Fuel Cell Testing at the Argonne Fuel Cell Test Facility

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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

- Two-year project funding: $850K from DOE
- FY09: $350K
- FY10: $500K

Objectives

- To provide DOE with an independent assessment of state-of-the-art fuel cell technology
- 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

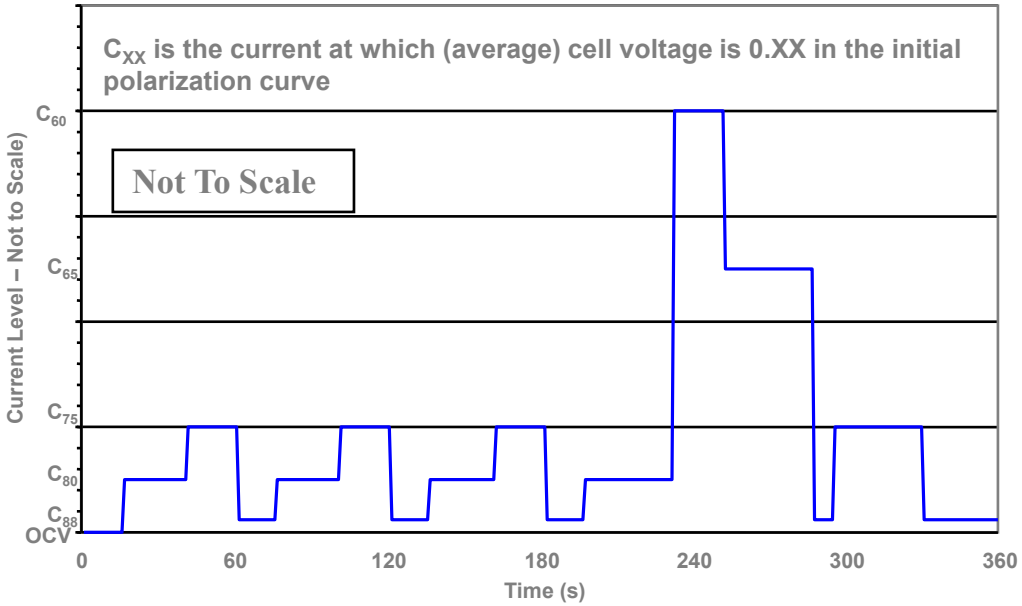
- Characterized several fuel cell stacks and systems, ranging in size from 720 W to 85 kW
  - Most fuel cell test objects performed as expected
  - Some had issues, most of which were resolved by working with the developer
- FY10 Progress:
  - Performance and life characterization of two 5-kW full systems
    - Observed performance changes over 1000+ h
  - Performance and life characterization of a 2-kW stack is underway
  - Test protocol comparison
    - Direct comparison of DOE test protocols with those developed in the EU

Testing the 5-kW Full Systems

- Data were acquired using testing protocols that are commonly used in transportation
- Transportation protocols were used for consistency with other tests
- 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

DST Cycling Profile for Accelerated Aging Tests

- Profile comes from battery testing



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

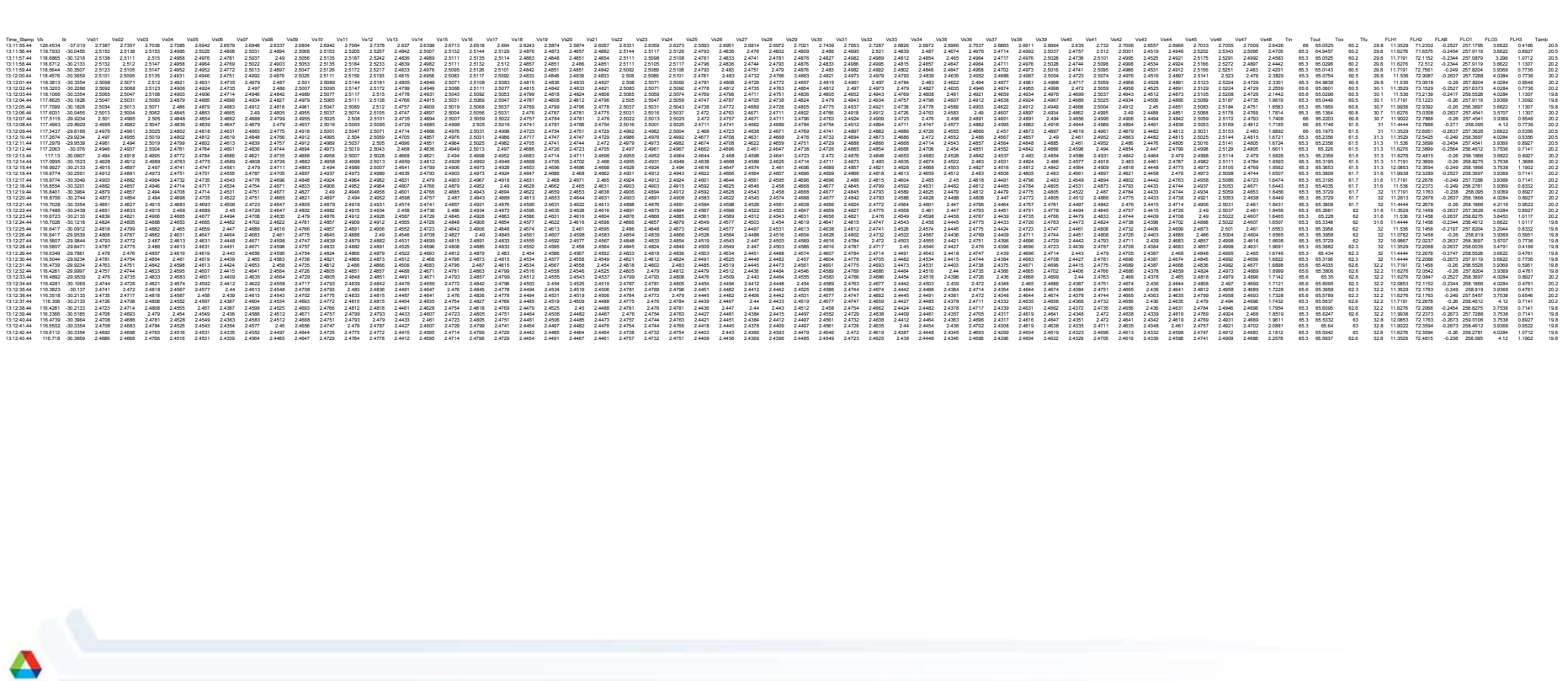
- The profile represents the power needed for acceleration and hill climbing
- DST profile cycles the stack voltage, stressing the stack

