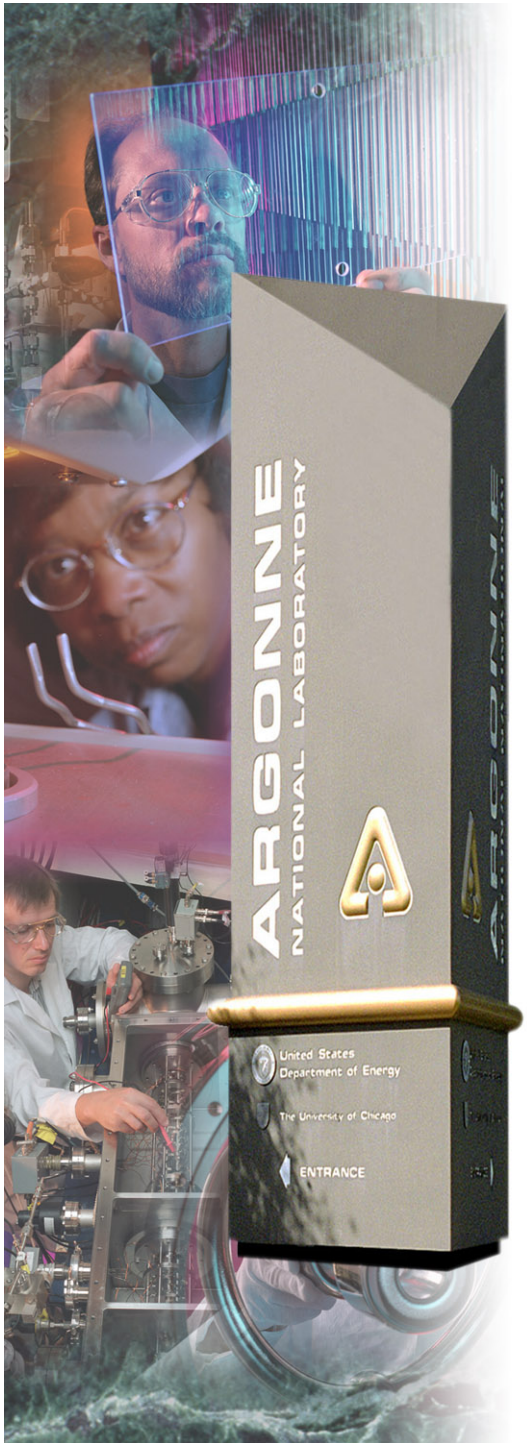


***Hydrogen, Fuel Cells and Infrastructure Technologies Program***

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

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*2005 DOE Hydrogen Program Review*
*May 23-26, 2005*

***Argonne National Laboratory***

Project ID# FCP29

*A U.S. Department of Energy*
*Operated by The University of Chicago*

**This poster does not contain any proprietary or confidential information.**

# 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

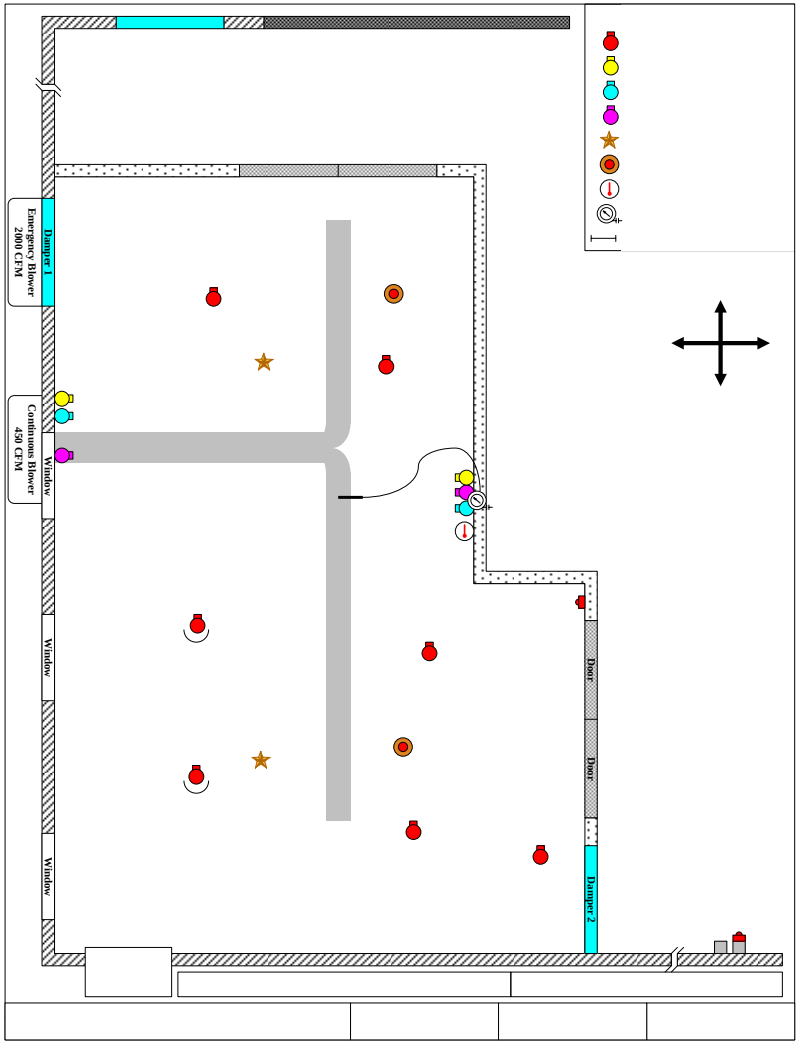
# Standards and Procedures (4)

