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Fuel Cell Testing at the Argonne Fuel Cell Test Facility

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FreedomCAR & Fuel Partnership

Overview

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 mature

Budget

- Total project funding: $300K/yr from DOE
- FY07: $300K
- FY08: $300K

Objectives

- To provide DOE with an independent assessment of DOE contract deliverables
- To benchmark commercial fuel cell technology developments

Collaborations

- FCTES^{QA} – International consortium (EU, Japan, US, etc) to develop standardized fuel cell test procedures
- FCTestNet Task Force
- IEC/TC105 – Secretary for Work Group 11/Single Cell Test Protocol
- USFCC
- ITRI (Taiwan), IE (Netherlands)

Approach

- Develop a flexible, adaptive Fuel Cell Test Facility to characterize the performance of automotive and other fuel cell systems and components
- Develop standardized test procedures for the evaluation of different stack technologies
- Characterize stack in terms of:
    - *Initial Performance (polarization, steady-state, drive-cycle)*
    - *Durability: Accelerated aging test to yield a reasonable projection of life in a reasonable amount of test time*
    - *Low-Temperature Performance*
- Modify Fuel Cell Test Facility, as needed, to accommodate unique needs of different technologies (hardware, software, control systems)

- Addresses Barriers
    - A. Durability
    - J. Start-up Time (future)

Technical Accomplishments: Progress and Results

- Characterized several fuel cell stacks and systems, ranging in size from 720 W to 85 kW

- FY08 Progress:
  - Performance characterization of a 1-kW stack
  - Performance and life characterization of a 5-kW stack
  - Characterized
    (a) 5-kW complete system and
    (b) 12-kW complete system

Example Results from a Fuel Cell Stack Test Specifications of the 1-kW Stack

- Construction: 36 PEM cells, air cooled
- Flow pattern: counter-flow
- Nominal voltage: 36 V OCV; ~22.4 V at rated power
- Cell active area: 100 cm^2
- Pt loading: (anode / cathode) 0.45 / 0.6 mg/cm^2
- Nominal operating temperature: 65^oC
- Stack weight: 9 kg; volume: 6.9 L

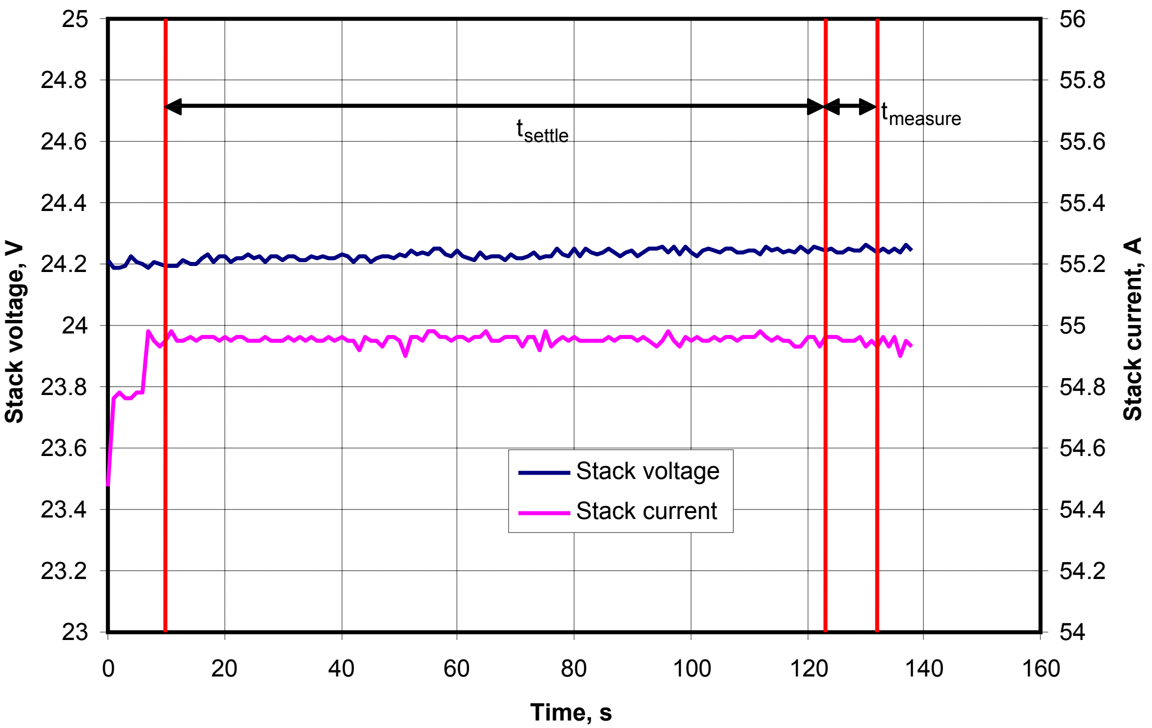
- Limits
  - Lowest cell voltage: 0.5 V
  - Minimum stack voltage: 18 V
  - Maximum constant current: 60 A