Table 1– Current Density vs Time for the Cycle Profile

Step	Duration sec	C_{XX}		Step	Duration sec	C_{XX}
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}

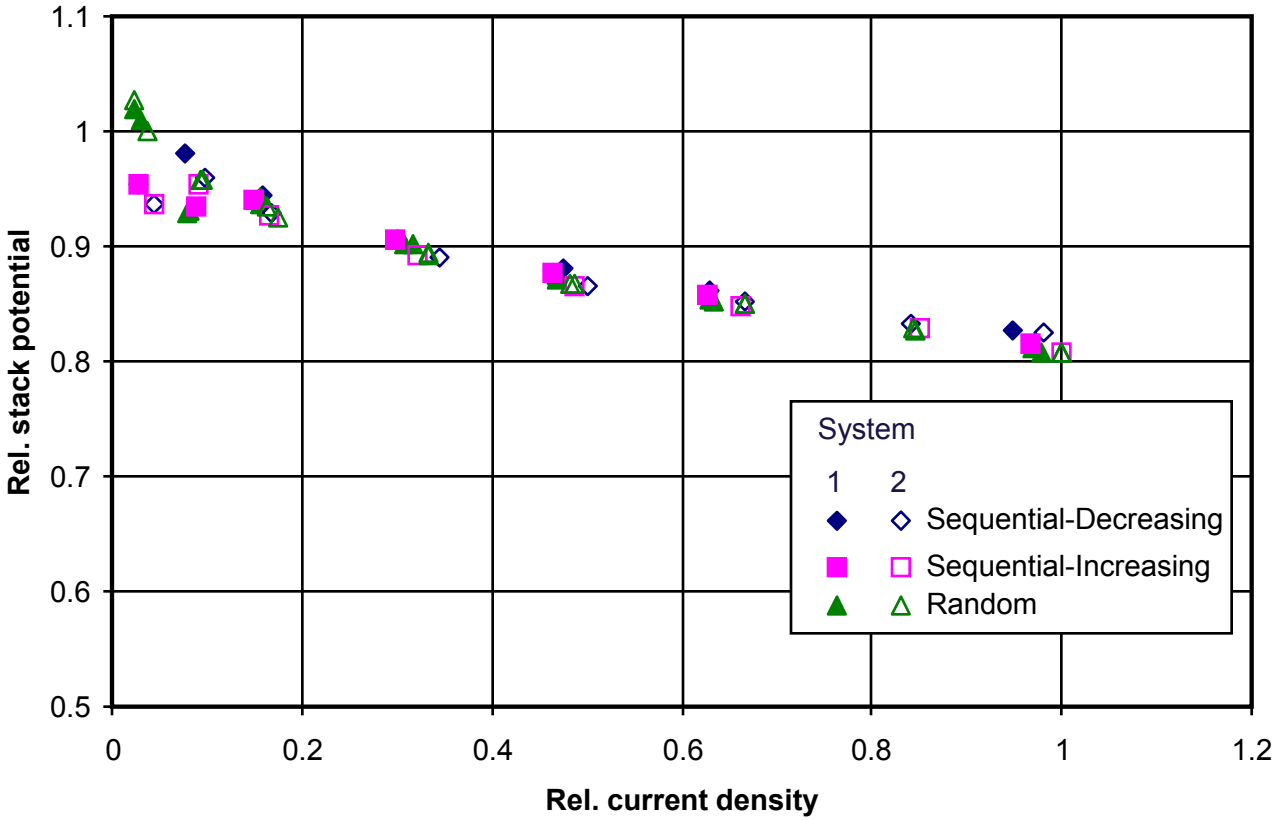
Many Parameters Are Measured During Testing

- Example raw test data shows the number of parameters measured. In the example below,
  - Vb refers to the stack voltage
  - Ib, the stack current
  - Vs, a string of 3 cells

