VII.6 Material Handling Equipment Data Collection and Analysis

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Project Start Date: October 2012
Project End Date: Project continuation and direction determined annually by DOE

Overall Objectives

- Evaluate fuel cell material handling equipment (MHE) by performing independent technology assessment in real world operation conditions
- Focus on fuel cell system performance and operation
- Leverage data processing and analysis capabilities developed under the fuel cell vehicle learning demonstration project
- Support market growth by providing analyses and results relevant to the market's value proposition
- Report on technology status to fuel cell and hydrogen communities and other key stakeholders like end users

Fiscal Year (FY) 2015 Objectives

- Leverage existing data and results developed under American Recovery and Reinvestment Act (ARRA) to continue the collection of MHE data on new systems on a voluntary basis
- Validate the status of the MHE market, which continues to expand and evolve
- Develop at least 20 updated composite and detailed data products on fuel cell MHE on durability, operation, and infrastructure performance

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section of the Fuel Cell Technologies Office (FCTO) Multi-Year Research, Development, and Demonstration (MYRDD) Plan:

(A) Lack of Fuel Cell Electric Vehicle and Fuel Cell Bus Performance and Durability Data

(D) Lack of Hydrogen Refueling Infrastructure Performance and Availability Data

Contribution to Achievement of DOE Technology Validation Milestones

This project contributes to the achievement of the following DOE milestones from the Technology Validation section of the FCTO MYRDD Plan:

- Milestone 4.2: Updated composite data products for material handling and backup power published. (3Q, 2012)
- Milestone 4.3: Report safety event data and information from ARRA projects. (3Q, 2013)

FY 2015 Accomplishments

- The ninth set of technical composite data products (CDPs) was published on performance and operation for fuel cell MHE with 24 updated results.
- Access to the largest single set of technology validation data in the program's history was negotiated, including hundreds of new-generation vehicles in two different MHE classes, from private commercial sites receiving no direct government funding. This data set represents a 30% increase in total vehicle hours from the ARRA project.
- Some of the key results included:
  - Over 2.6 million hours of MHE operation in commercial distribution facilities, collected from 720 vehicles, including 230 new vehicles, were documented.
  - Dispensing of almost 288,000 kilograms of hydrogen was validated.
  - A B50 time to 10% voltage decay of 10,000 hours was demonstrated.
  - Mean fueling time of 2.5 minutes (which is key to the fuel cell MHE value proposition) was validated.
  - Mean vehicle operating times between fueling of 3.7 hours were validated.

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INTRODUCTION

The U.S. Department of Energy designated more than $40 million in ARRA funds for the deployment of up to

1,000 fuel cell systems. This investment is enabling fuel cell market transformation through development of fuel cell technology, manufacturing, and operation in strategic markets where fuel cells can compete with conventional technologies. The strategic markets include MHE, backup power, stationary power, and portable power, and the majority of the deployed systems are in the MHE and backup power markets. NREL continues to analyze operational data from the MHE sector, because it is the market segment with the most rapid growth and technological evolution. MHE data are provided voluntarily by industry. The data collection has ended for backup power and stationary systems.

The project includes both end users and system developers: Air Products, FedEx, GENCO, Nuvera Fuel Cells, Plug Power, and Sysco Houston. The evaluation focused on fuel cell stack durability, reliability, refueling, safety, and value proposition. The deployment partners provided approximately $53 million in industry cost share [1]. In addition to the ARRA cofunded fuel cell backup power demonstrations, DOE supported additional demonstration projects with other federal agencies through interagency agreements. The Department of Defense and the Federal Aviation Administration are two agencies with fuel cell backup power demonstrations that also submitted operational and deployment data to NREL. All results covered in this report, will include ARRA, and private commercial sites that received no direct government funding. The degradation result, Figure 1, also includes interagency agreement data.

APPROACH

The project's data collection plan builds on other technology validation activities. Project partners collect operation, maintenance, and safety data for fuel cell system(s) and accompanying infrastructure. Then they send data to NREL in a manner consistent with security procedures. NREL receives the data quarterly, then stores, processes, and analyzes data in NREL's National Fuel Cell Technology Evaluation Center (NFCTEC). The NFCTEC is a controlled access, off network analysis facility. An internal analysis of all available data is completed quarterly, and a set of technical CDPs is generally published every six months. Publications are uploaded to NREL's technology validation website [2] and presented at industry relevant meetings. The CDPs present aggregated data across multiple systems, sites, and teams in order to protect proprietary data and summarize the performance of hundreds of fuel cell systems and thousands of data records. A review cycle is completed before the CDPs are published. This review cycle includes providing detailed data products (DDPs) of individual system- and site-performance results to the specific data provider. DDPs also identify the individual contribution to the CDPs.