Test Plan -- Overview

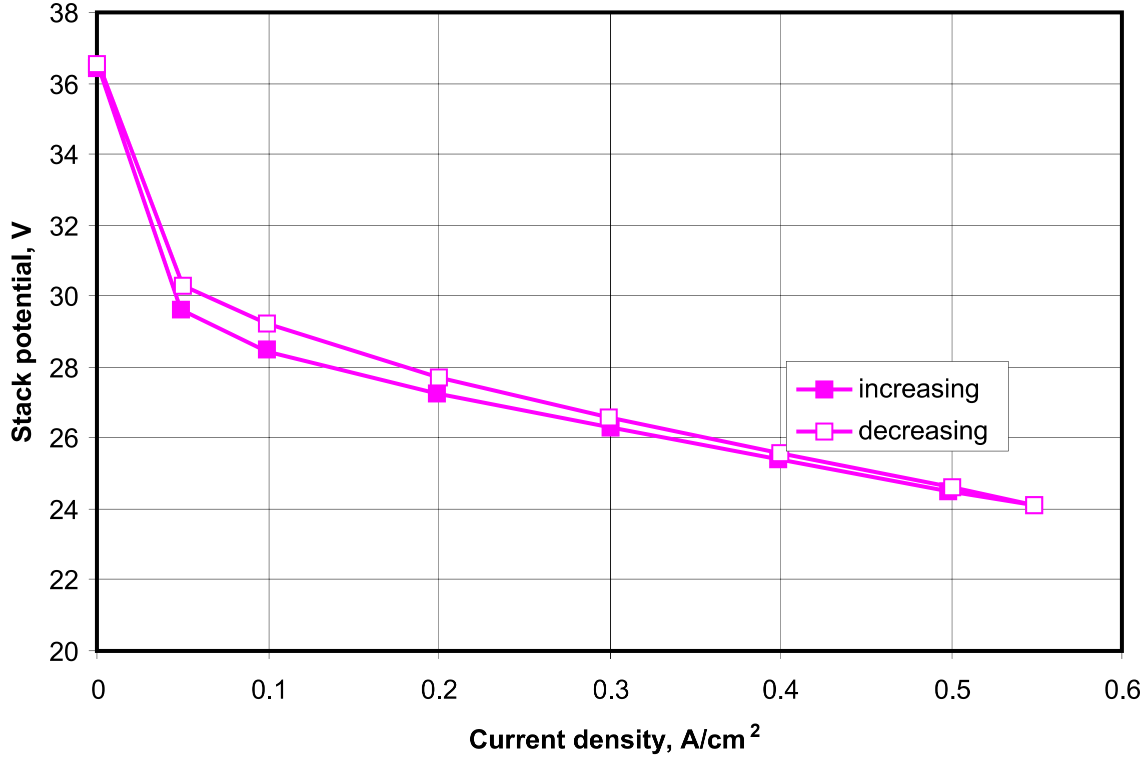
- Characterize the performance of the stack
  - Gases:
    - *Fuel: UHP hydrogen (99.999%)*
    - *Air: Zero air (synthetic mixture of 20.9% O_2, balance N_2)*
  - Baseline performance
    - *65°C, F/A stoichiometry=1.5:5, gas dewpoints (F/A)=55/65°C*
  - Effect of operating temperature at 100% RH
    - *Baseline conditions: same as above except dewpoint temperature of both gases was 65°C*
    - *Stack temperature = 55, 65, 75°C*
  - Effect of dew point temperature
    - *50 (RH=49%), 59 (76%), 65°C (100%)*
  - Effect of air and fuel stoichiometries
    - *Air: 2, 3, 4, 5 / fuel =1 .5*
    - *Fuel: 1.3, 1.5, 1.7 / air = 5*

How Measurements Were Made

- Data were acquired at 1 point/second. The following experimental parameters were measured and logged
  - Stack voltage
  - Stack current
  - Stack temperatures
  - Fuel/air inlet flows
  - Fuel/air inlet temperatures
- After settling/equilibration time, the points during the measurement interval were averaged to yield a data point for this condition

