Fuel Cell Testing at the Argonne Fuel Cell Test Facility:
A Comparison of US and EU Test Protocols

I. Bloom,[1] J. Basco,[1] L. Walker,[1] T. Malkow[2] and G. Tsotridis[2]

[1]Argonne National Laboratory

[2]European Commission, Directorate-General Joint Research Center, Institute For Energy

2011 DOE Hydrogen Program Annual Merit Review

Washington, DC

May 2011

This presentation does not contain any proprietary or confidential information

The work at Argonne National Laboratory was performed under the auspices of the US Department of Energy, Office of Hydrogen, Fuel Cells Technologies, under Contract No. DE-AC02-06CH11357.

The work at JRC is carried out under the FCTES^{QA} (Fuel Cell Systems Testing, Safety & Quality Assurance) STREP (Specific Targeted Research Project), in part funded by Sixth Framework Programme of the European Community on research, technological development and demonstration activities under contract # 020161.

FC051

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: $800K from DOE
- FY10: $500K
- FY11: $300K (tentative)

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
- FY11 Progress:
  - Characterized a 10-kW, PEM stack from NedStack
  - Test protocol comparison
    - Direct comparison of DOE test protocols with those developed in the EU
  - Performance and life characterization of a 2-kW stack is continuing

Characterization of a 75-cell, 10-kW PEM Stack From NedStack

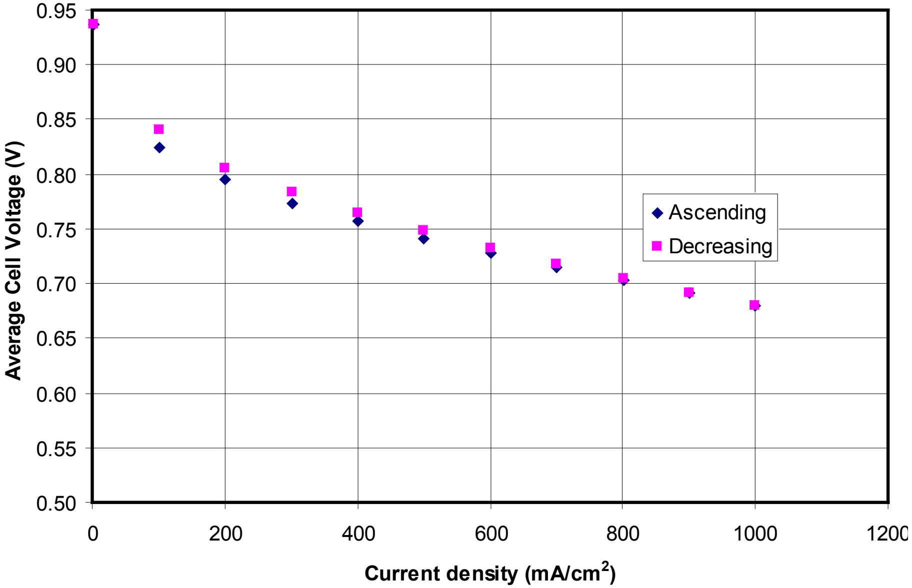
- The test plan consisted of polarization curves to define the performance characteristics of the stack under various conditions

- Baseline characterization: Sequential and random polarization curves
  - Stack temperature of 62.5°C
  - Air/fuel stoichiometries of 3/2
  - Dew point temperature of 60.1°C
  - Air pressure of 0.7 barg; fuel, 0.2 barg

