Fuel Cell Technologies Program Record	
Record #: 11003	**Date:** March 8, 2011
Title: Fuel Cell Stack Durability	
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Item

DOE-funded R&D work has enabled substantial improvements in durability, with automotive fuel cell stack and system durability in laboratory testing increasing from approximately 2,000 hours in 2006 to 4,000 hours in 2011. Durability in real-world testing of automotive PEMFC stacks has also improved, more than doubling from under 1,000 hours in 2006 to 2,500 hours in 2009.

Supporting Information

Laboratory Durability

In 2006, fuel cell durability was reported to be approximately 2,000 hours in laboratory testing [1], though the degree of degradation and the testing protocol did not necessarily conform to current DOE specifications. DOE support for development of advanced fuel cell materials has enabled dramatic increases in durability since 2006. By 2008, membrane electrode assemblies (MEAs) capable of operation with load cycling for over 7,300 hours had been demonstrated by 3M, though these MEAs did not yet satisfy DOE targets for PGM loading [2]. Subsequent advancements allowed durability to be maintained at lower PGM loading, and by 2010, MEAs with PGM loading of 0.15 mg/cm^2 (well below the 2010 target of 0.3 mg/cm^2) were capable of operation for 6,500 hours [3]. By 2011, continued progress had enabled up to 9,000 hours operation of these MEAs in the laboratory [4]. These long runtimes indicate a high degree of membrane durability, but catalyst durability and performance were not assessed in these tests. In separate testing, 3M demonstrated that MEAs containing 0.20 mg_{PGM}/cm^2 are already capable of meeting most 2017 accelerated stress testing targets [4], as summarized in Table 1.

Table 1. Status and targets for catalyst and MEA accelerated stress tests [4].

Test Protocol	Units	2011 Status (3M)	2017 Target
30,000 cycles, 0.6-1.0V	mV loss at 0.8 A/cm^2	40 mV loss	< 30 mV
	% Electrochemical surface area (ECSA) loss	18% loss	< 40%
	% mass activity	48 % loss	< 40%
1.2 V hold for 400 hours	mV loss at 1.5 A/cm^2	10 mV loss	< 30 mV
	% ECSA loss	10% loss	< 40%
	% mass activity	10 % loss	< 40%
Hold at open circuit voltage (OCV) for 500 hours	H_2 crossover mA/cm^2	13±4 mA/cm^2	< 20 mA/cm^2
	% OCV loss	12±5% loss	< 20%

In short stack testing with GM, 3M materials demonstrated 2000 hours durability with approximately 12% degradation in performance at 1.5 A/cm^2 [3,5]. The membranes used in this stack testing did not contain a chemical mitigator, which is often used to slow chemical degradation caused by free radicals.

In testing of commercial MEAs in full-size power plants, Nuvera Fuel Cells has demonstrated durability during load cycling of up to 9,000 hours with less than 4% degradation in power [6]. This result was achieved using durability protocols developed for material handling applications, and using catalyst loadings around 0.5 mg/cm^2, which are significantly higher than DOE target loadings; therefore, the result does not represent achievement of DOE transportation durability targets, but it does represent progress toward those targets.

Analysis of proprietary laboratory testing results (supplied by fuel cell developers) at NREL provides an annual update on durability status of state-of-the-art fuel cell short stacks and systems. The NREL analysis examines data for automotive, material handling, backup power, and stationary power applications, providing aggregate results for each application, while protecting the proprietary data (Figure 1). As of April 2012 [7], average operating hours of automotive stacks in the aggregate data was 2,700 hours, while projected time to 10% voltage degradation averaged 4,000 hours. Projected time to 10% degradation varied with the type of stack being tested, with short stacks exhibiting slightly higher durability (4,400 hours) than full stacks (3,600 hours). The composite data represents a range of testing procedures with significant variation in degradation. Average projected time to 10% voltage degradation decreased with increasing severity of testing, ranging from 5,600 hours for steady-state testing, to 4,500 hours under an automotive duty cycle, to 2,700 hours for accelerated stress testing. Although catalyst loadings and testing protocols used in the proprietary testing do not necessarily conform to DOE specifications, the updated durability data provides an indication of the status from several developers of fuel cell durability for a range of applications.

