Fuel Cell Testing at the Argonne Fuel Cell Test Facility

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DOE Hydrogen Program

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: $350K/yr from DOE
- FY08: $300K; equipment funds were also provided for facility upgrades
- FY09: $350K

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
- Institute for Energy (The Netherlands)

Approach

- Develop standardized test procedures for the evaluation of different stack technologies
- Characterize stacks and systems in terms of:
    - *Initial Performance*
    - *Durability: Accelerated aging test to yield a reasonable projection of life in a reasonable amount of test time*
    - *Low-Temperature Performance (future)*

- Adapt the Fuel Cell Test Facility (FCTF) hardware and software as needed to accommodate the unique needs of different technologies

- 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
  - Most fuel cell test objects performed as expected
  - Some had issues, such as bad connections, which were resolved by working with the developer
- FY09 Progress:
  - Facility upgrade
    - *Improved cooling system; replaced data acquisition and control computer*
  - Performance and life characterization of two 5-kW full systems
    - *Observed performance changes over 1000+ h*
  - Performance and life characterization of a 12-kW system
  - Model validation
  - Test protocol comparison
    - *Direct comparison of DOE test protocols with developed in the EU*

FCTF Is Being Upgraded to Enhance Flexibility

- Added unique capability of operating fuel cell stacks at high temperatures and pressure
  - Added to accommodate new high-temperature membranes being developed by DOE contractors
  - Maximum operating temperature and pressure increased to 130^{o}C and 2.7 bar
  - Maintain high water quality: 17 MΩ-cm
- Upgraded data acquisition and control capabilities
  - Replaced aging computer with a LabView®-based system
  - Added the ability to use modern transportation-based data interfaces, such as CAN

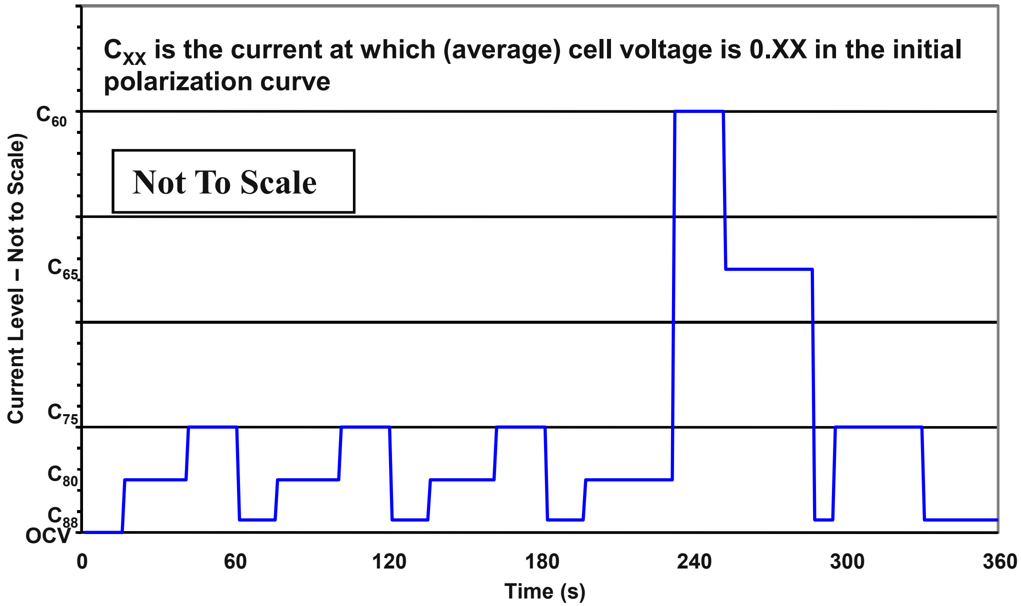
100-kW cooling system installed in the Fuel Cell Test Facility

Example Results from a 5-kW Full System

- Data were acquired using a data protocol which is commonly used in transportation
- Test Plan
- Test plan is based on generic protocols and is developed in collaboration with the developer
  - Characterize the initial performance of the stack using three polarization experiments:
    - *Sequential, current-increasing*
    - *Sequential, current-decreasing*
    - *Random*
  - Constant power test at 25% of rated power for 120 h
  - Dynamic cycling using the DST profile for 1000+ h
  - These tests characterize the initial performance of the system and how the performance changes with time

