V.A.7 Fuel Cell Testing at Argonne National Laboratory

Ira Bloom (Primary Contact), John Basco, Panos Prezas, Lee Walker
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439
Phone: (630) 252-4516
E-mail: Ira.Bloom@anl.gov

DOE Technology Development Manager:
Nancy Garland
Phone: (202) 586-5673
E-mail: Nancy.Garland@ee.doe.gov

Start Date: 1996
Projected End Date: Project continuation and direction determined annually by DOE

Objectives

- Provide DOE with an independent assessment of the performance of fuel cell systems and components developed under DOE contracts.
- Characterize and benchmark the performance of state-of-the-art commercial fuel cell technology available in the market.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section (3.4) of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Durability
(C) Performance
(D) Water Transport within the Stack
(G) Start-up and Shut-down Time and Energy/Transient Operation

Contribution to Achievement of DOE Fuel Cells Milestones

This project will contribute to achievement of the following DOE milestones from the Fuel Cells section of the Fuel Cell Technologies Program Multi-Year Research, Development, and Demonstration Plan:

- *Milestone 86: Evaluate short stack against 2011 targets for operation over the full operating temperature range. (4Q, 2010)*
  We are testing stacks from different developers and documenting their performance according to well-defined test protocols for comparison of the measured performance against DOE targets.
  Milestone 87: Test and evaluate fuel cell systems and components such as MEAs, short stacks, bipolar plates, catalysts, membranes, etc., and compare to targets. (1Q, 2011)
  We are testing fuel cell stacks, balance-of-plant components, and complete systems to document their performance for comparison to DOE targets.
- *Milestone 88: Test and evaluate fuel cell systems and components such as MEAs, short stacks, bipolar plates, catalysts, membranes, etc., and compare to targets. (4Q, 2015)*
  We are testing fuel cell stacks, balance-of-plant components, and complete systems to document their performance for comparison to DOE targets and to document the improvements made in meeting those targets.

Accomplishments

- Characterized two 5-kW complete systems.
- Characterized one 12-kW complete system.
- Began characterization of a 2-kW stack which contains bipolar plates designed for high-temperature operation.
- Participated in and made technical presentations at meetings of the International Organization for Standardization Working Group 11 under Technical Committee 105 of the International Electrotechnical Commission, held on February 8-9, 2010, in Milan, Italy. The goal of this international group is to draft the technical specification of a single-cell test protocol. Representatives from six countries attended. The technical specification has been published.
- Initiated collaborative effort to compare the test protocols developed by the European Fuel Cell Testing and Standardization Network (FCTESTNET)/fuel cell testing, safety, and quality assurance (FCTES^{QA}) and by DOE to characterize and age fuel cell stacks. The objective of the effort is to determine if the results depend on the protocol used or if the results are protocol-independent.

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Introduction

This project helps DOE determine and document progress toward achieving its technical targets by providing an independent assessment of evolving fuel cell technology. In addition, in this project we develop standardized fuel cell testing procedures to aid in the evaluation of different stack technologies on a common basis. The procedures and methods used at the Argonne Fuel Cell Test Facility do not depend on the technology being tested, that is, they are transparent to the technology being tested; thus, they provide a means for easy comparison of the performance and expected life of the technology from many different developers. In these procedures, the stack is characterized in terms of initial performance, durability, and room-temperature performance. To further accelerate fuel cell technology developments, these procedures are compared with similar procedures developed by other national and international organizations.

The initial performance establishes a baseline for comparison as the fuel cell ages. The aging process is accelerated to yield a reasonable projection of life at constant power and under driving duty cycles in a reasonable amount of testing time. Periodically during the aging test, the test is interrupted and the stack performance is re-characterized. A life projection is then made by comparing the most recent performance characteristics with those measured earlier.

Approach

We have developed standardized fuel cell and stack test procedures to aid in the evaluation of different stack technologies. These test procedures characterize the stack in terms of initial performance (e.g., power and voltage vs. current, efficiency, hydrogen cross-over), durability, and low-temperature performance. The testing is repeated during and after defined aging under steady-state and cycling operations to determine performance decay over time.

The test facility is flexible enough to accommodate the unique needs of different fuel cell technologies. Modification and upgrading of the test facility is an ongoing process that is carried out in consultation with fuel cell developers and DOE.