RESULTS

The initial ARRA funding for MHE kicked off rapid growth of the fuel cell MHE industry. This growth is reflected directly in the large amount of additional data NREL was able to secure from private commercial sites receiving no direct government funding.

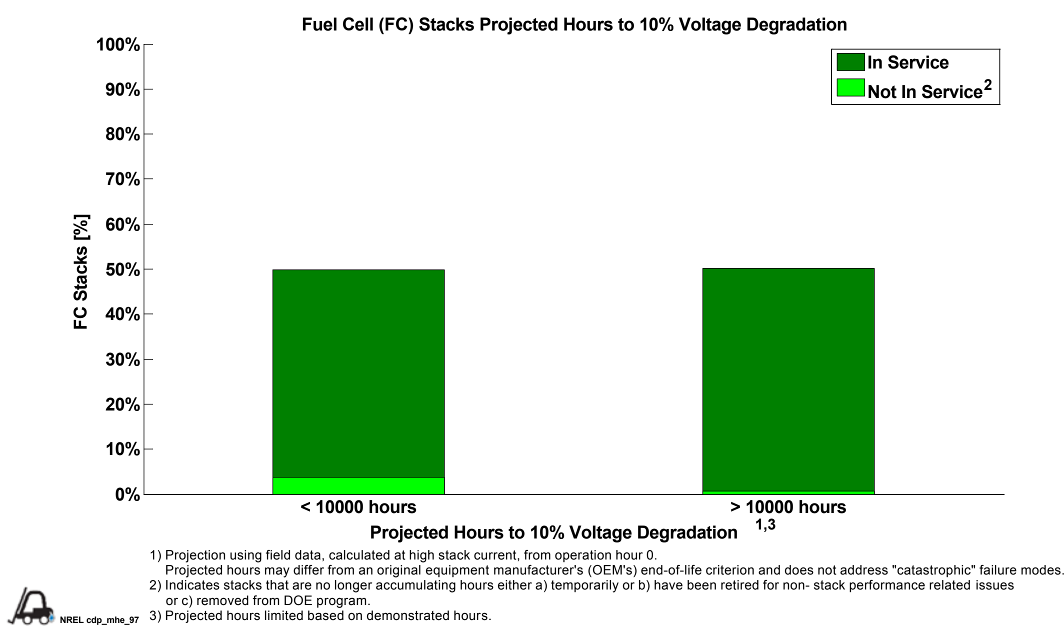

FIGURE 1. Fuel cell stacks projected hours to 10% voltage decay degradation (cdp_mhe_97)

The new data set represents an increase in vehicle operation hours of approximately 30% over the previous ARRA sites, and adds 230 new vehicles to the data set [3]. Yet, these data represent only a piece of the MHE fleet deployed in United States logistics warehouses. Total MHE operating hours tracked in this program now stands at nearly 2.7 million across all fleets and classes. MHE are broken down into classes based on the capabilities of the vehicle. These data represent Classes I (sit-down counterbalance), II (stand-up, high reach, narrow aisle), and III (powered pallet jacks and tow tractors) trucks.

The new fleet data represent newer systems, which are newer generation technologies. This can be seen in Figure 2, represented in a move of the mean operating hours on each vehicle from 4,700 to 4,100. The maximum actual stack hours remains at 16,610, as was reported in previous CDPs under the ARRA program [5].

The projected B50 time to 10% voltage decay for the stacks is 10,000 hours across all vehicle classes. See Figure 1. In other words, half of the vehicles are projected to reach 10% voltage decay of their stacks in 10,000 hours. The 10% decay metric does not represent end of life, but rather a metric for measuring decay in fuel cell stack performance. The fraction of vehicles projected to reach 10% decay before 10,000 hours was increased somewhat by the new data set, partially because some of the machines in operation have design lifetimes less than 10,000 hours.

As reported earlier in this project [4], refueling time is critical to the value proposition for fuel cell MHE. The mean refuel time is just over 2.5 min, with the majority of refuel events completing in less than 5 min. See Figure 3. The mean fuel amount delivered is 0.7 kg, and the mean operating time between fueling is 3.7 h. This does not necessarily represent the vehicle autonomy, as there are other human factors that dictate when fueling is convenient (e.g., breaks, shift changes, or proximity to a fuel dispenser).

One-third of fueling events take place within 5 min of one another, and 73% within 20 min. See Figure 4. This usage pattern has important implications for station design with respect to back-to-back fills, something that light duty vehicle stations also currently struggle with. The fueling largely takes place at 350 bar, which represents a shift from 250 bar used earlier in some applications.

CONCLUSIONS AND FUTURE DIRECTIONS

- NREL has secured an additional new data set, beyond that presented here, that represents a large fraction of the commercial fuel cell MHE installations in the United States. The data includes approximately 2,000 vehicles, or four times the size of the original ARRA project. The source and types of data are different, which may lead to different results and findings.
- NREL wishes to continue to track the progress of this important market segment and report CDPs publicly, while providing important value-added analysis back to industry.