Accelerated Aging Using the DST Cycling Profile

- Profile comes from battery testing



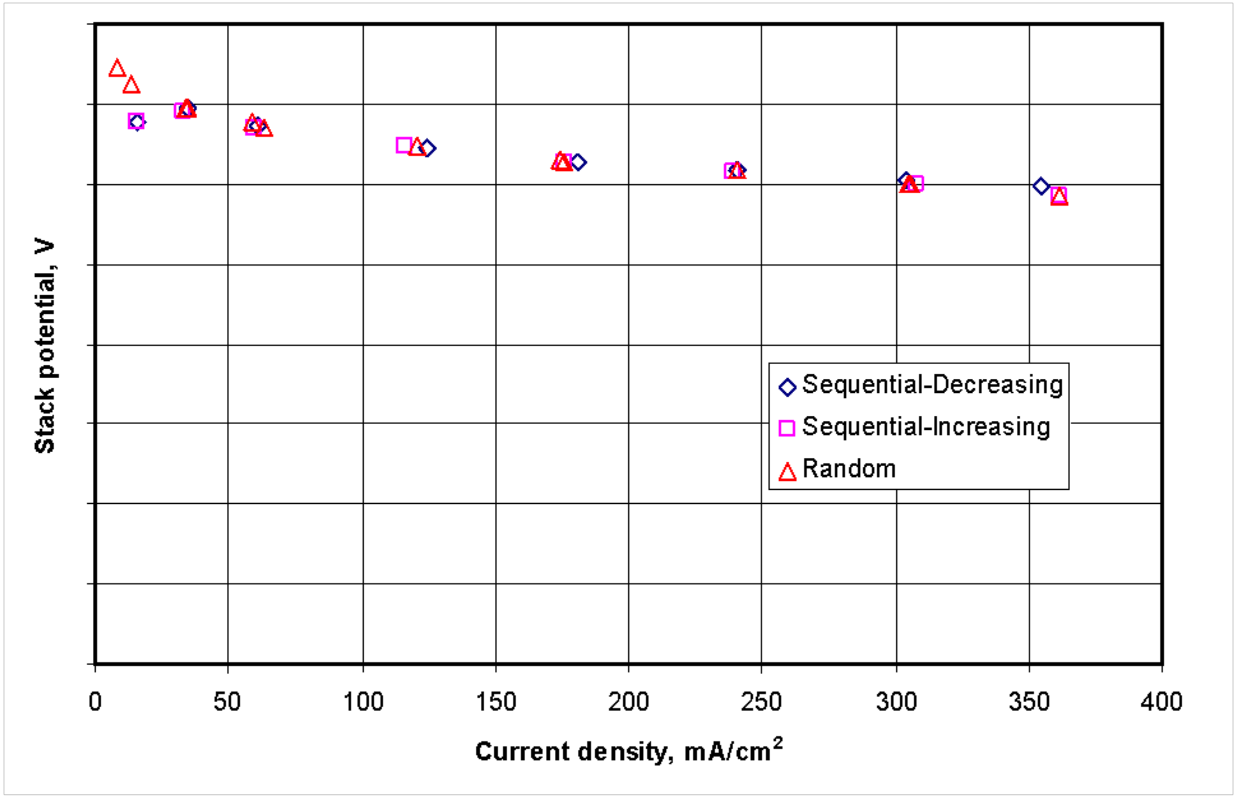
- The profile represents the power needed for acceleration and hill climbing
- DST profile cycles the stack voltage, stressing the stack

