V.A.8 Fuel Cell Testing at the Argonne Fuel Cell Test Facility: A Comparison of U.S. and EU Test Protocols

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

Collaborators:
G. Tsotridis and T. Malkow
European Commission, Directorate-General Joint Research Center, Institute For Energy
Petten, The Netherlands

DOE Manager
HQ: 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

Fiscal Year (FY) 2011 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.

FY 2011 Accomplishments

- Characterized a 10-kW fuel cell stack from NedStack on both the U.S. and European Union (EU) test and aging protocols.
- There was no significant difference between the results obtained with the two different test protocols.

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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 provide a means for easy comparison of the performance and expected life of the technology from different developers. In these procedures, the stack is characterized in terms of initial performance and durability. 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 potential or load 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

There is interest in the U.S. and in the 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 participated in a round-robin experiment where the results from different test sites are compared using a common fuel cell stack and the $FCTES^{QA}$ test protocols for sequential polarization curves. To complete our work on comparing polarization protocols, we also tested the stack using the DOE protocols. The major differences between the EU and DOE protocols are the sequence of currents used and the portion of the polarization experiment that is reported as the resulting data. Figure 1 shows that the DOE protocol starts at open circuit, and then sequentially increases and decreases the stack current in turn. The FCTESTNET protocol, on the other hand, can start at almost any current setting. In prior work, we used the FCTESTNET example shown Figure 1. Here, the test protocol starts at about 50% of the rated current; the current then increases, decreases, and finally increases again.

For the current work, we used the FCTESTNET protocol shown schematically in Figure 2, which starts

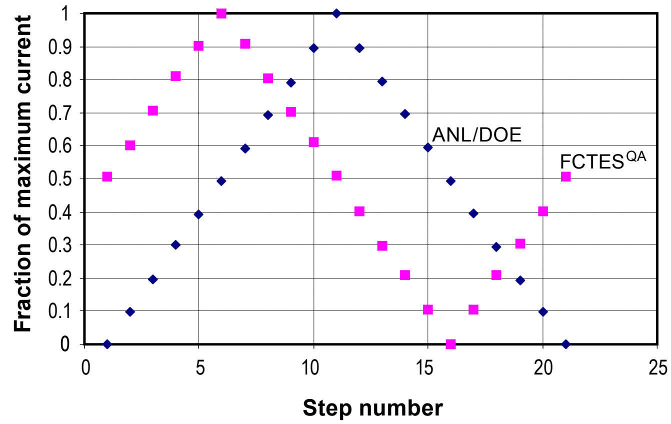

FIGURE 1. Sequence of current levels used in the polarization protocols developed by DOE and by FCTESTNET used in prior work.

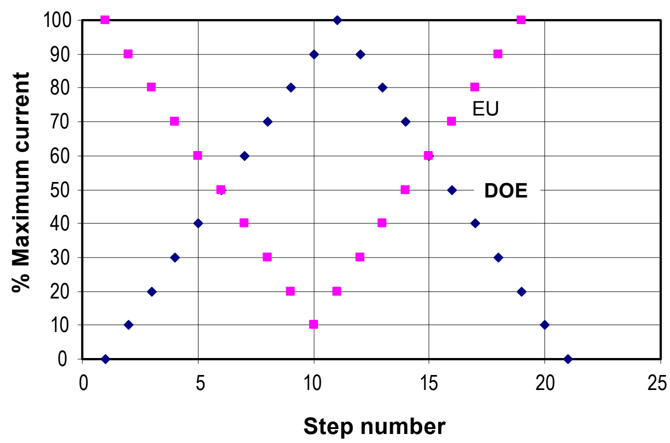

FIGURE 2. Sequence of current levels used in the polarization protocols developed by DOE and by FCTESTNET used in current work.

at 100% of the rated current before decreasing and then increasing. As before, 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 3 shows the current-decreasing portion of the polarization curves obtained from the 75-cell, 10-kW stack using the two protocols. There was no significant difference between the two curves.

To further characterize the stack as well as the difference between the two protocols, we performed a temperature sensitivity test on the stack. Here, the area-specific resistance (ASR) of the stack was calculated from the polarization results measured at four temperatures, 52.5, 57.5, 62.5 and 67.5°C, and at 1,000 mA/cm^2. These results are summarized in Figure 4.