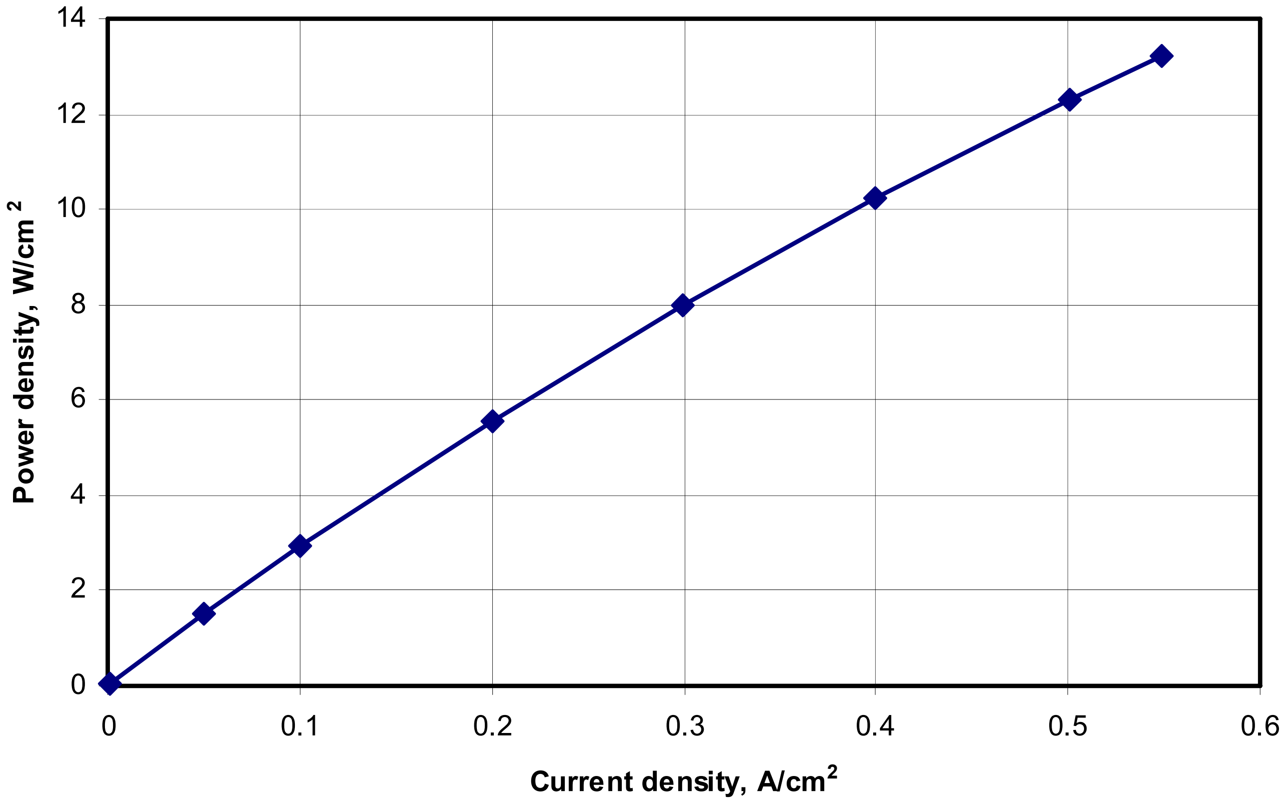


Results from Baseline Polarization Curve Experiment



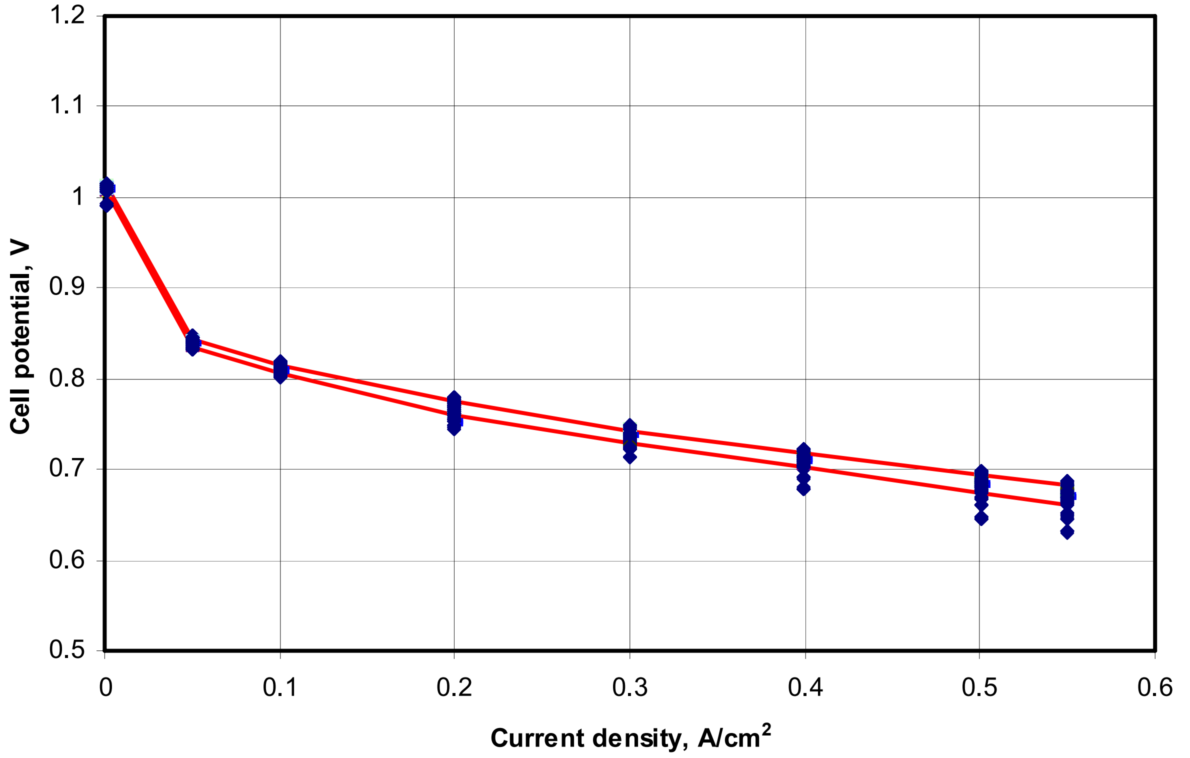
Power Curve

- Measured power, ~1.3 kW, is greater than rated



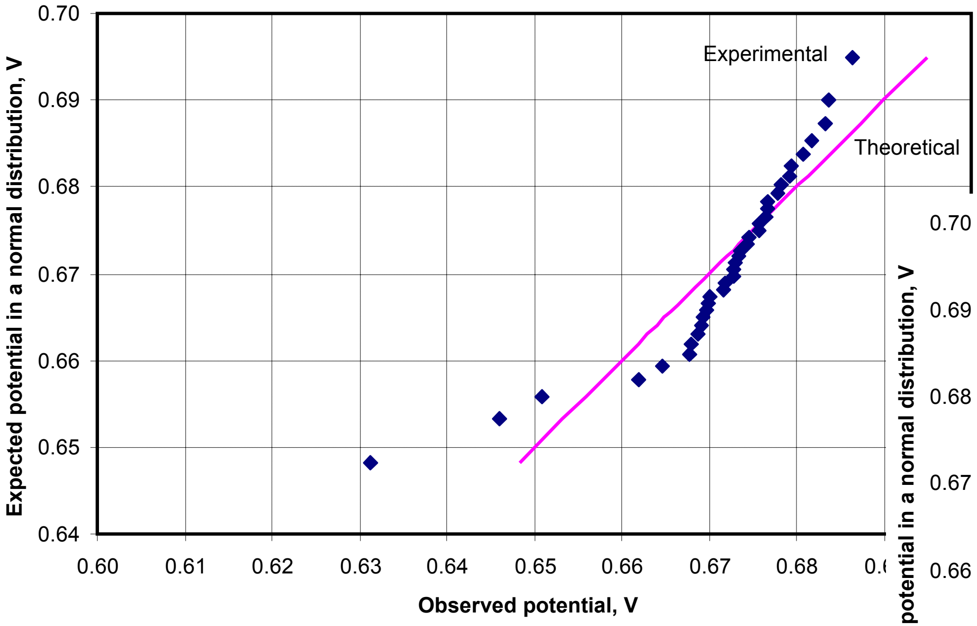
Cell Voltage Distribution

- Cell voltage vs current density plot shows that most of the data lie between bounds of average +/- 1 std. deviation. However, some points lie outside these