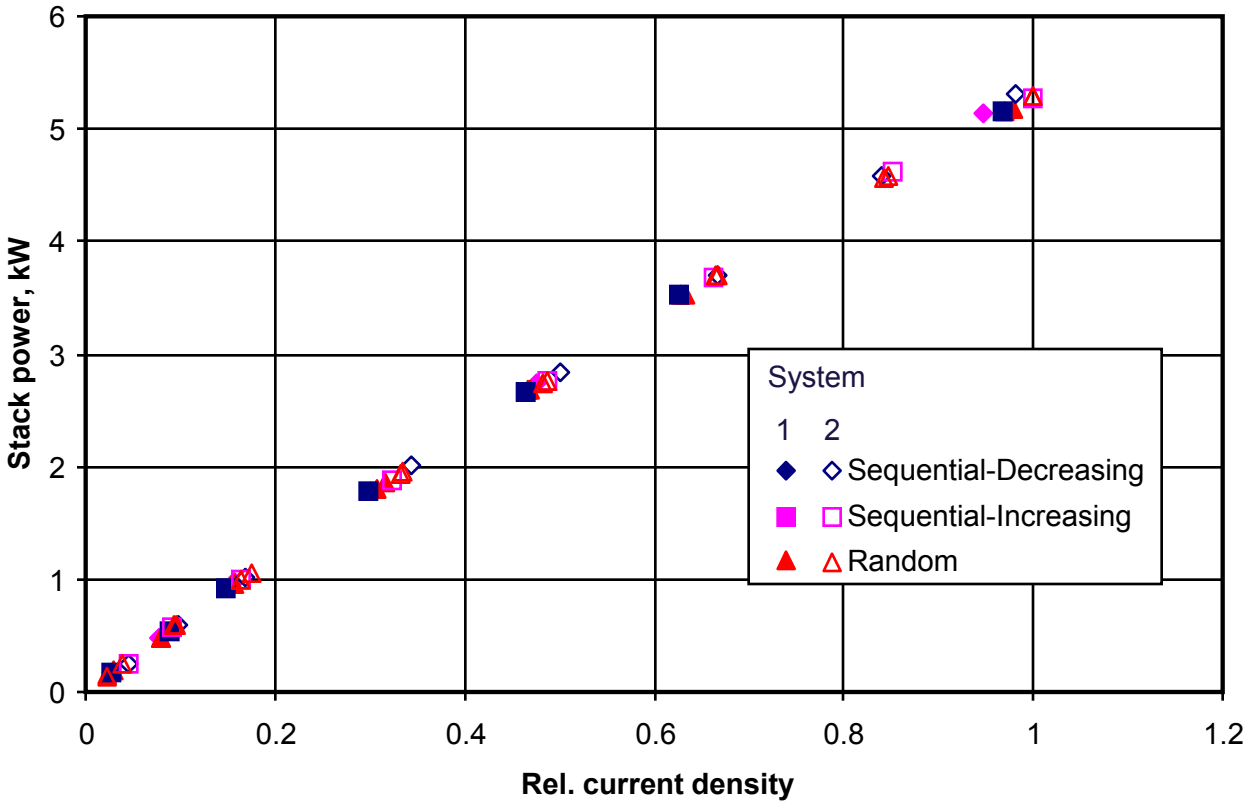


Initial Polarization Results
Polarization Behavior of Both Stacks Was Comparable

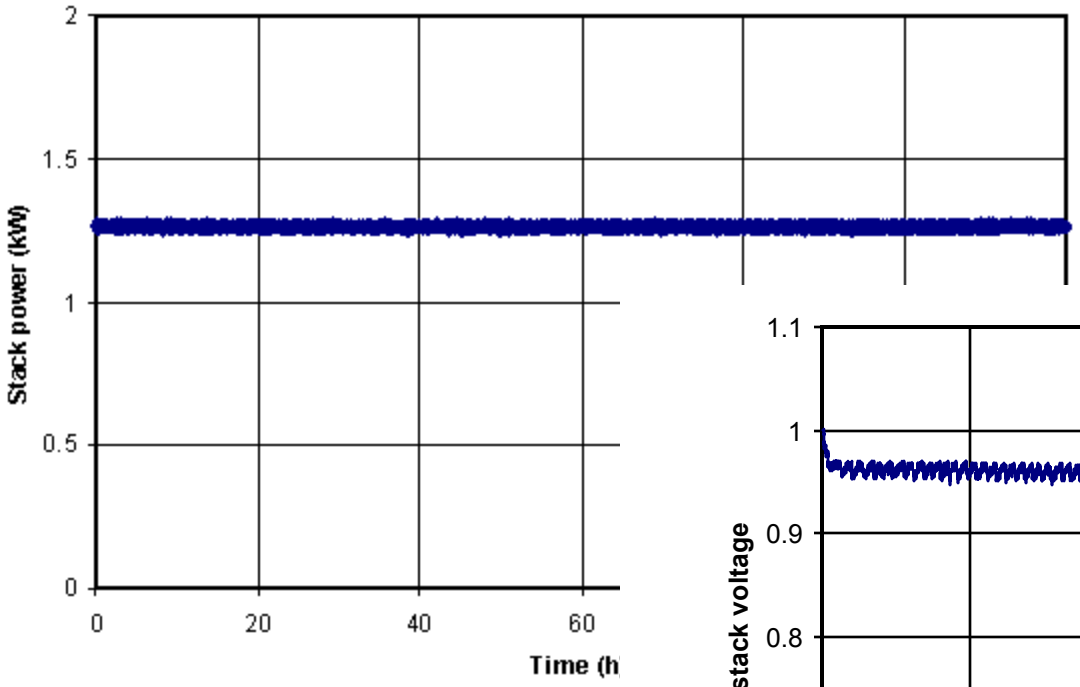
- Systems were procured in May 2008
- Stacks consisted of 40 cells each