A linear regression of the data shown in Figure 4 was performed. The regression coefficients, also shown in Figure 4, were greater than 0.95, indicating a strong

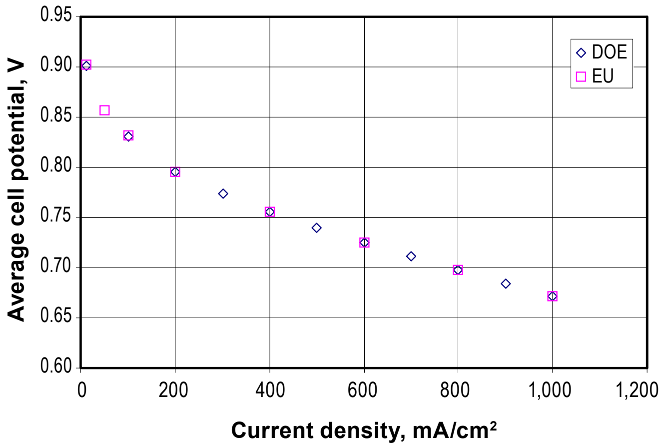

FIGURE 3. Comparison of polarization curves using the current levels and sequence shown in Figure 2. Test conditions: temperature, 62.5°C, air pressure, 0.7 barg; fuel pressure, 0.2 barg; air/fuel stoichiometries, 3/2; inlet gas relative humidity, 85%.

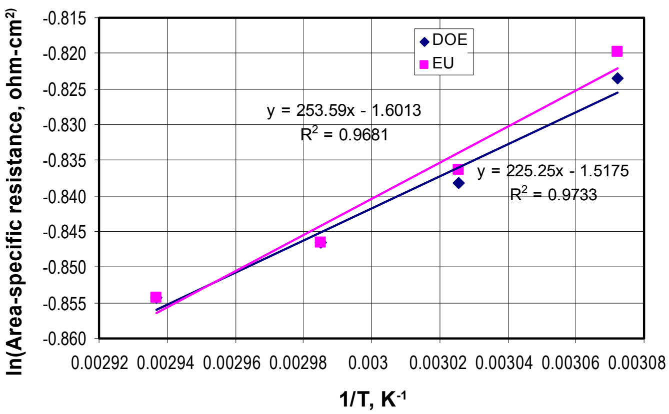

FIGURE 4. Arrhenius plot of stack area-specific resistance measured by both the DOE and EU protocols at 1000 mA/cm^2. The same conditions as described under Figure 3 were used, with the exception of stack temperature.

linear relationship between ln ASR and reciprocal absolute temperature. Thus, the results are consistent with Arrhenius kinetics. Figure 4 also shows that there was a slight difference between the two regression lines, which was due to slight differences (<0.5%) in the calculated values of the ASR.

Finally, we compared our results using the conditions described in Figure 3 with those obtained at JRC's Institute for Energy, as shown in Figure 5. The results showed that, at 1,000 mA/cm^2, there was ~14 mV difference in the average cell potential. It is possible that the slightly higher performance obtained in the testing at ANL versus results obtained at JRC are due to a more precise control of the humidification levels.

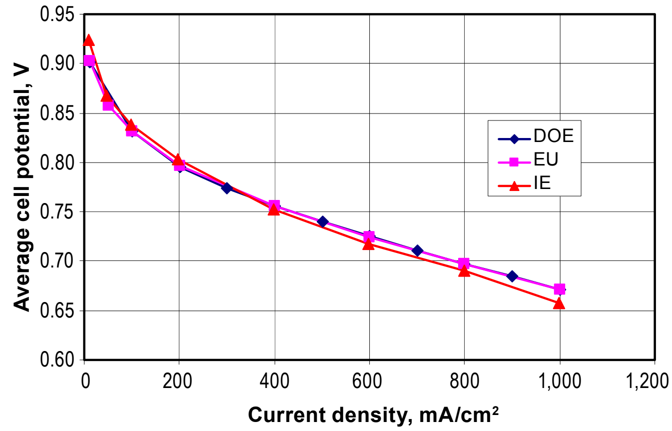

FIGURE 5. Polarization results obtained at ANL and at JRC's Institute for Energy. The curves denoted as DOE and EU were obtained at ANL using the DOE and EU protocols, respectively, under the conditions described under Figure 3. The curve denoted as IE was obtained at JRC's Institute for Energy using the same conditions.

Additional work is needed to evaluate the effects of accelerated aging protocols developed by DOE and FCTESTNET. There may be differences in stress levels under the two testing protocols, which, in turn, may cause differences in aging characteristics. Since we will perform these tests sequentially on the same stack, there may be additional effects in the data, such as path dependency. We will perform the same aging experiments in reverse order to determine if there is path dependency in the results.

Conclusions and Future Directions

- 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 10-kW stack showed that there was no significant difference between the polarization curves obtained under these two different 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). Additionally, as part of our work in TC/105/Work Group 11, we will begin to draft a technical specification for single-cell solid oxide fuel cell testing.

FY 2011 Publications

1. "A Comparison of Fuel Cell Test Protocols," I. Bloom, L.K. Walker, J.K. Basco, T. Malkow, G. De Marco and G. Tsotridis, ECS Transactions - 2010 Fuel Cell Seminar & Exposition Vol. 30, "Degradation in PEM Fuel Cells," Feb 2011.