bounds, indicating that the data are not normally distributed



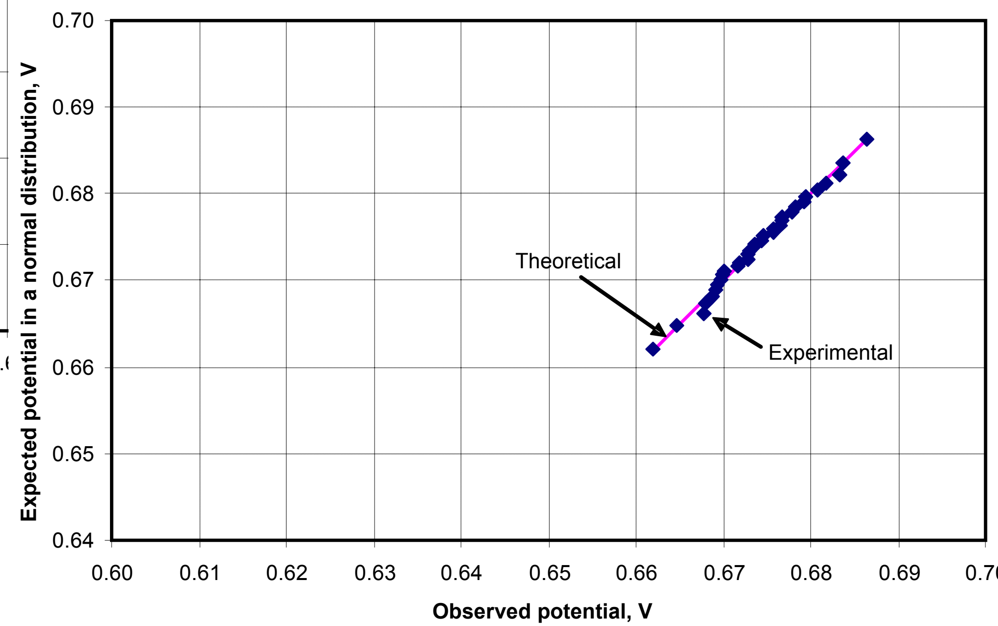
Cell Uniformity Analysis

- Data were from polarization curve at 0.55 A/cm^2
- Plotting actual cell voltage distribution vs. theoretical distribution clearly shows outliers (which were primarily at the lower cell voltages, higher cell resistances); outliers were most likely due to temperature distribution in the stack