Results

The performance of two 5-kW, direct hydrogen fuel cell systems was characterized in terms of polarization behavior (sequential and random polarization curves) of the fuel cell stack. For these tests, the system was cycled using the dynamic stress test (DST) profile shown in Figure 1 to simulate accelerated aging of the stack. The DST profile consists of several steps representing different current levels ranging from 0 A to current values where the average cell voltage in the stack is 0.6 V/cell. After every ~100 h (1,000 DST cycles) of this accelerated aging protocol, the DST cycling was interrupted and the stack performance was characterized by measuring a sequential polarization curve.

The performance and aging characteristics of the two 5-kW stacks were very similar; the results from one will be used in the following discussion. The stack-only polarization data from this accelerated aging test are shown in Figure 2. The initial performance was in very good agreement with the rated performance of the stack. Further, the data in Figure 2 indicate that there was very little change in the performance of the stack over the first about ~1,200 h of the accelerated aging under the DST cycling conditions. After that, however,

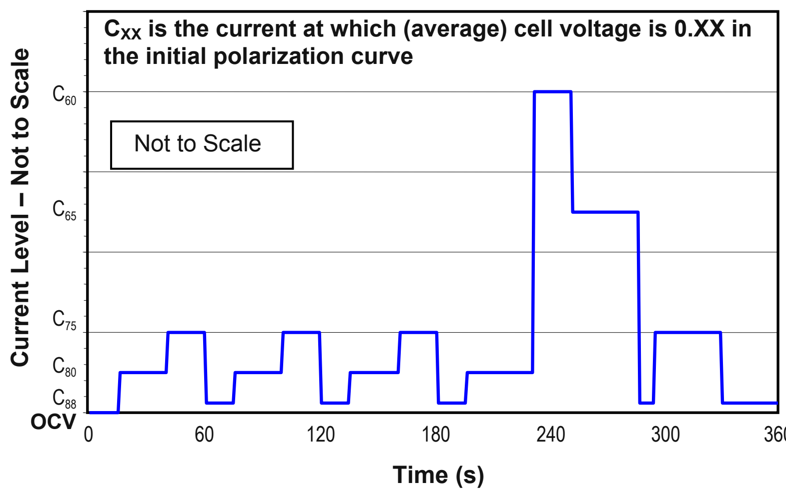

FIGURE 1. Dynamic Stress Test Profile used for Cycling Tests

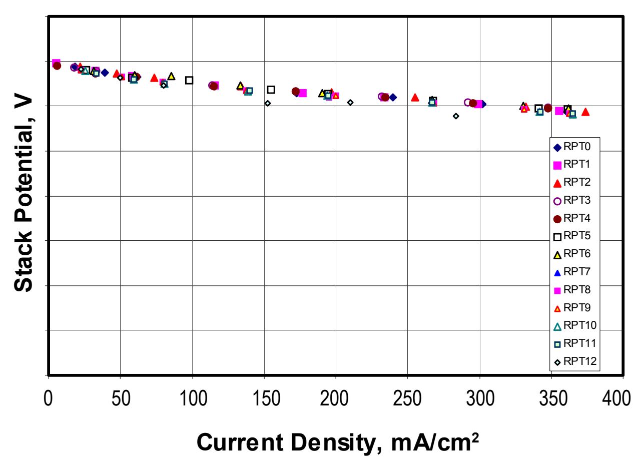

FIGURE 2. Polarization data from the aging experiment. The curves RPT0 to RPT12 represent polarization data taken after every ~100 h of operation with cycling according to the DST test profile.

there was a significant decrease in the measured performance of the stack.

The power vs. current density curves were calculated from these data (see Figure 3). As expected, very little change in these curves was seen during the first ~1,200 h of DST aging.

There is interest in the U.S. and in the European Union (EU) to standardize testing protocols. It is hoped that with standardized protocols, fuel cell development will be accelerated and information exchange will be increased. Under the FCTESTNET framework program, the EU has developed a set of protocols it is proposing as standards. These protocols are being validated under the FCTES^{QA} program in a number of EU laboratories.

As part of our collaboration with FCTES^{QA}, we compared the performance of a previously-tested, hydrogen-fueled, 15-kW stack using the sequential polarization protocols developed by FCTESTNET and by DOE. The major differences between the two polarization protocols are the sequence of currents used and the portion of the polarization experiment that is reported as the resulting data. Figure 4 shows that the DOE protocol starts at open circuit, and then increases and decreases the stack current in turn. The FCTESTNET protocol, on the other hand, can start at almost any current setting. In the example shown in Figure 4, the test protocol starts at about 50% of the rated current; the current then increases, decreases, and finally increases again. The DOE protocol reports data from both the current-increasing and the current-decreasing sections; for the FCTESTNET protocol, only the results from the current-decreasing portion are reported. Figure 5 shows the current-decreasing portion of the polarization curves obtained from the 15-kW stack using the two protocols; there was no significant difference between the two curves.