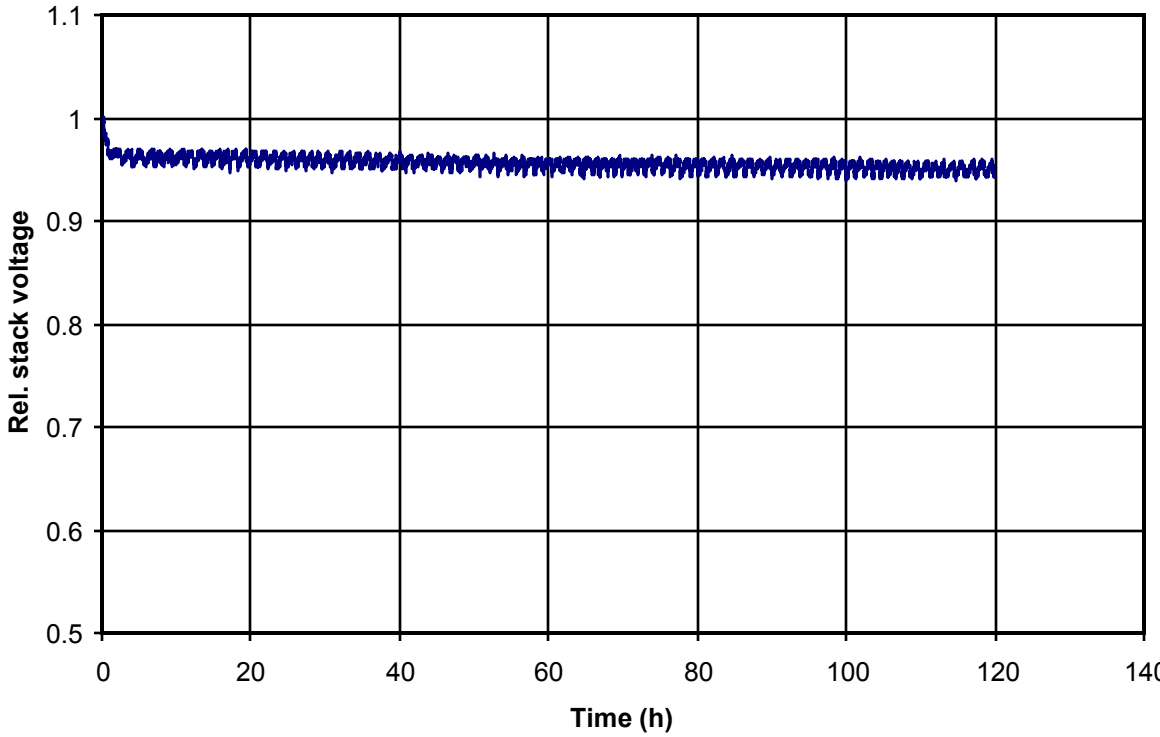
Initial Polarization Results
Power vs. Current Curves Were Almost Identical



Example Results from Constant Power Test



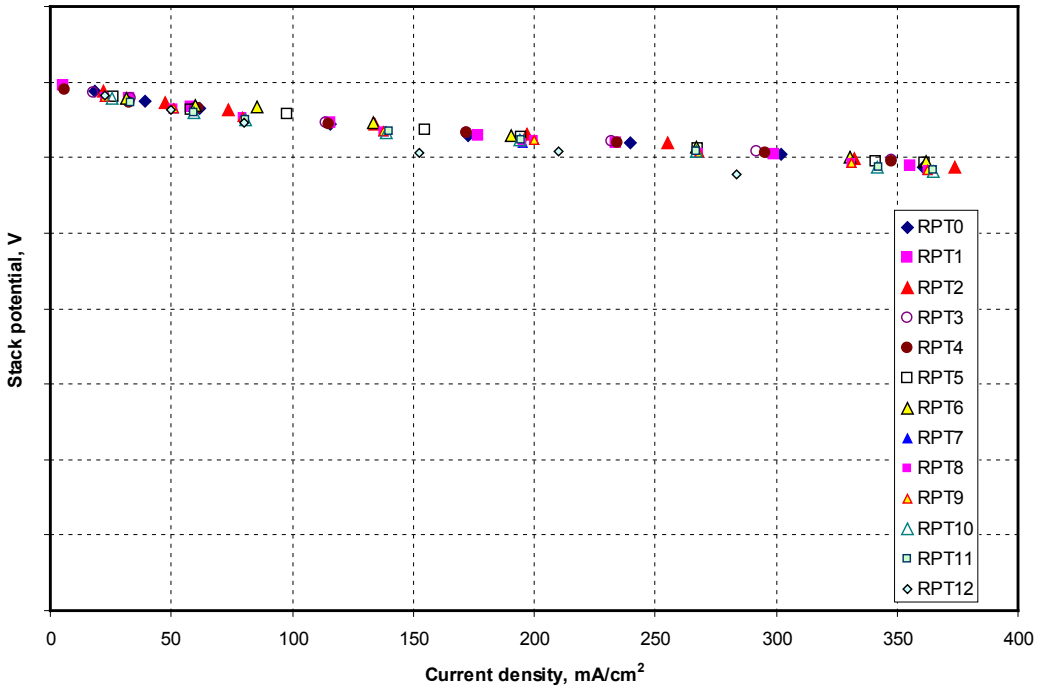
- Test ran for 120 continuous hours
- Test system operated unattended (but with shutdown safety systems activated)