Table 1– Current Density vs Time for the Cycle Profile

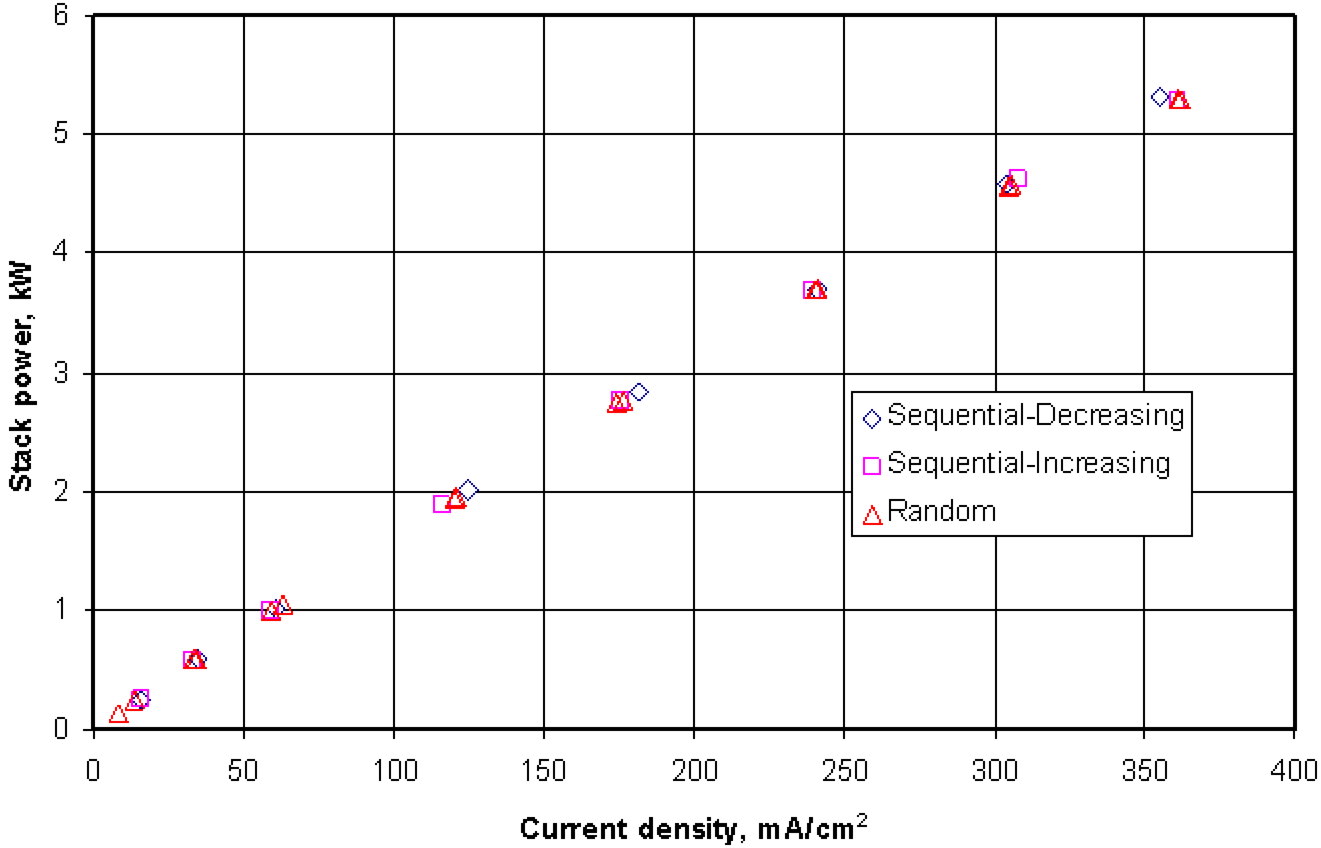
Step	Duration sec	Cxx		Step	Duration sec	Cxx
1	**15**	**OCV**		9	20	C_{75}
2	25	C_{80}		10	15	C_{88}
3	20	C_{75}		11	35	C_{80}
4	15	C_{88}		12	20	C_{60}
5	24	C_{80}		13	35	C_{65}
6	20	C_{75}		14	8	C_{88}
7	15	C_{88}		15	35	C_{75}
8	25	C_{80}		16	40	C_{88}

- The current densities used in the DST profile are adjusted to accommodate the stack under test

Initial Polarization Results – Stack in the Fuel Cell System Showed Very Little Hysteresis