Based on the genesis of the protocols, differences in the levels and profiles of stress placed on the fuel cell or stack may be expected to affect how the cell or stack ages during a durability test. The U.S. durability protocol was based on the accelerated testing of automotive-class traction batteries (Figure 1). Those used by the EU were based on different assumptions, such as a smooth power increase followed by power off (Figure 6a) or on-off cycling (Figure 6b). Aging experiments were conducted to measure the relative stress imposed by the test profile. Here, the DST and FCTESTNET Profile B were used to age the stack; each aging test lasted about 75 h. The change in performance of the stack with aging profile was gauged by polarization curves (see Figure 7). As can be seen from Figure 7, the DST profile produced a 7.4% decrease in performance at the maximum current density. The FCTESTNET Profile B produced an additional 2.0% decrease in performance. Thus, the DST profile seems to age the stack faster. FCTESTNET Profile A will be used next to complete the study as well

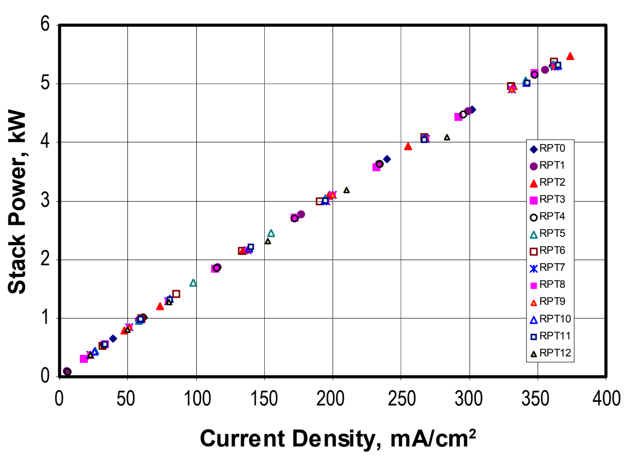

FIGURE 3. Polarization data from the aging experiment. The curves RPT0 to RPT12 represent polarization data taken after every ~100 h of operation with cycling according to the DST test profile. Stack power vs. current density. The curves RPT0 to RPT12 represent polarization data taken after every ~100 h of operation with cycling according to the DST test profile.

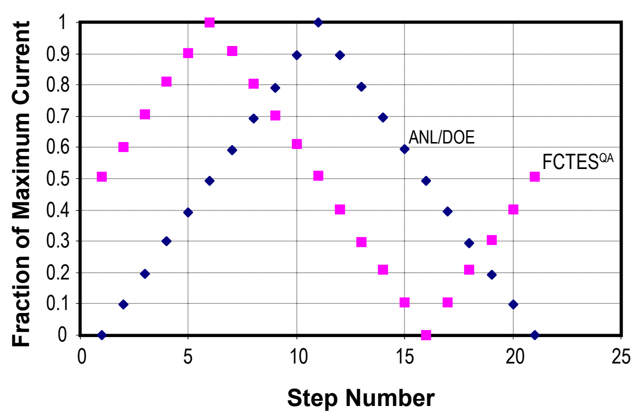

FIGURE 4. Sequence of current levels used in the polarization protocols developed by DOE and by FCTESTNET.

