V.A.4 Fuel Cell Testing at Argonne National Laboratory

Ira Bloom (Primary Contact), John Basco, Panos Prezas, Lee Walker
Argonne National Laboratory (ANL)
9700 South Cass Avenue
Argonne, IL 60439
Phone: (630) 252-4516; Fax: (630) 252-4176
E-mail: Ira.Bloom@anl.gov

DOE Technology Development Manager: Nancy Garland
Phone: (202) 586-5673; Fax: (202) 586-9811
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 Hydrogen, Fuel Cells and Infrastructure 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 Hydrogen, Fuel Cells, and Infrastructure 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.

Accomplishments

- Characterized one 5-kW complete system.
- Participated in and made technical presentations at the third and fourth meetings of the International Organization for Standardization Working Group 11 under Technical Committee 105 of the International Electrotechnical Commission, held on October 13-14, 2008, in Pusan, Korea, and on April 6-7, 2009, in Vancouver, BC, Canada, respectively. The goal of this international group is to draft the technical specification of a single-cell test protocol. Representatives from six countries attended.
- Began collaborative effort to compare the test protocols developed by the European FCTESTNET/ FCTES^{QA} and by DOE. The objective of the effort is to determine if there are significant differences in the procedures used to characterize the performance of fuel cell stacks and to age the stacks.

✧ ✧ ✧ ✧ ✧

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 standard fuel cell testing procedures to aid in the evaluation of different stack technologies. The procedures and methods used 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 low-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 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 a 5-kW, direct hydrogen fuel cell system 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 of this accelerated aging protocol, the DST cycling was stopped and the stack performance was characterized by measuring a sequential polarization curve.

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 1.100 h of the accelerated aging under the DST cycling conditions.

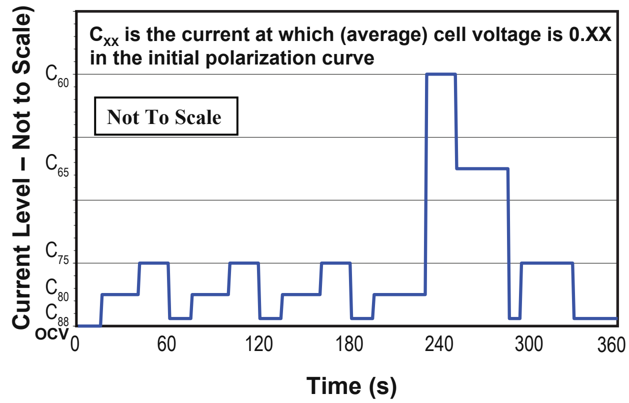

FIGURE 1. Dynamic Stress Test Profile used for Cycling Tests

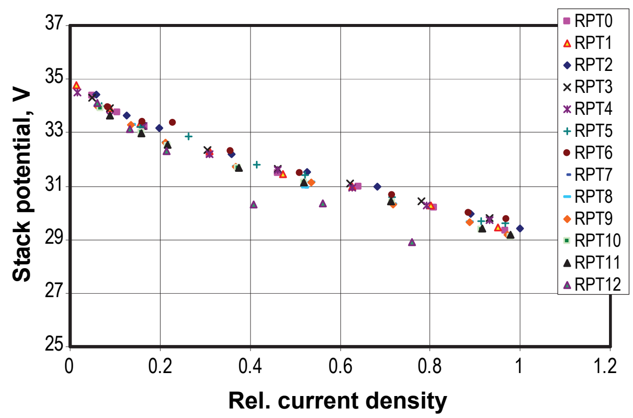

FIGURE 2. Polarization data from the aging experiment. The curves RP T0 to RP T12 represent polarization data taken after every ~100 h of operation with cycling according to the DST test profile. There were 40 cells in the stack.

After that, however, there was a significant decrease in the measured performance of the stack.

The stability of the stack voltage under load was then measured by running a constant power test at 25% of rated power for 120 h (Figure 3). These data indicate that under these conditions, there was a degradation of stack potential with time at a rate of approximately 16 mV/h.

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.