- Voltage oscillations
  - Cycle time: ~2 h
  - Magnitude of fluctuation: ~0.7%

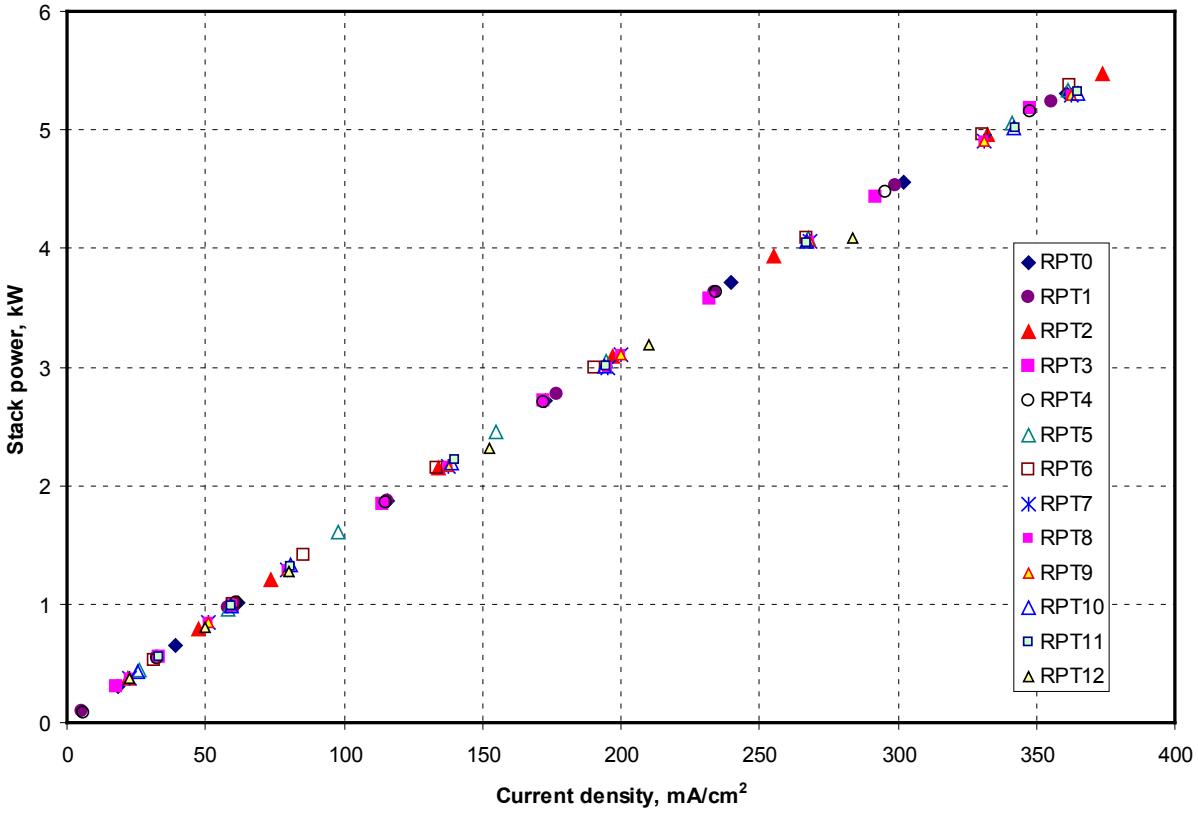
Example Results from DST Aging Test (1)

- After every 100-125 hours, the performance 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