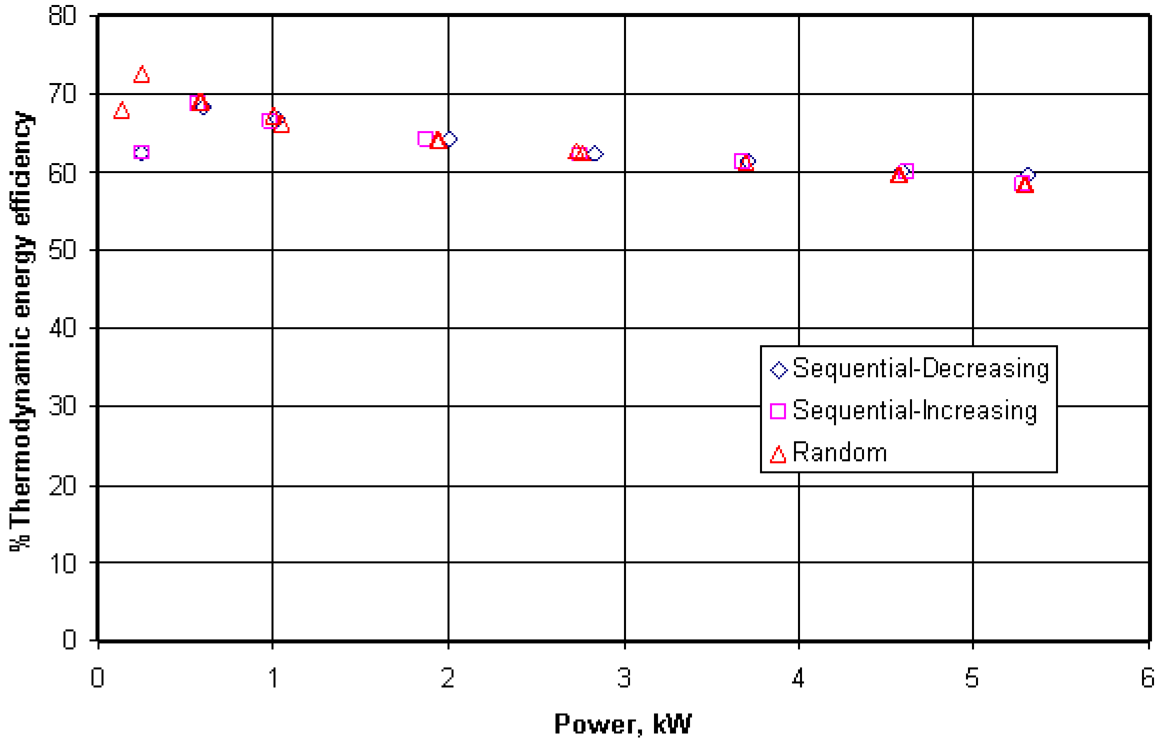


Initial Polarization Results – Stack in System Delivered More Than Rated Power

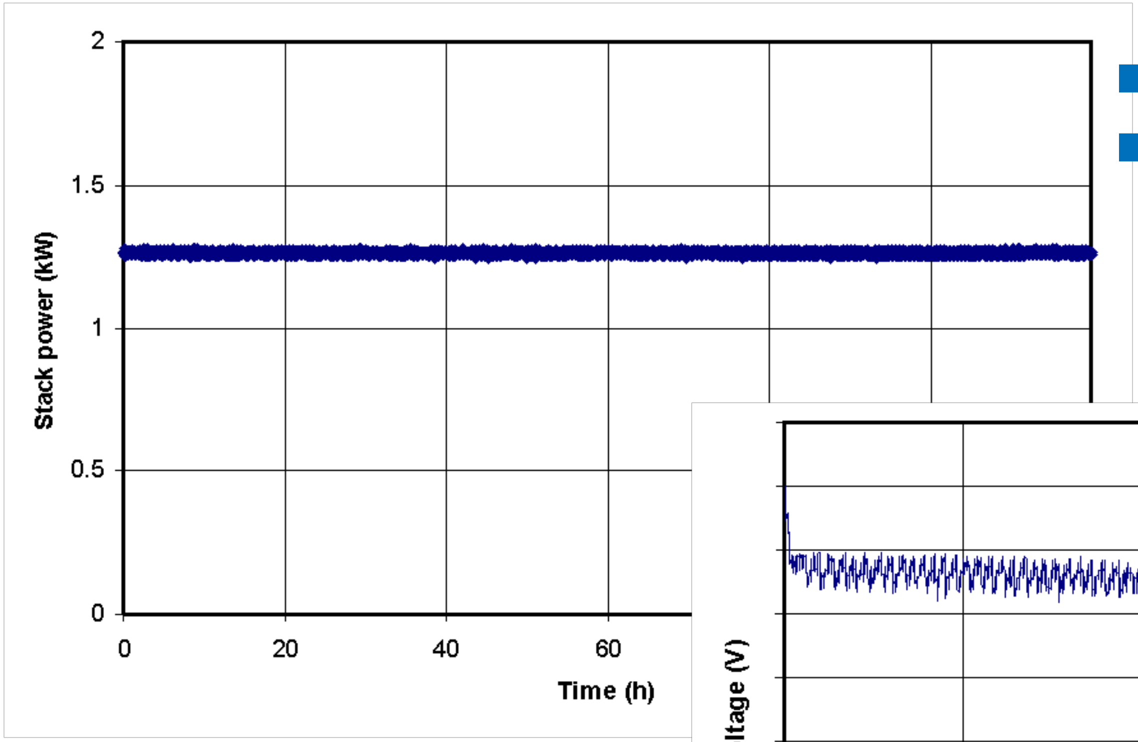


Initial Polarization Results – Thermodynamic Energy Efficiency of Stack in System