As part of the collaboration with FCTES^{QA}, we compared the performance of a hydrogen-fueled, 15-kW stack using the sequential polarization protocols

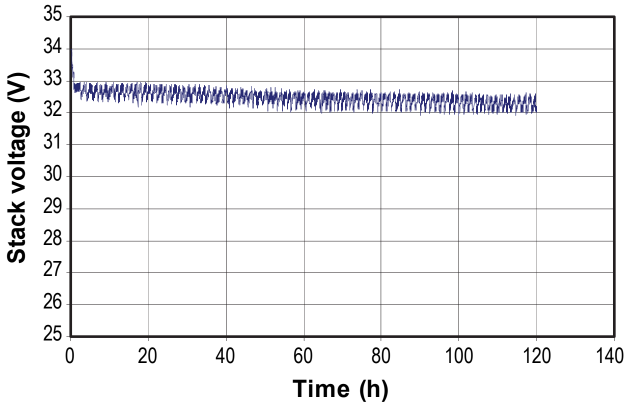

FIGURE 3. Plot of stack voltage vs. time during constant power test. The apparent oscillations in the voltage trace are due to peripherals (pumps, valves, etc.) switching on and off.

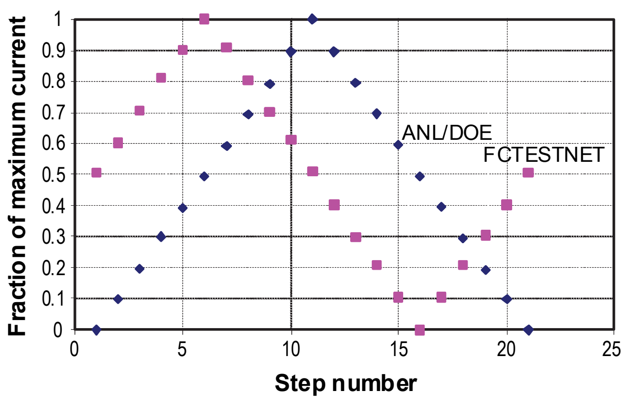

FIGURE 4. Sequence of current levels used in the polarization protocols developed by DOE and by FCTESTNET.

developed by FCTESTNET and by DOE. The major differences between the two are the sequence of currents used and the portion of the polarization experiment that is reported as the polarization curve. Figure 4 shows that the DOE protocol starts at open circuit then increases and decreases the current. The FCTESTNET protocol, on the other hand, starts at about 50% of the rated current then increases, decreases and finally

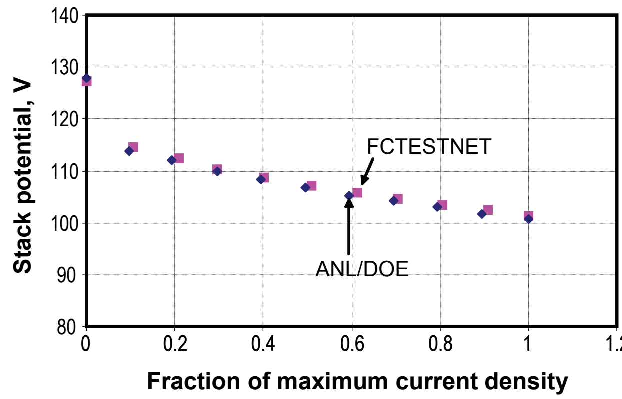

FIGURE 5. Comparison of polarization data obtained using the two protocols.

increases the current. The DOE protocol uses both current increasing and decreasing sections; that from FCTESTNET, only the current-decreasing portion is reported. Figure 5 shows the current-decreasing portion of the polarization curves obtained using the two protocols. There was no significant difference between the two. The observed difference between the curves is within the range of experimental error.

Conclusions and Future Directions

- Continue to characterize DOE fuel cell contract deliverables.
- Continue to benchmark other fuel cell technologies.
- Continue to collaborate with other fuel cell testing laboratories, such as the Institute for Energy (Netherlands), and FCTES^{QA}.
- Continue to work with Working Group 11 to draft the technical specification for a single-cell test protocol.
- Continue to upgrade the test facility by installing new test hardware and software and increasing the temperature and pressure limits of the cooling system.