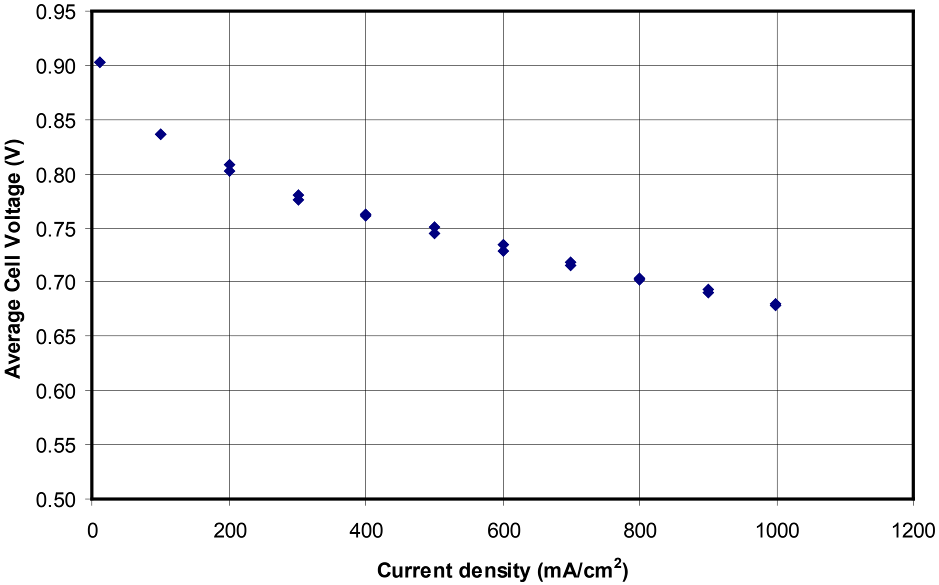
- Sensitivity tests
  - Stack temperature: 52.5, 57.5 and 62.5°C
  - Fuel stoichiometries: 1.7, 1.8, 1.9, and 2.0
  - Air stoichiometries: 2.25, 2.5, 2.75, and 3.0
  - Dew point: 61.4, 60.1 and 58.9°C