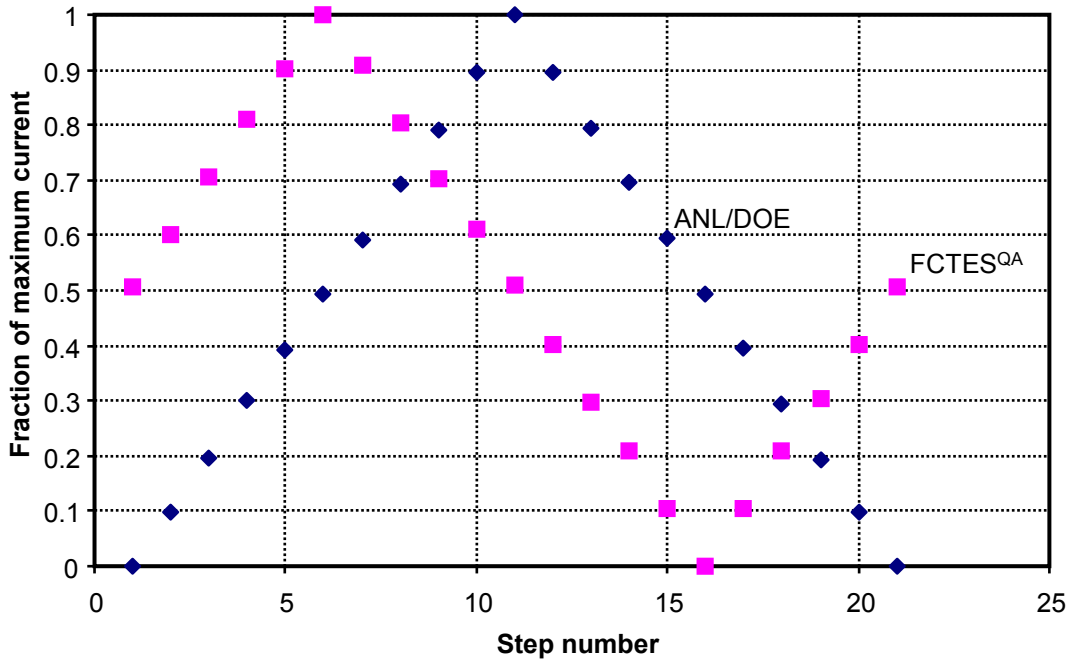


Protocol Comparison

- 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 was developed that incorporated both sets of protocols and the test was performed at Argonne
  - An old, 15-kW stack was used in these tests

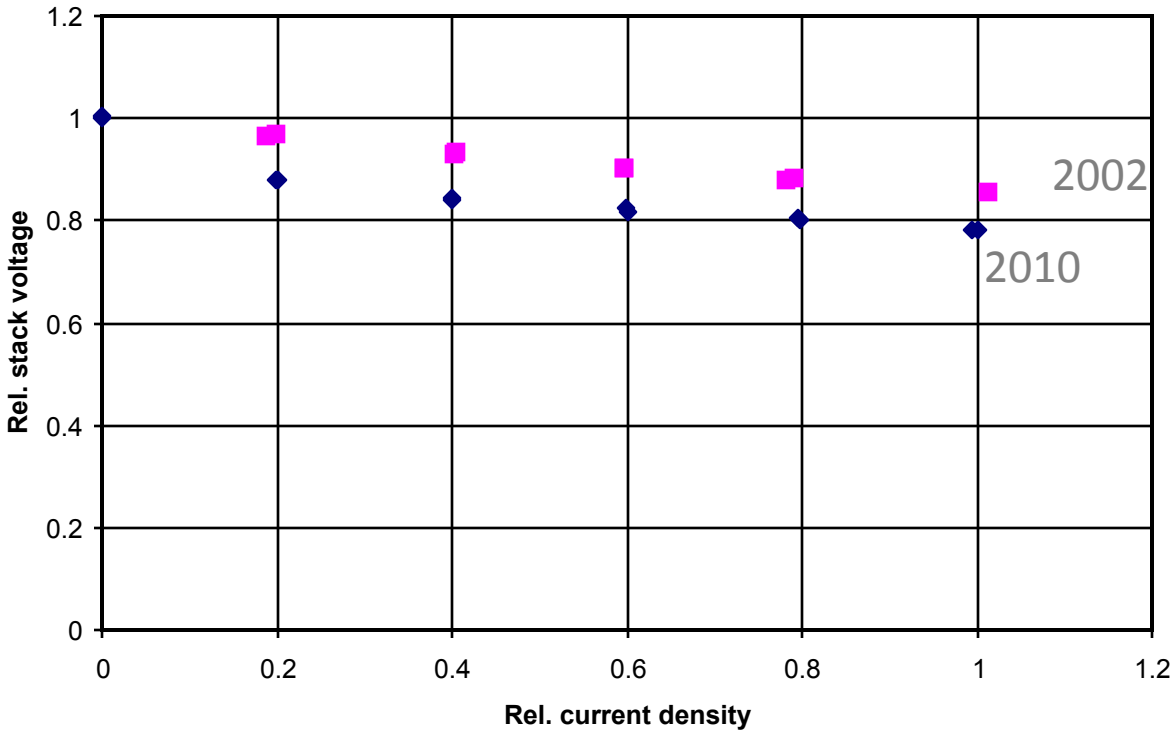
Comparison with Polarization Curve Protocol Used in EU

- In the sequential polarization test, the protocols start at different current densities and proceed monotonically up and down in current density
  - FCTES^{QA} protocol specifies that only the current-decreasing portion of the curve be reported
- The FCTES^{QA} protocol has no equivalent of a random polarization curve
- Conditions used:
  - T=65°C; 1 atm
  - 100% humidification
  - Fuel utilization: 56%
  - Oxidant utilization: 35%
  - These conditions can change with system needs