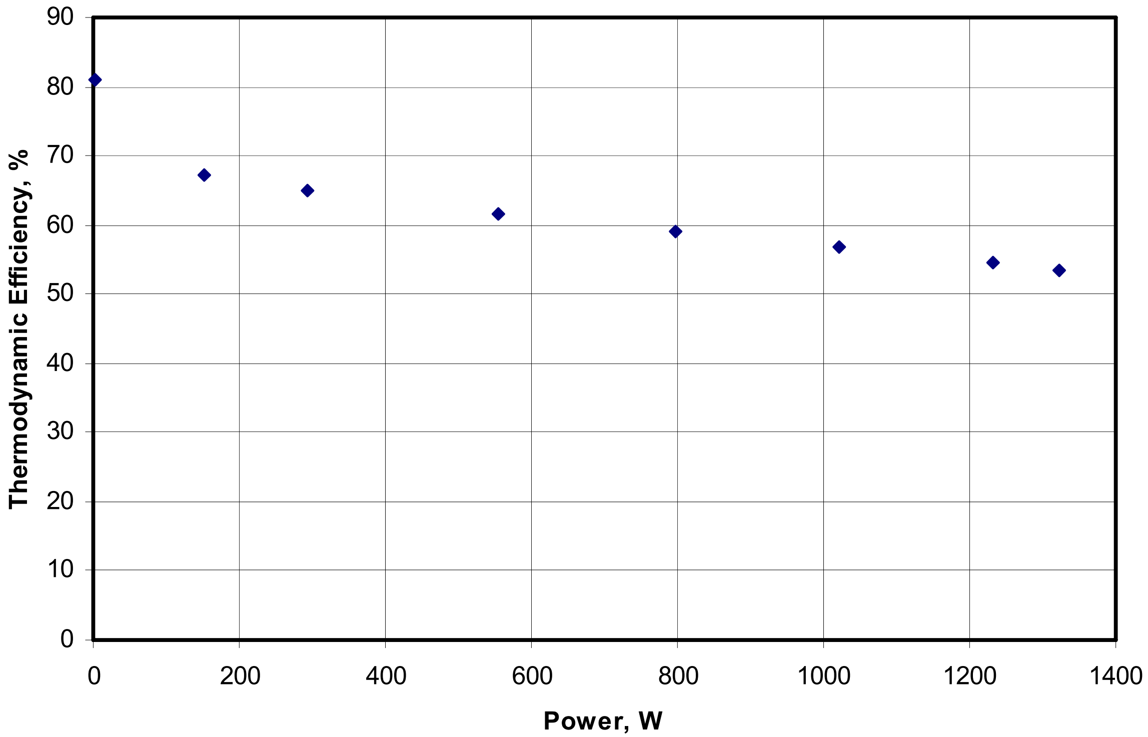
Initial data

Outliers removed



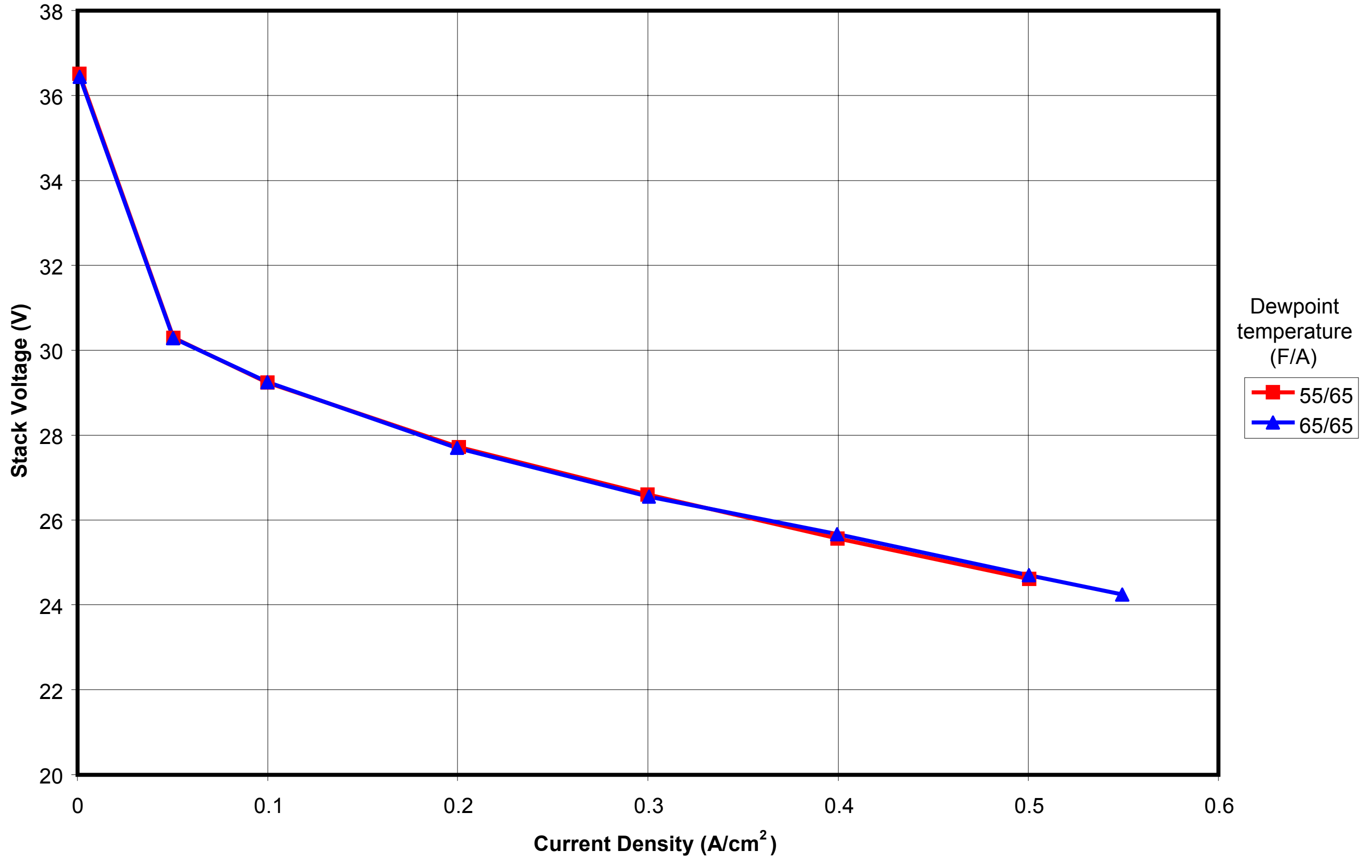
Thermodynamic Energy Efficiency

- Thermodynamic energy efficiency was calculated from the data
  - At 25% of rated power, efficiency = 65% and at rated power, 57%