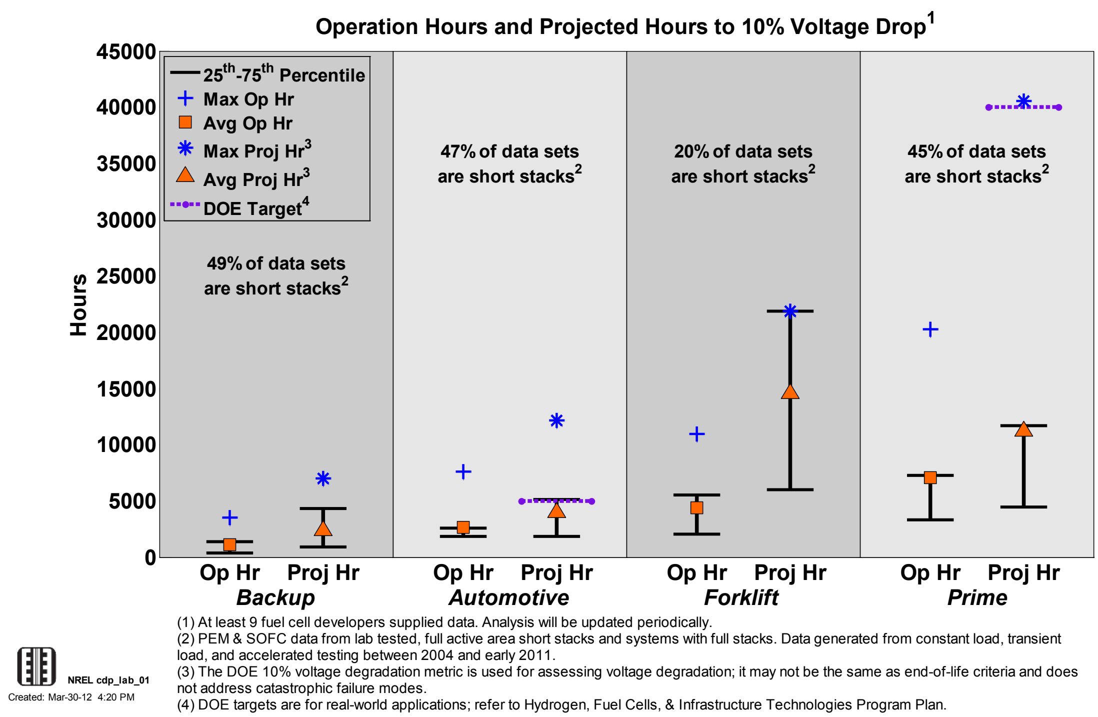

Figure 1. Aggregate durability results from laboratory testing of fuel cell short stacks and systems.

On Road Durability

Through the Technology Validation's Learning Demonstration, vehicles have been driven in real-world operation over the last 7 years. Data have been collected on hours of operation of generation 1 and 2 vehicles. Analysis of the data by NREL has shown that the maximum projected durability with 10% degradation has more than doubled since 2006. In 2006, the maximum projected durability was 950 hours [8], increasing to 2,500 hours in 2009 [9]. Limited data sets and the need to protect proprietary data have prevented publication of maximum projected durability in the years since 2009. However, average durability (projected time to 10% degradation) was 1,700 hours in 2011 [10], an increase from 700 hours in 2006 [8] and 1,100 hours in 2009 [9].

References

[1] DOE Hydrogen Program Record #5036, "Fuel Cell Stack Durability," April 20, 2006. http://www.hydrogen.energy.gov/pdfs/5036_fuel_cell_stack_durability.pdf

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[3] Mark K. Debe et al., "Advanced Cathode Catalysts and Supports for PEM Fuel Cells," in: FY 2010 Progress Report for the DOE Hydrogen Program, U.S. Department of Energy, Washington, DC, 2010, pp. 790. http://www.hydrogen.energy.gov/pdfs/progress10/v_e_1_debe.pdf

[4] Mark K. Debe et al., "Advanced Cathode Catalysts and Supports for PEM Fuel Cells," presentation at the 2011 U.S. DOE Hydrogen and Fuel Cells Program Annual Merit Review and Peer Evaluation. http://www.hydrogen.energy.gov/pdfs/review11/fc001_debe_2011_o.pdf

[5] Mark K. Debe, 3M Company, private communication, June, 2011.

[6] Scott Blanchet et al., "Durability of Low Platinum Fuel Cells Operating at High Power Density," in: FY 2011 Progress Report for the DOE Hydrogen Program, U.S. Department of Energy, Washington, DC, 2011. http://www1.eere.energy.gov/hydrogenandfuelcells/annual_reports.html

[7] Jennifer Kurtz et al., "State-of-the-art Fuel Cell Voltage Durability Status 2012 Composite Data Products," CDP#1: "Lab Data Hours Accumulated and Projected Hours to 10% Stack Voltage Degradation," http://www.nrel.gov/hydrogen/pdfs/55288.pdf

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[10] *Ibid*., CDP#87: Fuel Cell Stacks Projected Hours to 10% Voltage Degradation with Two Fits