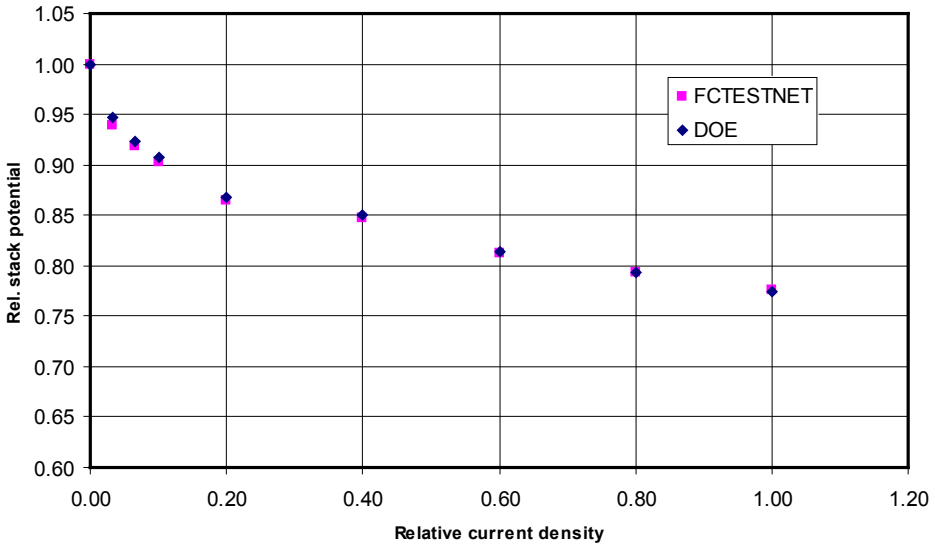
Comparison of Results from the Two Protocols (1)

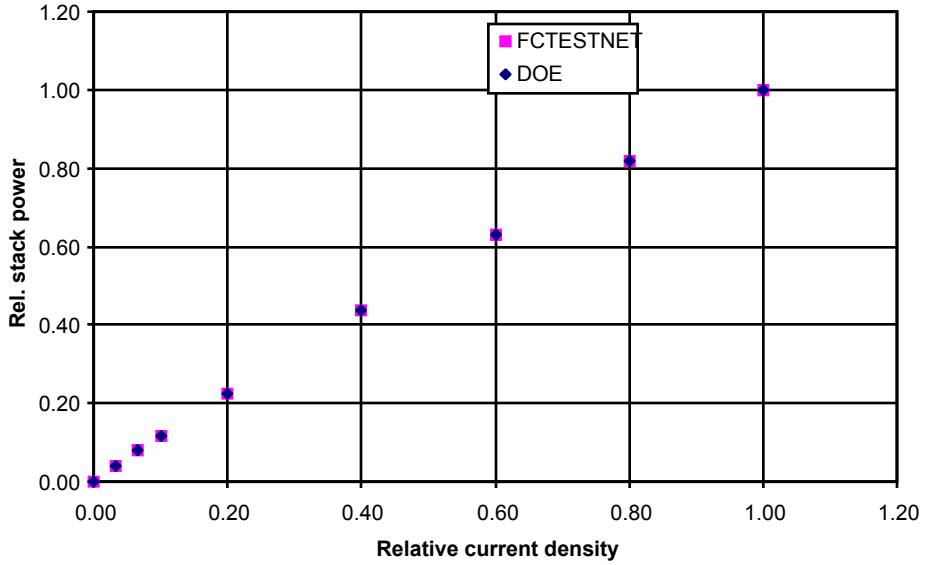
- An old, previously-tested 15-kW stack was characterized and used for the tests
- Comparing the current polarization behavior with that measured in 2002 shows some degradation, ~7.5% at maximum current density



Comparison of Results from the Two Protocols (2)

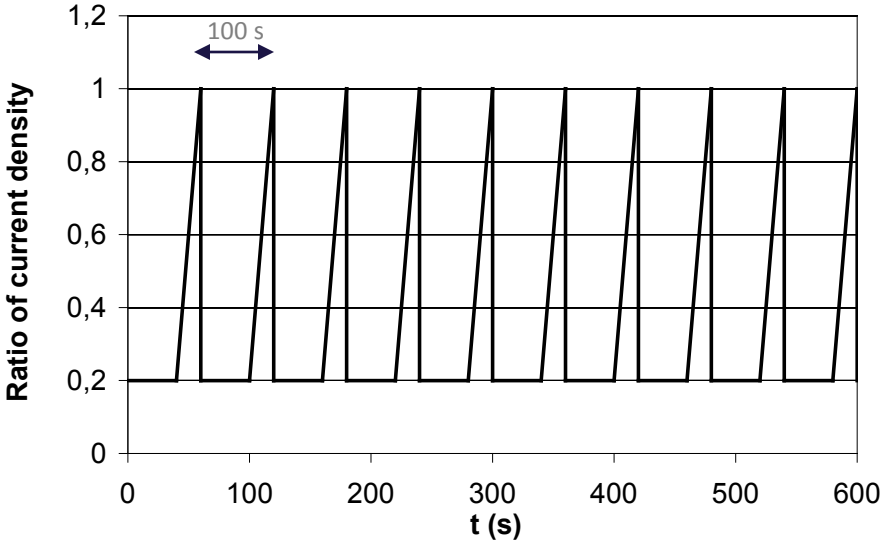
- No significant differences seen between the two protocols