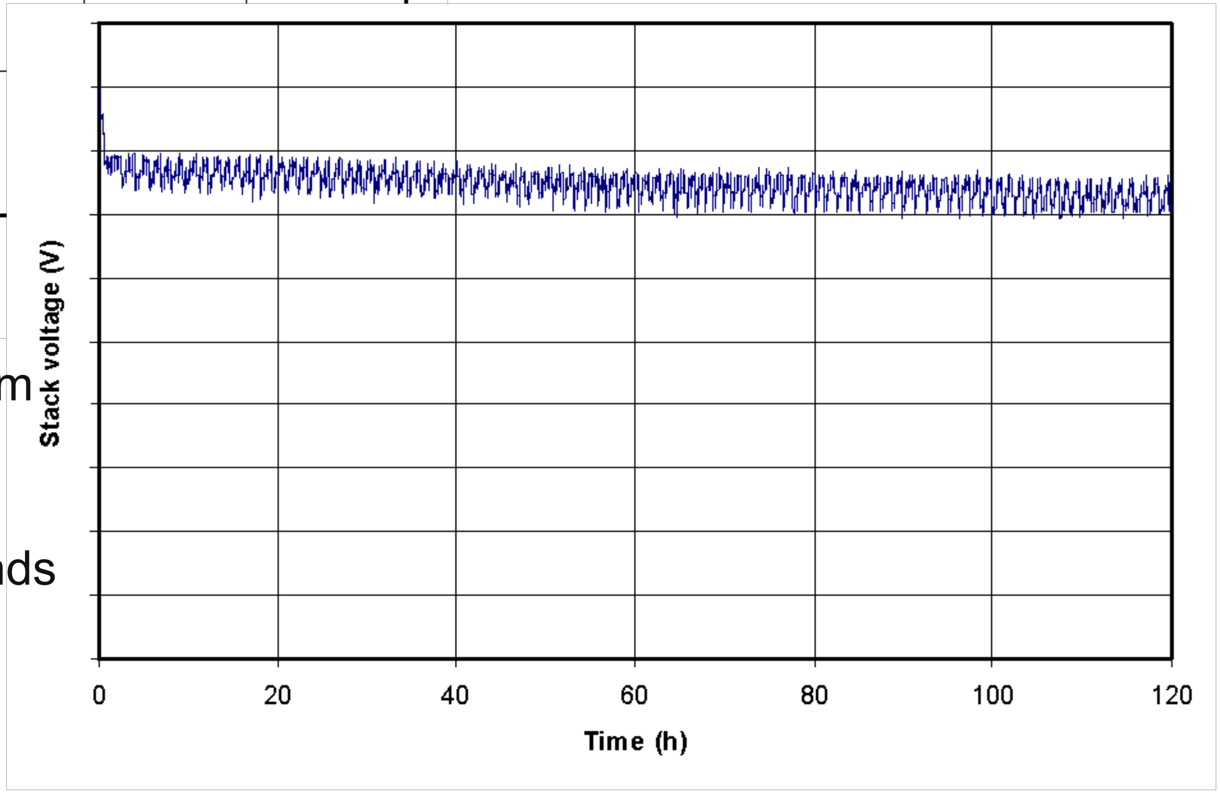
- Thermodynamic energy efficiency = (Power, kW)/[(kg H_2 consumed/h)*LHV_{H2}]
- Efficiency at rated power ~ 60% and at 25% of rated, 65%
- Compares well to DOE's technical targets for a stack: 55% at rated power; 60% at 25% of rated power