Baseline Characterization

Sequential polarization curve



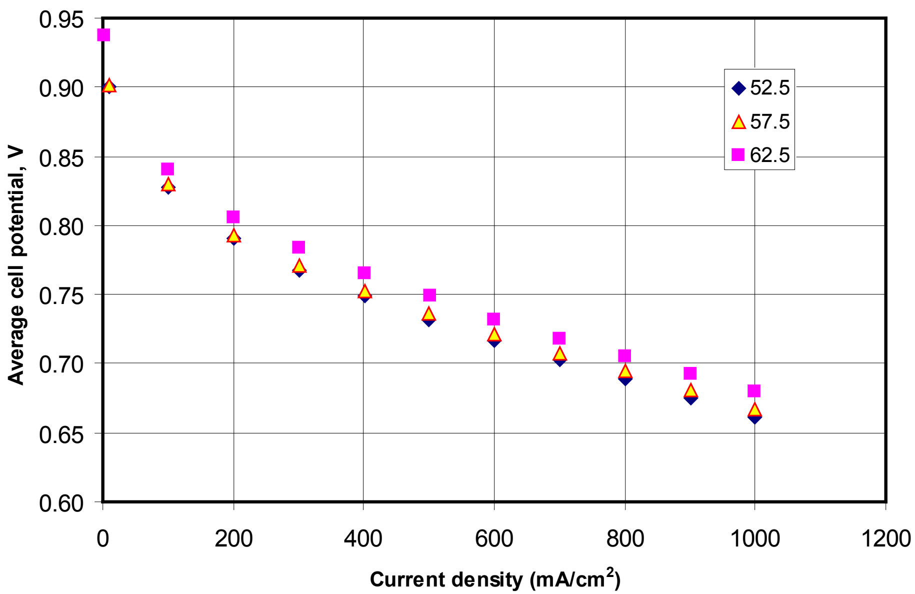
Random polarization curve

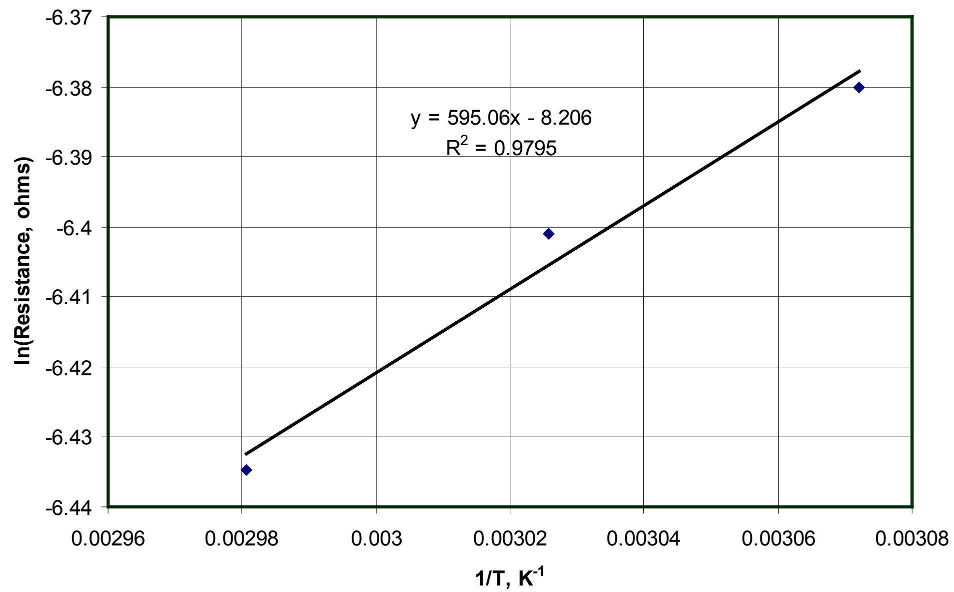


- There is very little difference between the two sets of polarization curves

Sensitivity Studies - Example: Stack Temperature

- Relative humidity was kept constant
- Stack performance is sensitive to operating temperature