- **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)

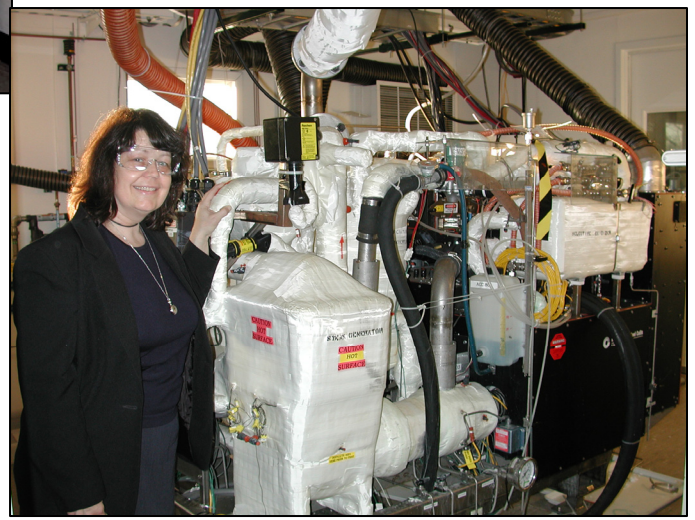
- **Two Levels of Alarm: Warning and Danger**
  - Warning – Testing is suspended and fuel supply is shut off
  - Danger – Same as warning with the addition of fire department notification, emergency ventilation system activated, facility power removed from non-critical instruments
- **Continuous room 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) |