Example Results from Constant Power Test



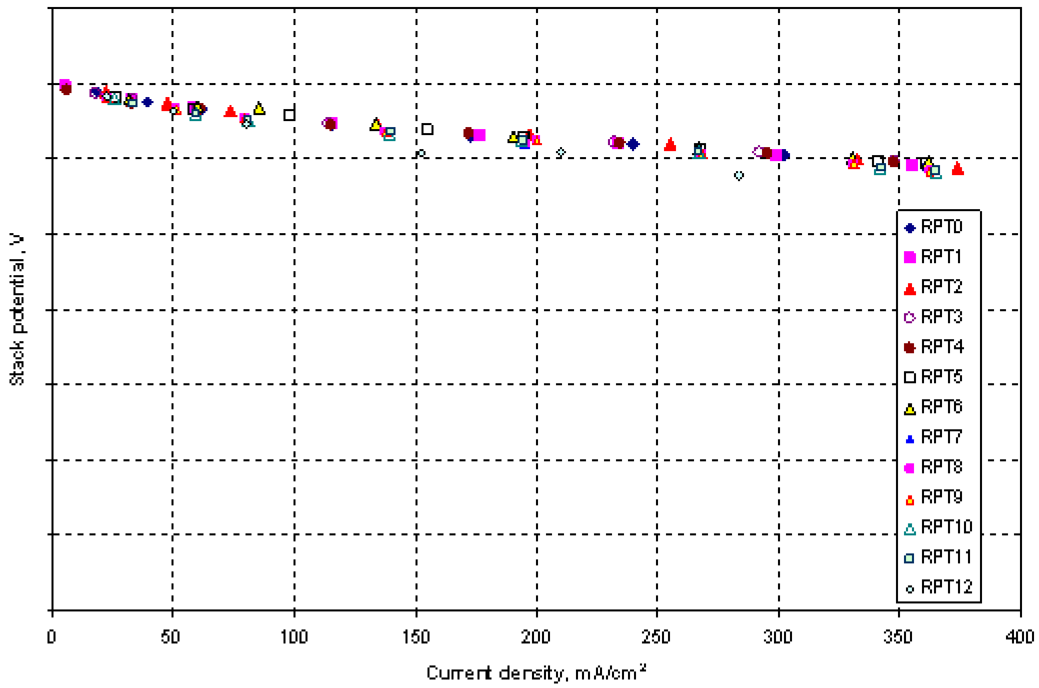
- Test ran for 120 continuous hours
- Test system operated without an operator nearby



- Voltage oscillations are from balance-of-plant (fans, compressors, pumps, etc.)
  - Parasitic power demands