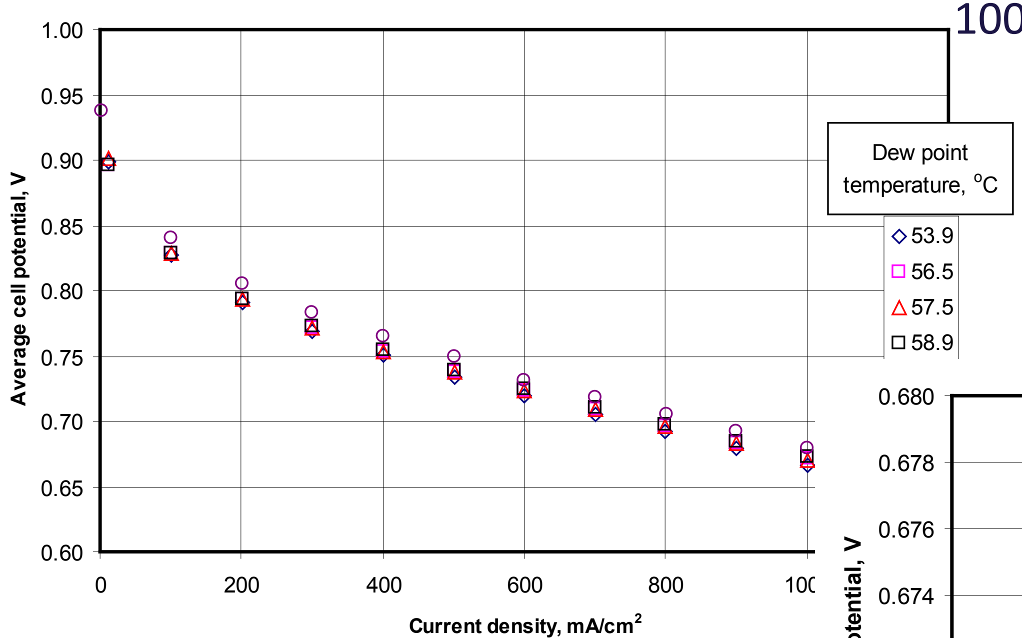


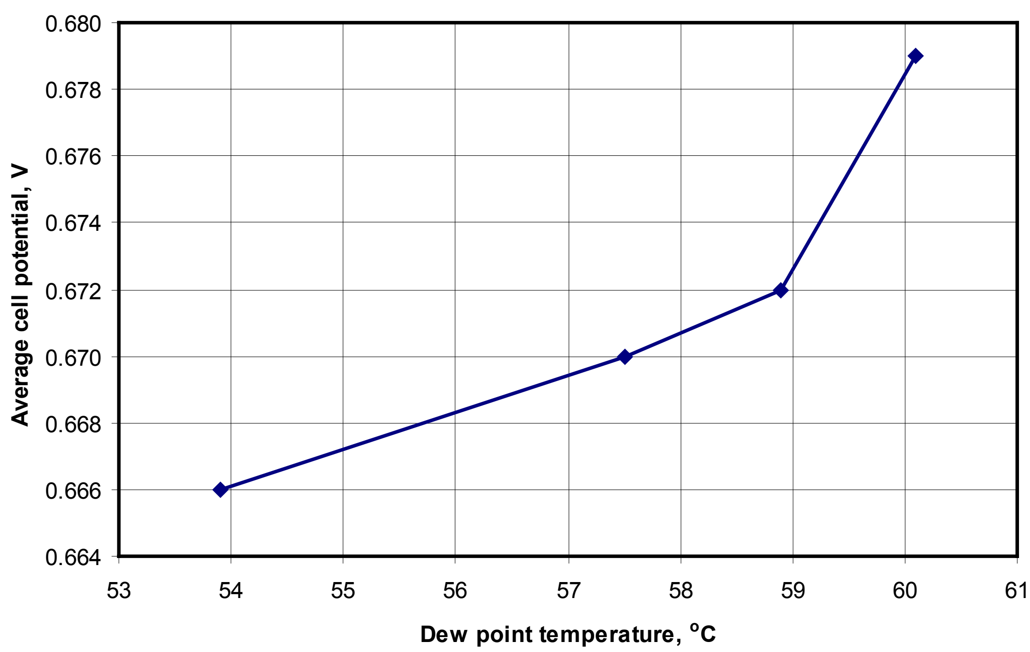


- Resistance of stack at 1000 mA/cm^2 is consistent with Arrhenius kinetics

Sensitivity Studies - Example: Dew point temperature

- Dew point temperature (humidification) has an effect on stack performance at 1000 mA/cm^2



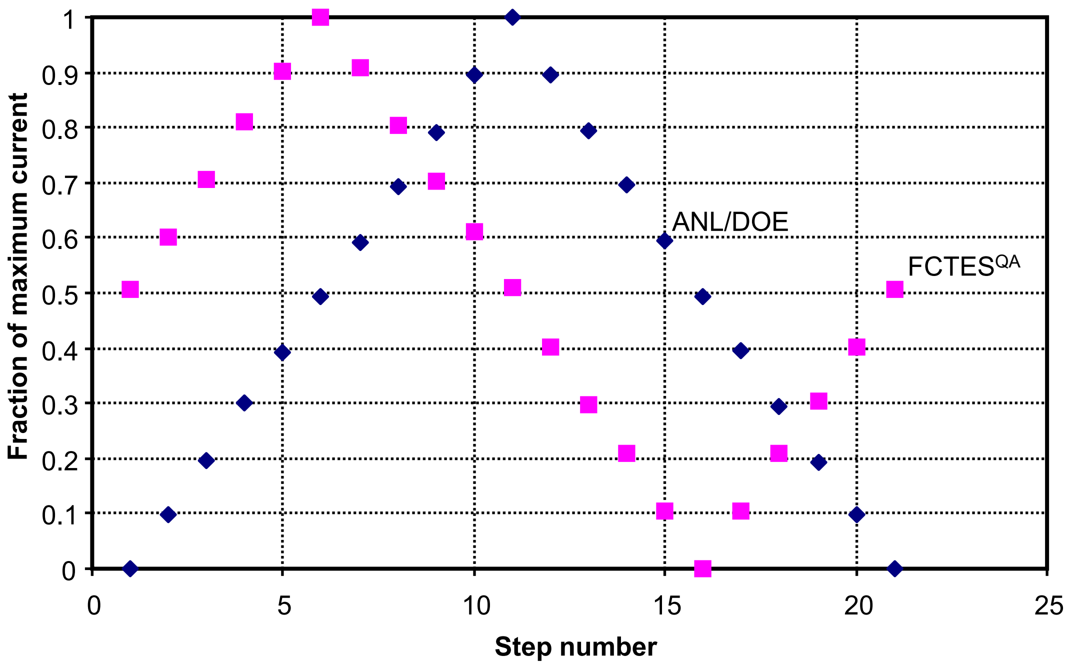


Protocol Comparison

- Background
  - 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 performance?
  - Understanding the differences will help DOE and fuel cell developers better understand test results
  - May facilitate fuel cell development
- Approach
  - A test plan was developed that incorporated both sets of protocols and the test was performed at Argonne
  - Additionally, resulting data were then compared to those obtained at JRC/IE