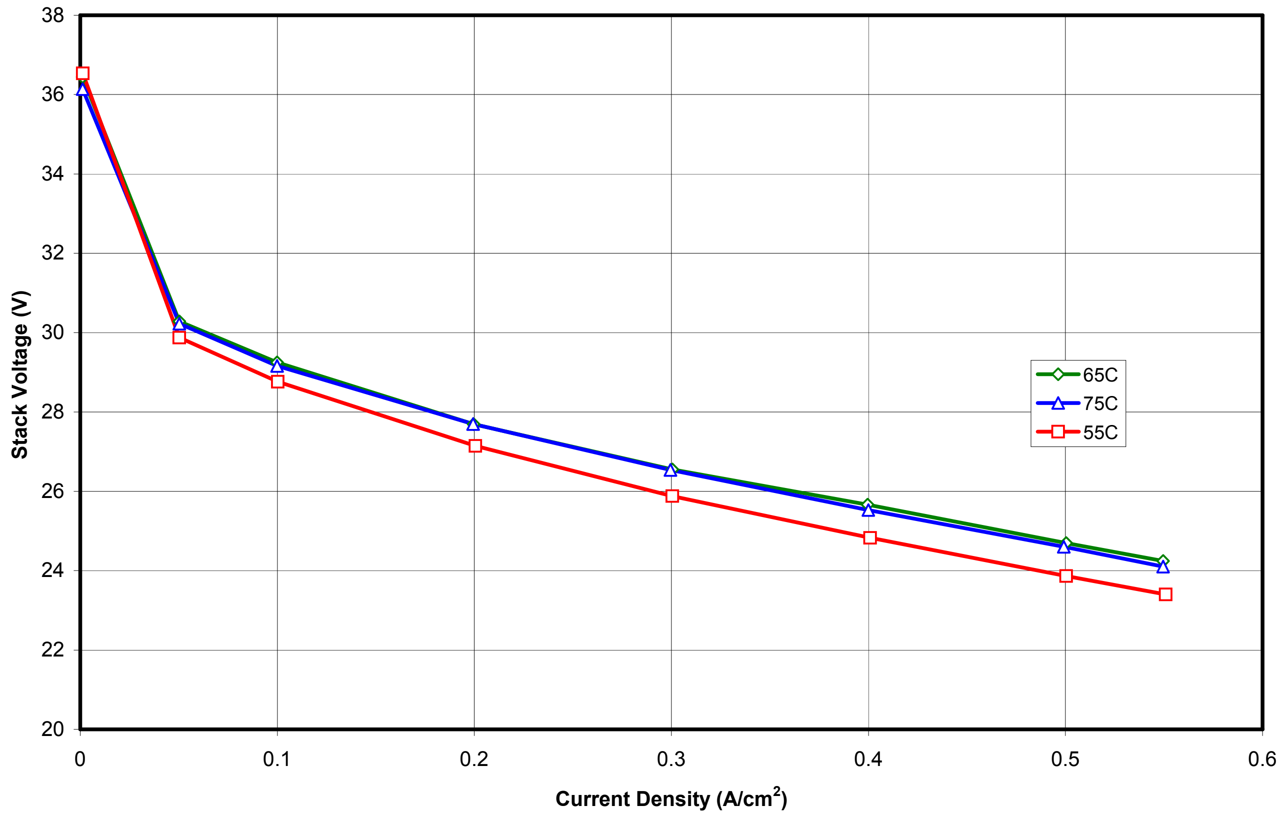
Effect of Fuel Humidification Levels

- Stack temperature=65°C
- Dewpoint on air side was 65°C; that on the fuel side was varied: 55°C (RH=63%) and 65°C (100%)
- Very little difference was seen



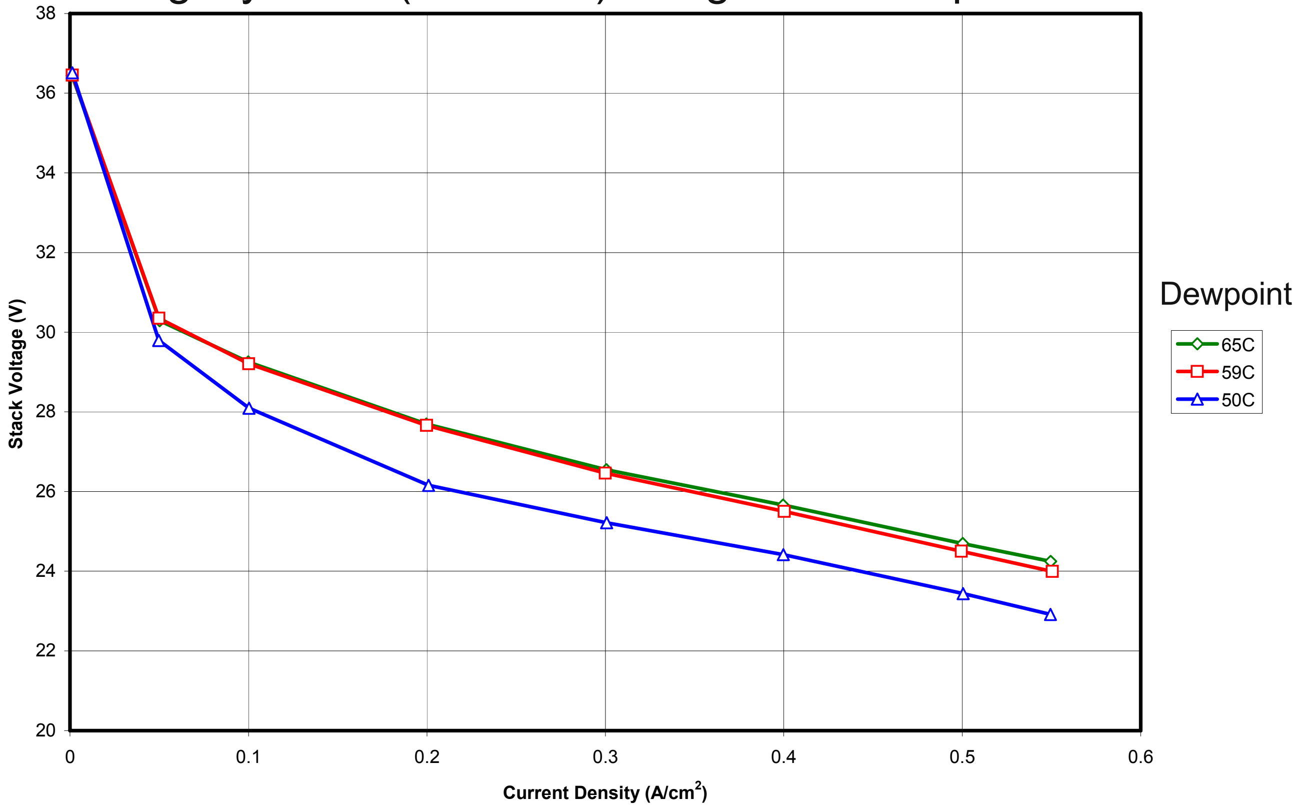
Effect of Stack Operating Temperature (100%RH)