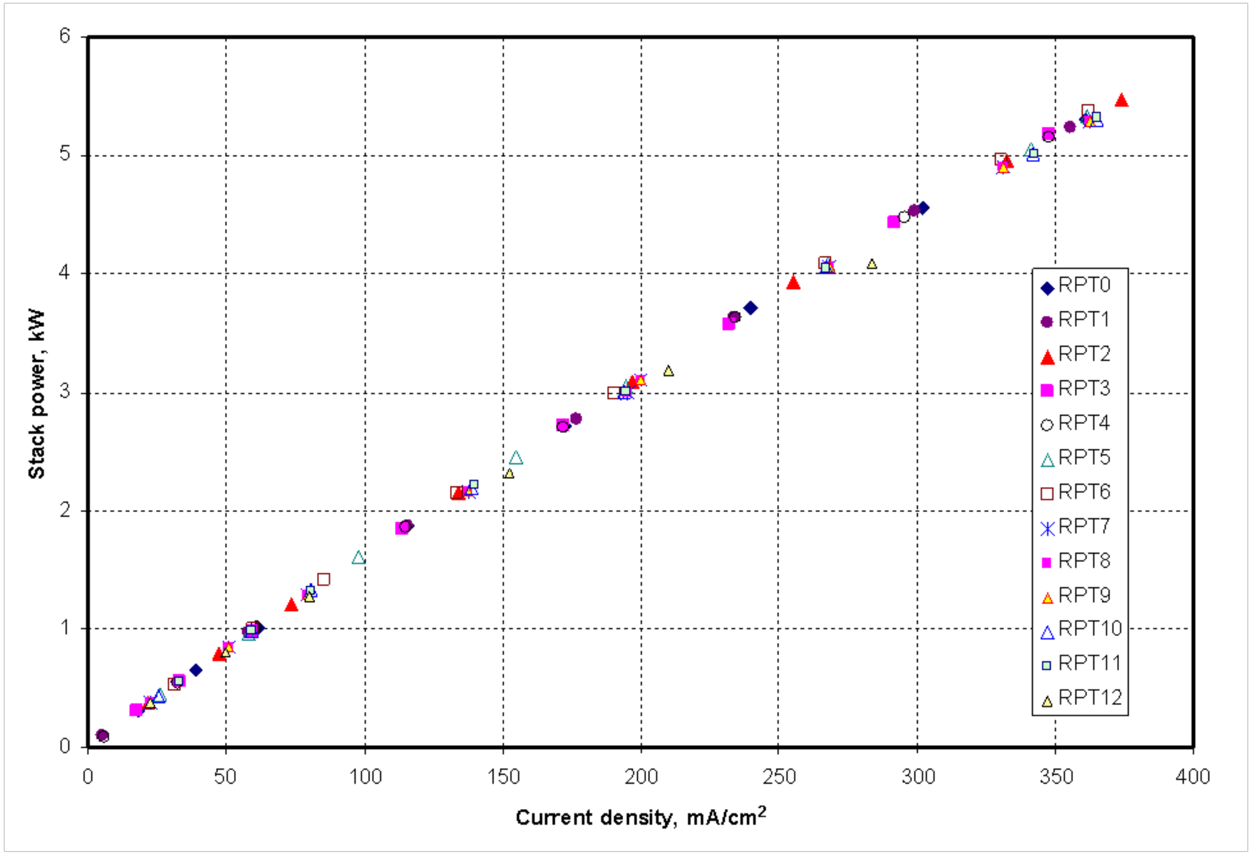
Example Results from DST Aging Test (1)

- After every 100-125 hours, the performance system of the system was characterized by reference performance tests (RPTs) which included polarization curves
- Over the course of the experiment, very little change in stack voltage was seen



Example Results from DST Aging (2)