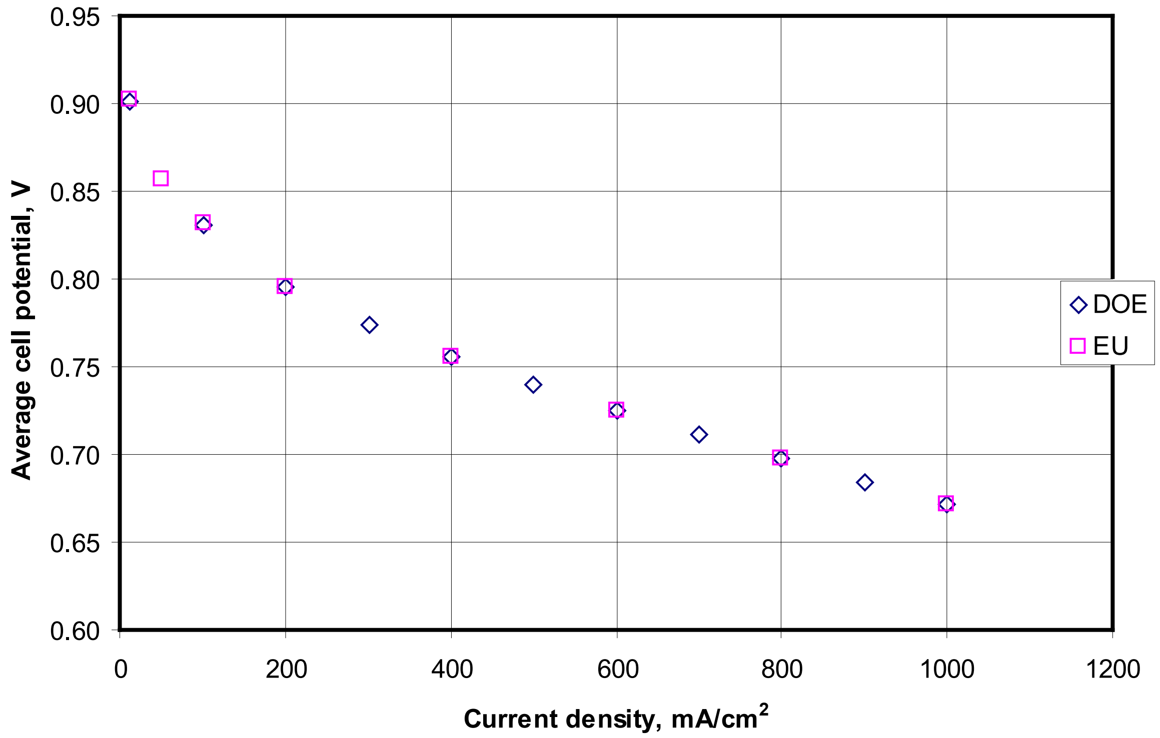
Comparison with Polarization Curve Protocol Used in EU

- 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



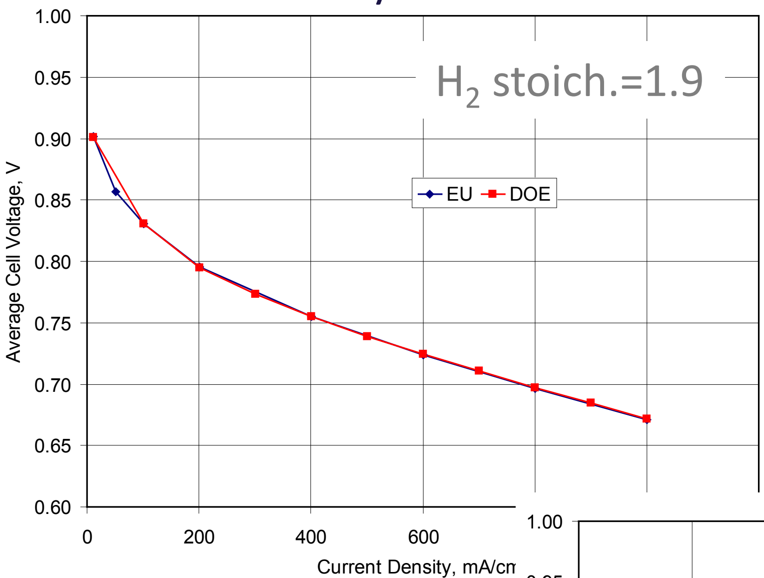
Comparison of Polarization Curves Using Both Protocols (1)