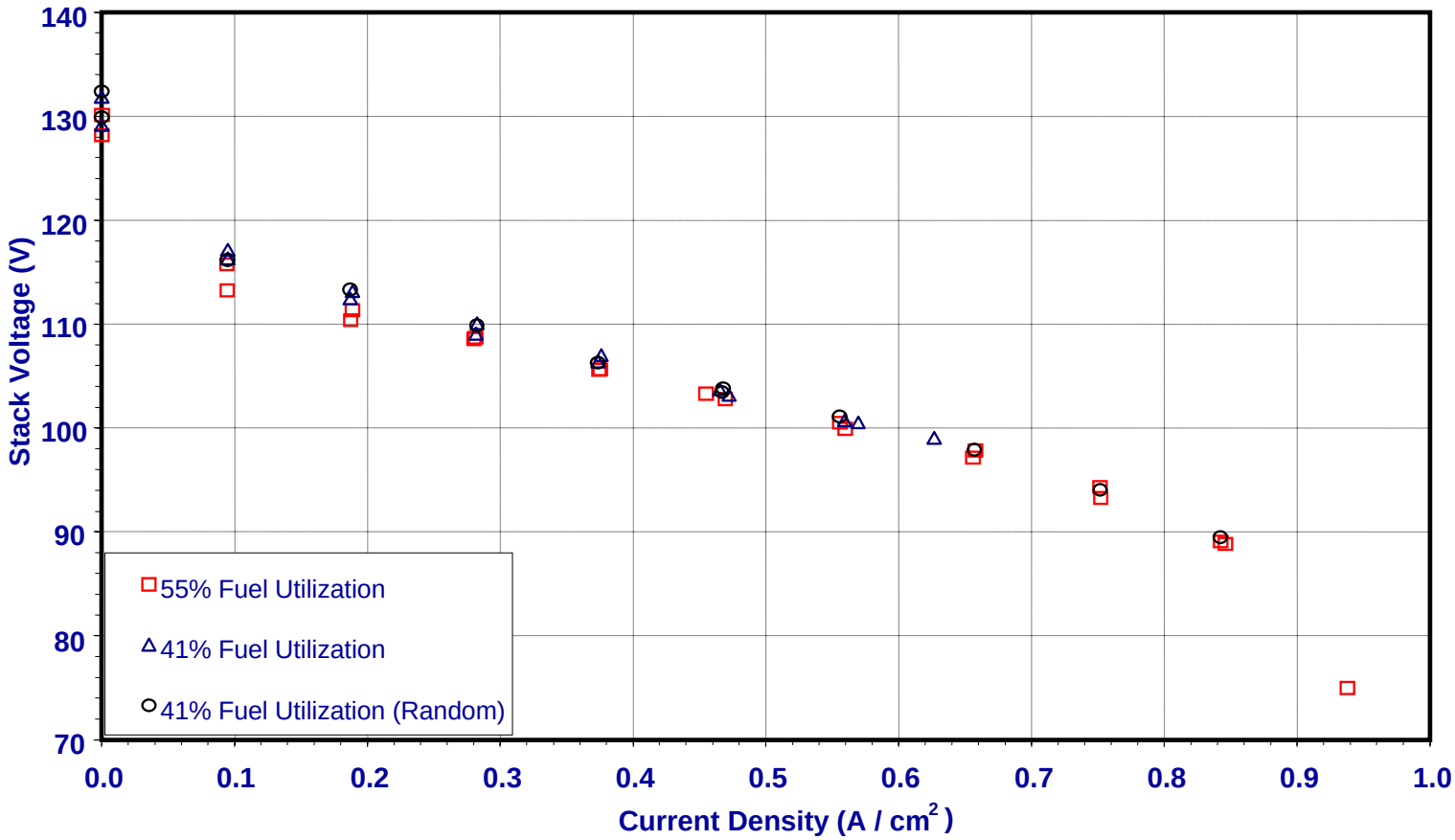
# Evaluation Experience

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



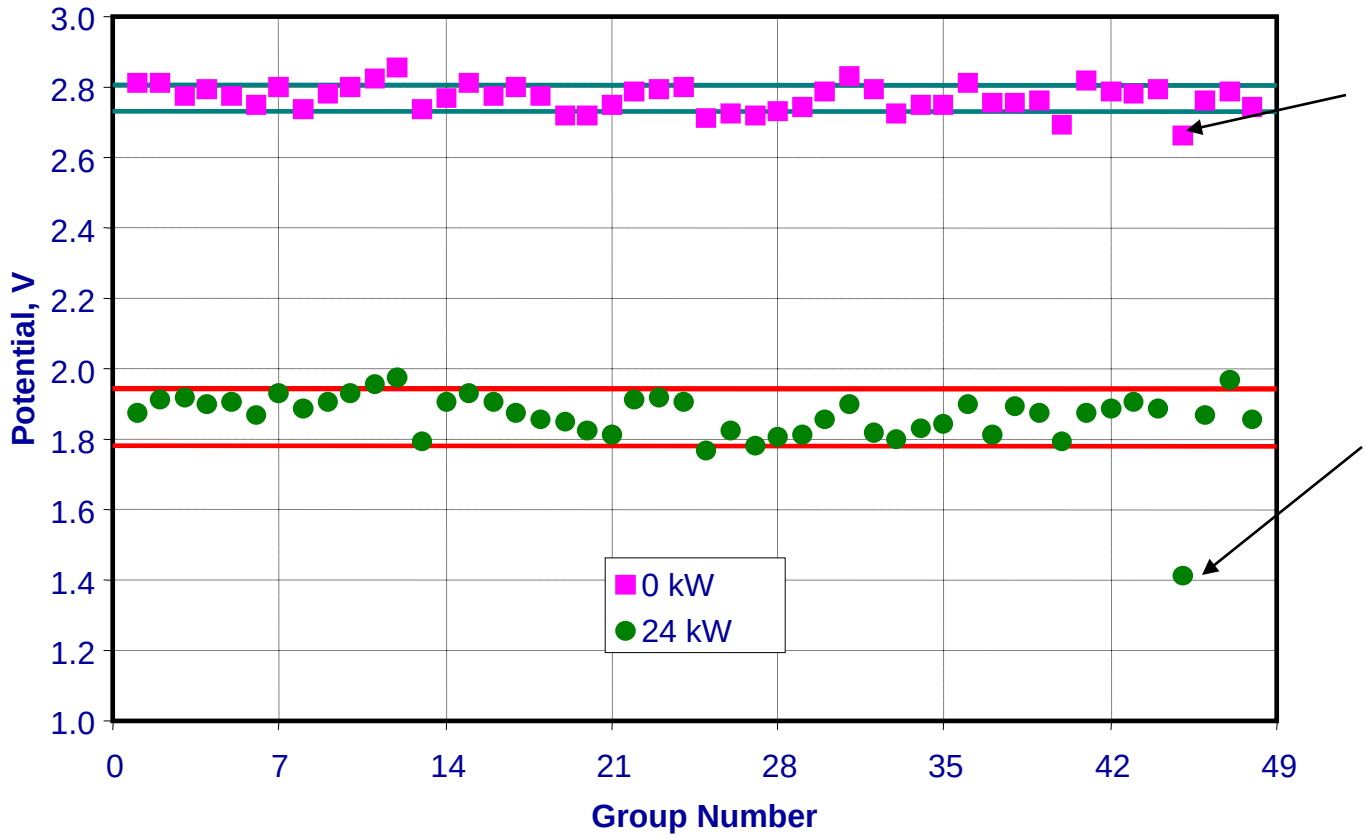
# Evaluation Experience (2)

## 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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