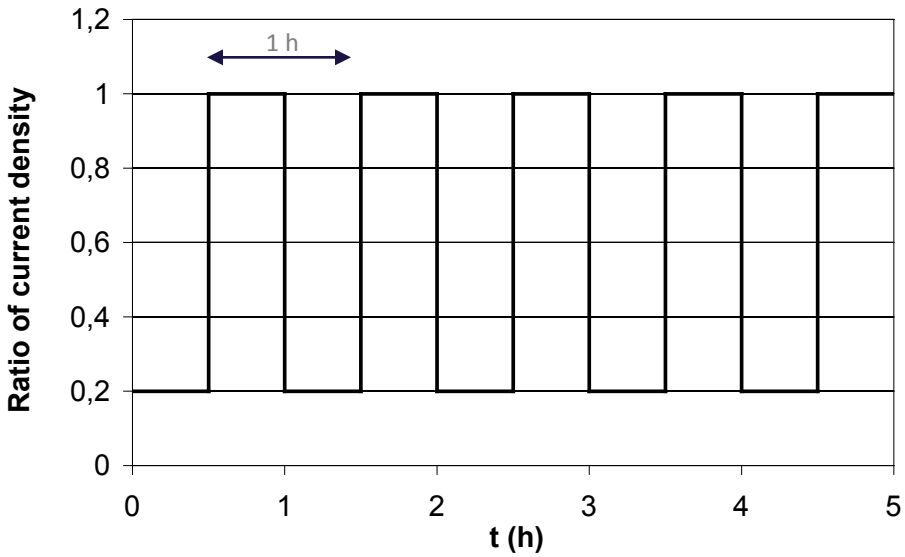


Comparison of Results from Dynamic Cycling DOE vs. FCTES^{QA}

- Two dynamic profiles have been proposed by FCTES^{QA}, A and B
- Comparing the profiles from DOE and from FCTES^{QA} shows:
  - Different current densities, times, and ramp rates are used for current on / current off
- Question: How does the dynamic cycling profile affect aging?



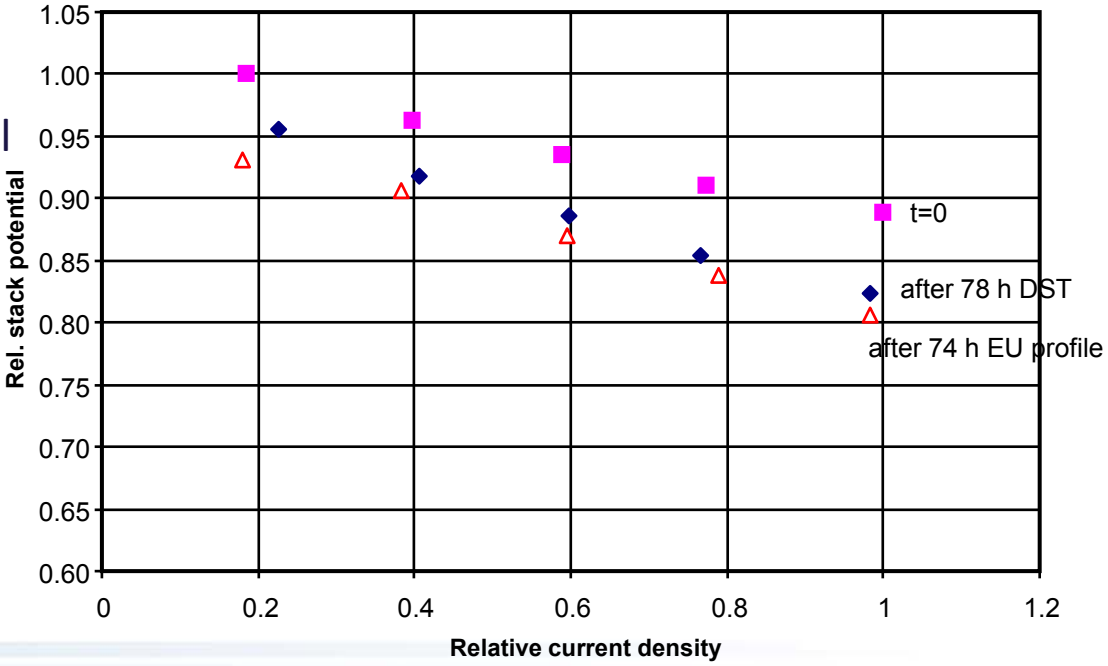
A



B

Dynamic Cycling – Comparison of Effect of DST Profile with That of FCTES^{QA} Profile B on Stack Performance

- Perform ~75-h cycling tests using DST profile and using FCTES^{QA} profile B on old, 15-kW stack
- Sequential polarization curves show effect on stack performance
  - DST: 7.4% change in performance
  - FCTES^{QA} B profile: an additional 2.0% change in performance
- DST profile seems to age the stack faster; we will use FCTES^{QA} profile A next to complete the study as well as investigate path dependencies



Summary

- FCTF acquires and benchmarks commercial fuel cell stacks and systems to provide DOE with information regarding the state-of-the art in the technology

- Testing in FCTF is modeled after US protocols. International test protocols 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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