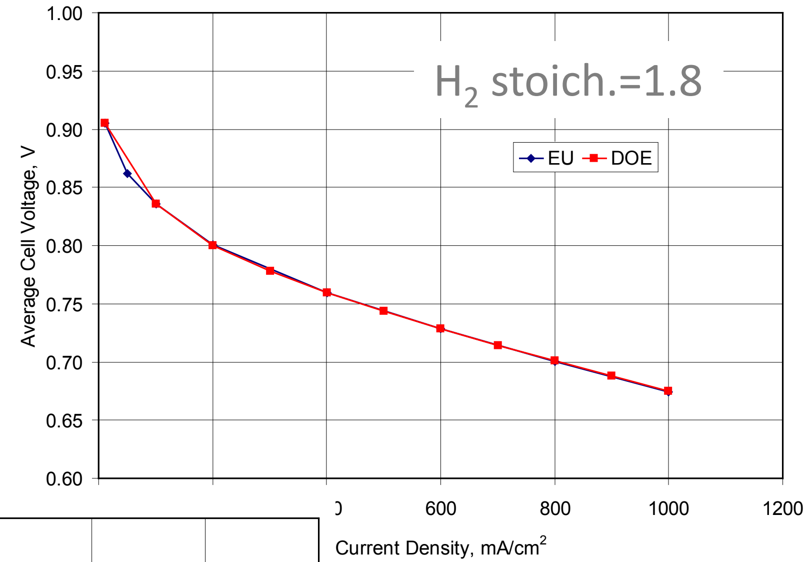
- Baseline conditions used
  - Temperature=62.5°C; air pressure=0.7 barg; fuel pressure, 0.2 barg
- No significant difference between results from the two protocols

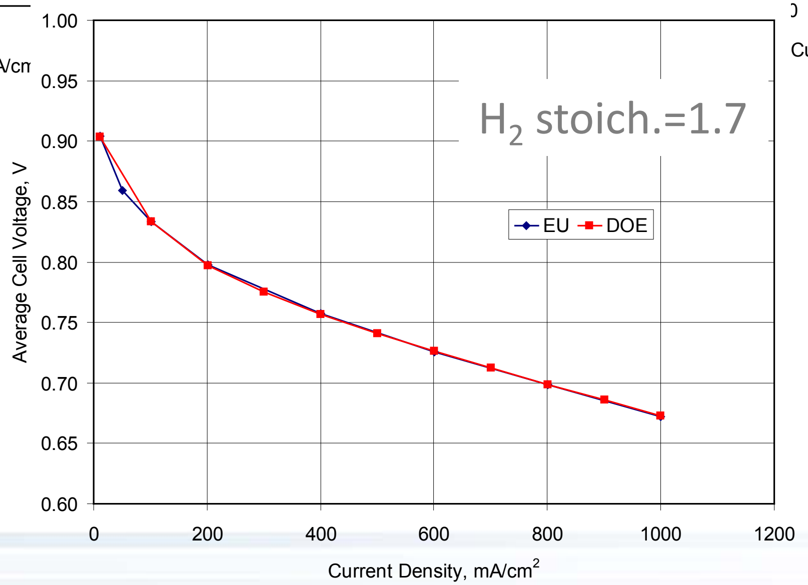


Comparison of Protocols (2) - Sensitivity Tests: H_2 Stoichiometry

- Tests were performed under baseline conditions, except that the hydrogen stoichiometry was varied