- At 55°C at 0.55 A/cm², stack performance degrades markedly (850 mV). Stack performance at 75°C degrades slightly (150 mV) as compared to the performance at 65°C



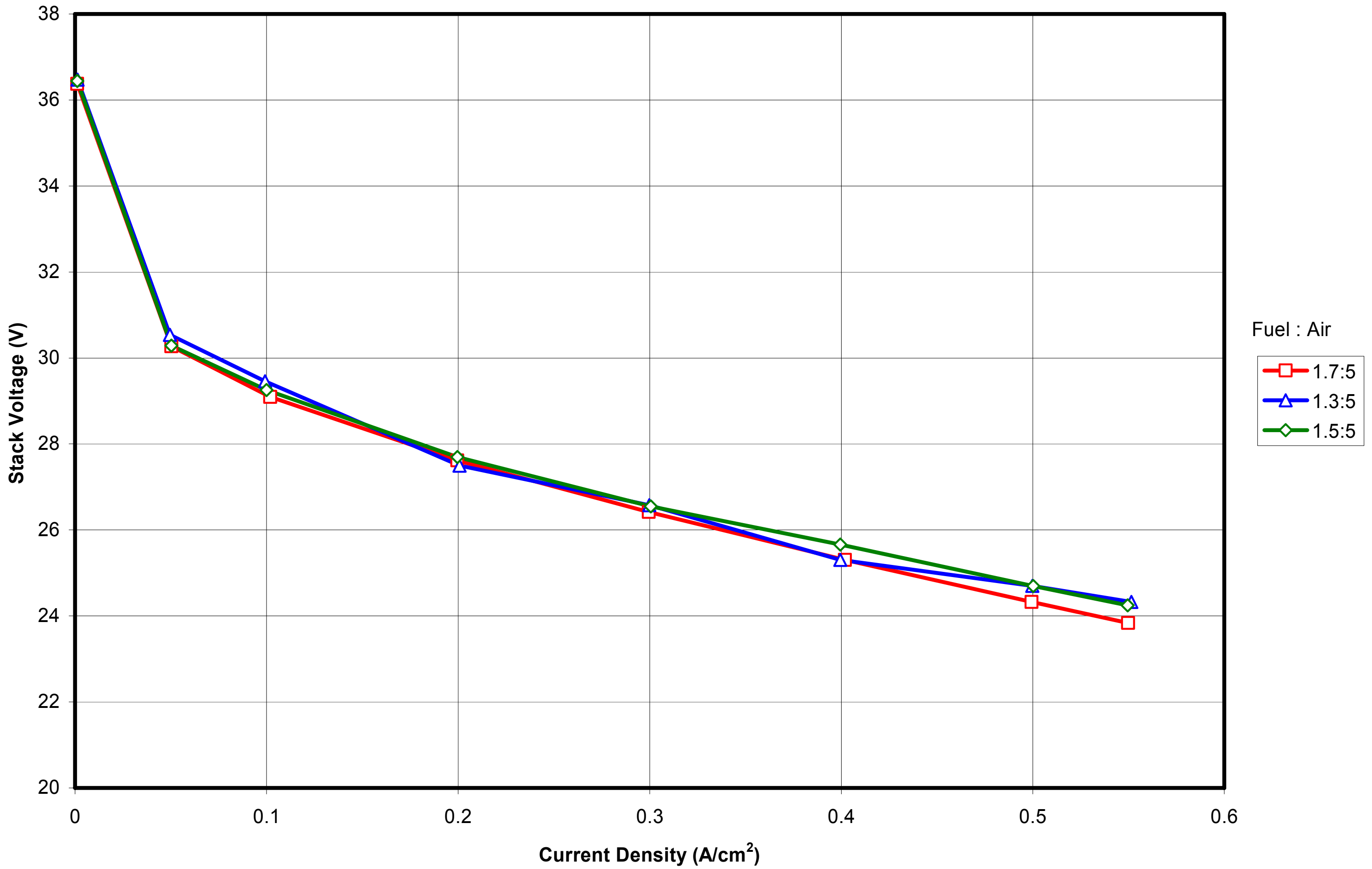
Stack Performance Sensitivity to Dew Point Temperature

- Stack temperature = 65^{o}C
- Dew points for both gases were the same
- Stack performance decreases with dew point temperature. Using 59^{o}C dew point, stack voltage is 1.332 V less than using 65^{o}C dew point. Stack performance is slightly lower (~250 mV) using 59^{o}C dew point.