- Over the course of the experiment, very little change in stack power was seen

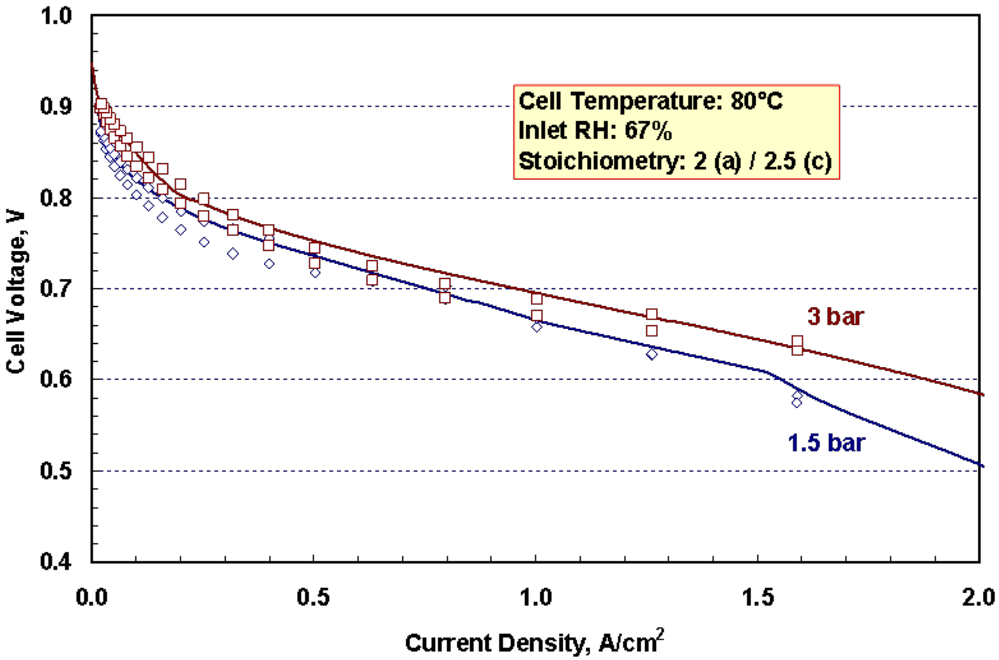


Collaboration with the Institute for Energy (The Netherlands)

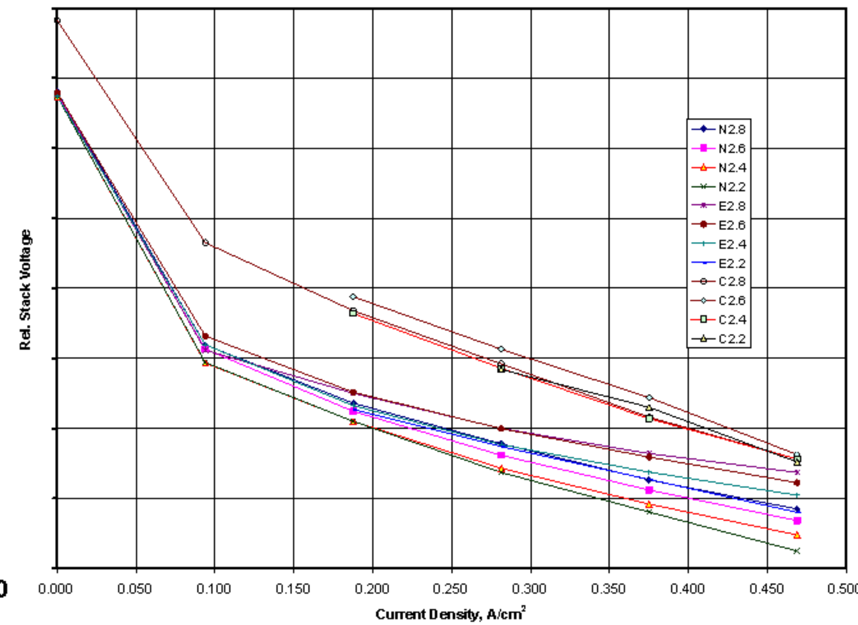
- Different sets of fuel cell stack testing protocols were developed by DOE and by FCTES^{QA} (a Framework Program in the EU)
- Both sets of protocols characterize the performance and life of fuel cell stacks
- Basic question to be answered: How do the differences in the protocols impact the observed fuel cell life? For example, does one set of test protocols stress the stack more than the other?
  - Understanding the differences will help DOE and fuel cell developers better understand test results
  - May facilitate fuel cell development
- A test plan is being developed which will incorporate both sets of protocols
  - It will be used at both test sites on the same 12-kW fuel cell stack and the results will be compared

Fuel Cell Model Validation

- Using current testing facility, models of fuel cell stacks can be validated
- Use same parameters and range in model and in the actual test
  - Effect of T, P, dew point, etc., on stack performance
  - This was done for cells; extend to stacks



Actual (symbols) vs. simulated (solid line) for a single cell



Stack data showing the effect of pressure and method of pressure control (N=no control at 5 psig; E=equal pressure maintained, 5-30 psig, depending on flow rate; C=constant pressure maintained, regardless of flow rate

Summary

- FCTF acquires and benchmarks commercial fuel cell stacks to provide DOE with information regarding the evolution of the technology

- 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 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 temperatures)

Acknowledgment

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