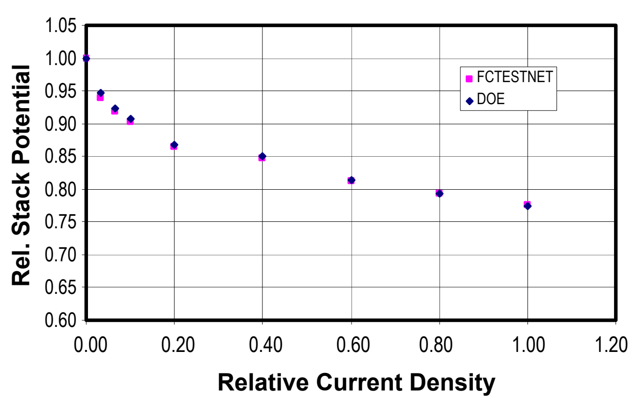

FIGURE 5. Comparison of Polarization Data Obtained Using the Two Protocols

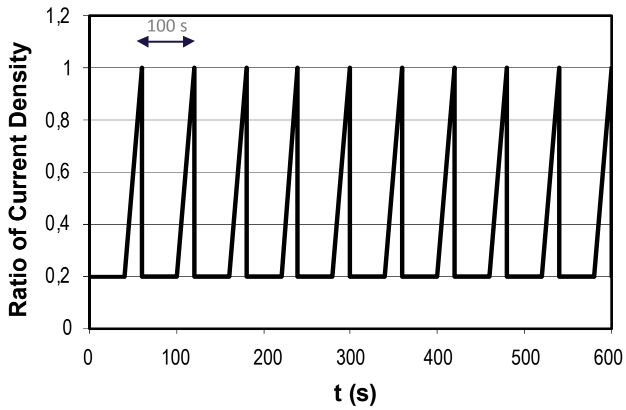

FIGURE 6a. A Dynamic Test Profile Proposed by FCTESTNET

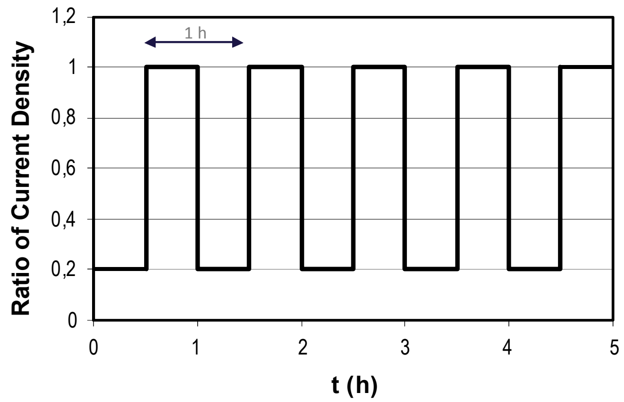

FIGURE 6b. Another Dynamic Test Profile Proposed by FCTESTNET

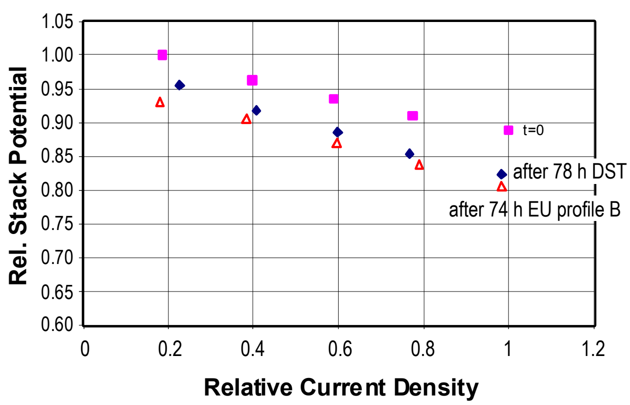

FIGURE 7. Polarization curves comparing of the aging effects of the DST profile with that of the FCTESNET Profile B. Each test lasted ~75 h.

as to investigate whether the order in which the tests are performed affects the results (path dependency).

Conclusions and Future Directions

- We have characterized the performance of two identical 5-kW systems, a 12-kW system, and a 2-kW stack, the last containing bipolar plates designed for high-temperature operation.
- The performance of the two 5-kW stacks was observed to be essentially identical and representative of this particular fuel cell technology.
- Testing of the stacks under an accelerated aging regime of current and potential cycling showed little change in performance over the first ~1,200 h (12,000 DST cycles); however, the stack performance degraded rapidly after 1,200 h.
- We are collaborating with the EU's FCTESTNET program to compare and validate the fuel cell test protocols being developed by the EU and the DOE. Preliminary results from the testing of a 15-kW stack of circa 2002 technology showed that there was no significant difference between the polarization curves obtained under these two different protocols. More detailed work is still needed to confirm these early results for the state-of-the-art fuel cell technology, and to evaluate the effects of accelerated aging schedules under the two testing protocols.
- In future work we will continue to characterize DOE fuel cell contract deliverables, as well as benchmark other fuel cell technologies.
- We will continue to collaborate with other fuel cell testing laboratories, such as the Institute for Energy (Netherlands), and we will begin the maintenance of the technical specification that Working Group 11 has produced (single-cell test protocol).