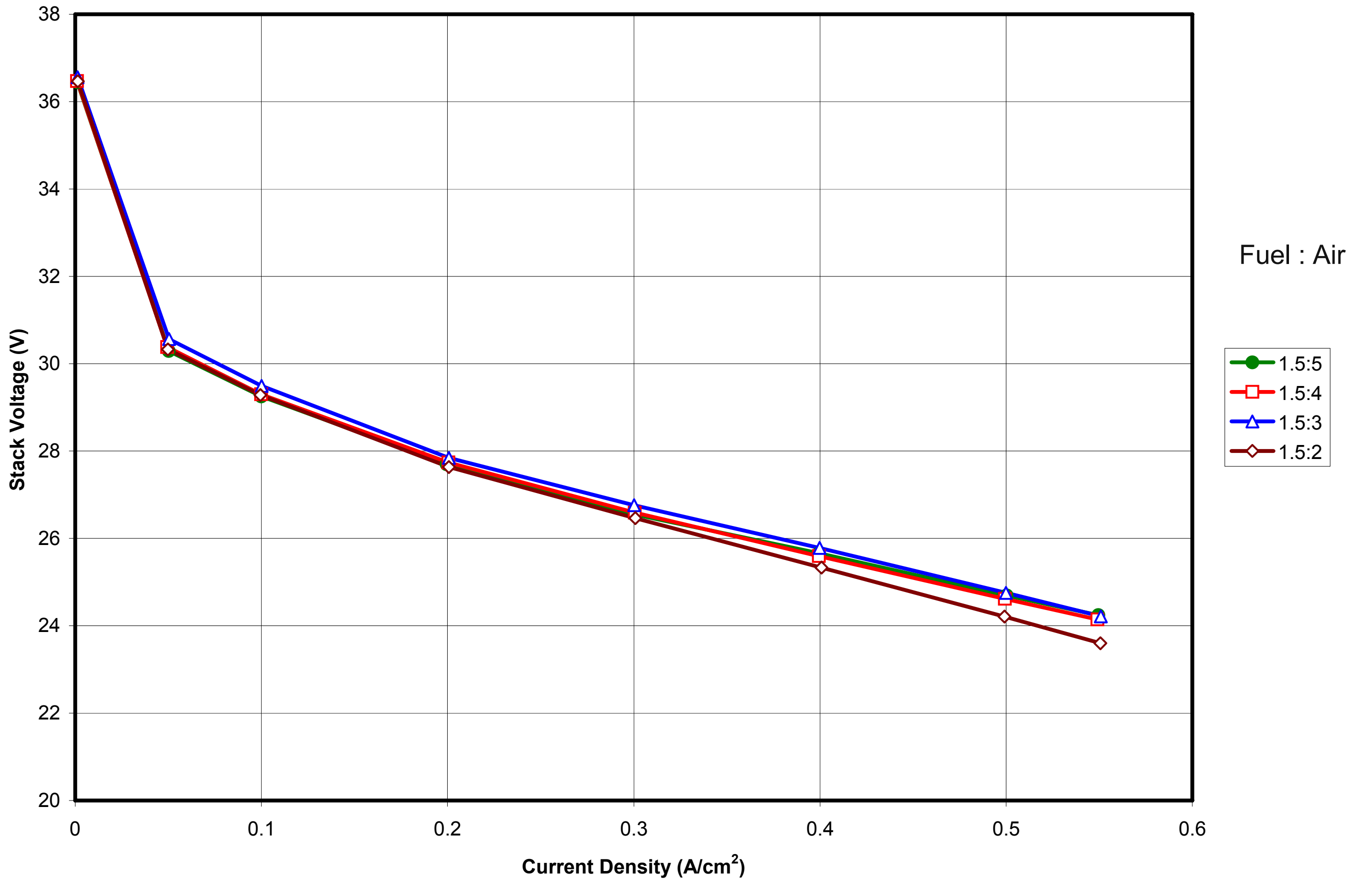
Stack Performance Sensitivity to Fuel Stoichiometry

- Very little sensitivity to fuel stoichiometry seen



Stack Performance Sensitivity to Air Stoichiometry

- There was a decrease of 650 mV at an air stoichiometry of 2. A possible cause for the decreased performance was flooding; there was not enough air flow to force the reaction water out of the stack.



Summary

- FCTF has the ability to gauge development of fuel cell technology and is continuously upgrading capabilities (e.g., larger cooling capacity, fast gas transients, and low temperature operation).
- Testing in FCTF is modeled after US standards. International standards would facilitate data exchange and, hence, technology validations. The FCTF is active in the proposal, evaluation and adoption of standardized test methods.
- FCTF acquires and benchmarks commercial fuel cell stacks to provide DOE with information regarding the evolution of the technology.
- FCTF is responsive to the needs of the sponsors, fuel cell developers, and end users.

Acknowledgment

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