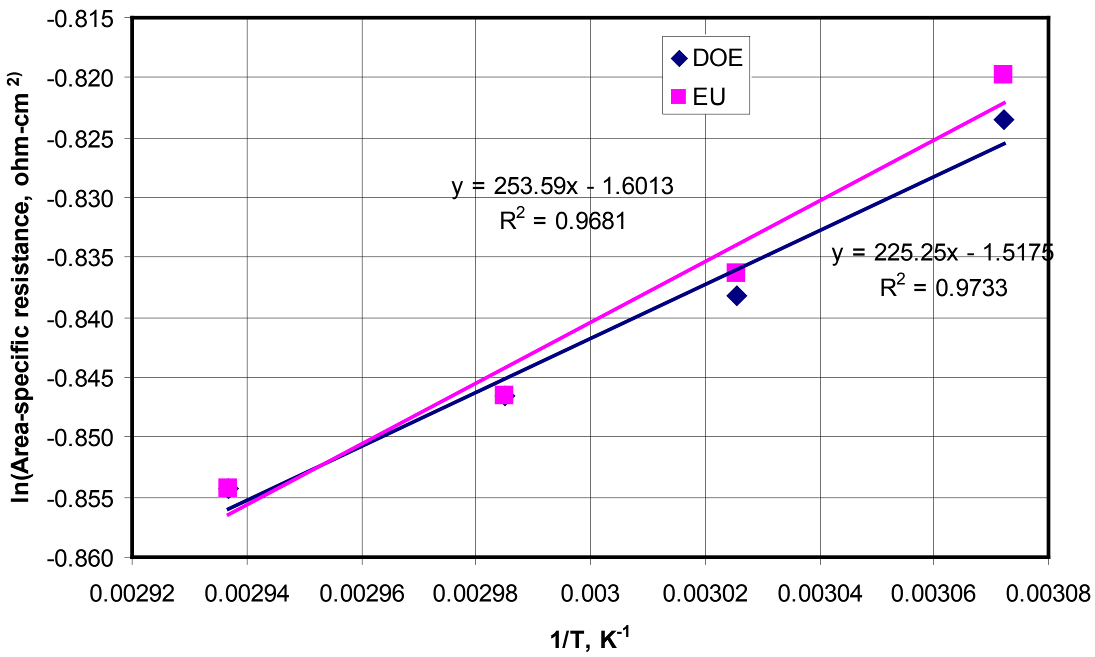




- H_2 stoichiometry has little effect on stack performance
- Results from two protocols agree

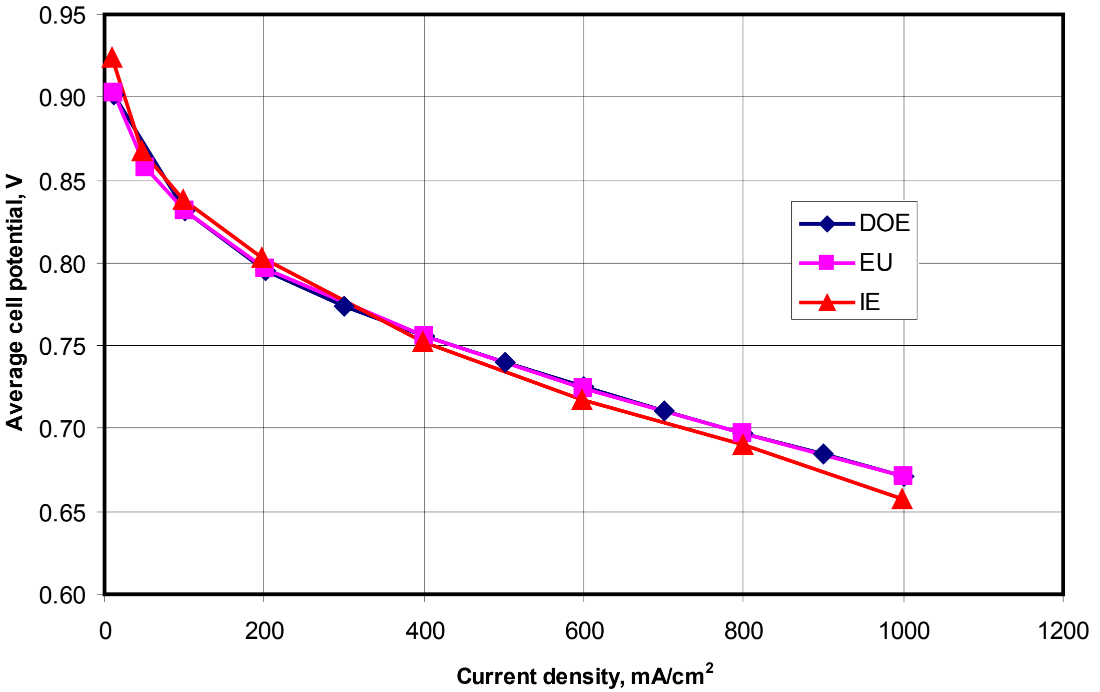
Comparison of Protocols (3) - Sensitivity Tests: Stack Temperature

- Repeat temperature sensitivity test using the EU protocol and compare these results to those obtained using the DOE protocol
- Plotting the average cell area-specific resistance at 1000 mA/cm^2 on an Arrhenius plot shows slight differences between them (~0.5% max. in calculated resistance)



Comparison of Data Between Test Sites

- Compare polarization data between ANL and JRC-IE, using the baseline condition
- The results show a 14-mV difference in average cell potential at 1000 mA/cm^2 (~2%)
- Cause of the difference is under investigation



Summary

- ANL and JRC-IE are collaborating with the European Union's FCTES^{QA} project to compare and validate the fuel cell test protocols being developed by the European Union and the United States. These protocols consist of how to obtain polarization curves and cycling profiles. The work at Argonne showed that when performed at one site, there were no significant differences in the shape and trend of the polarization curve. These findings were observed using two fuel cells stacks representing different technologies. In the polarization data there was a test-site-to-test-site difference, on the order of 5%.

- 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).