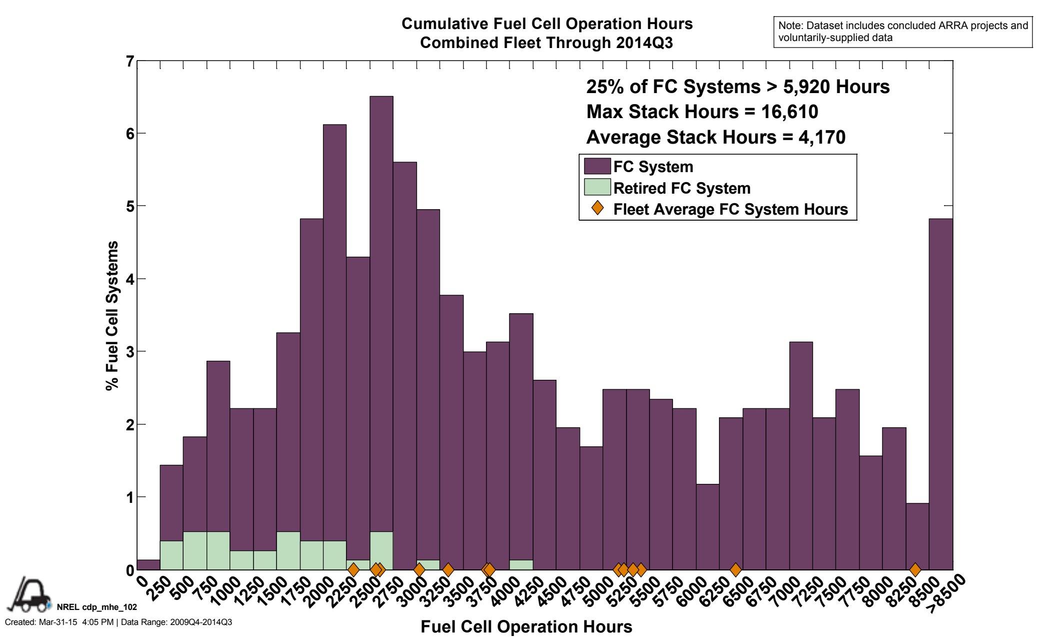

FIGURE 2. Cumulative fuel cell operation hours combined fleet through 2014Q3 (cdp_mhe_102)

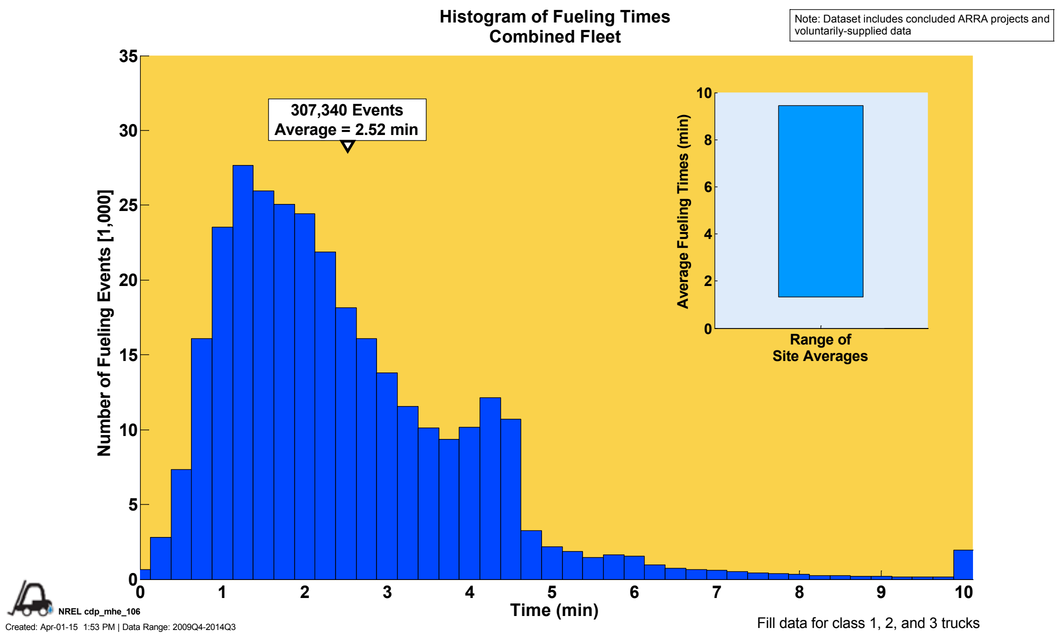

FIGURE 3. Histogram of fueling times, combined fleet (cdp_mhe_106)

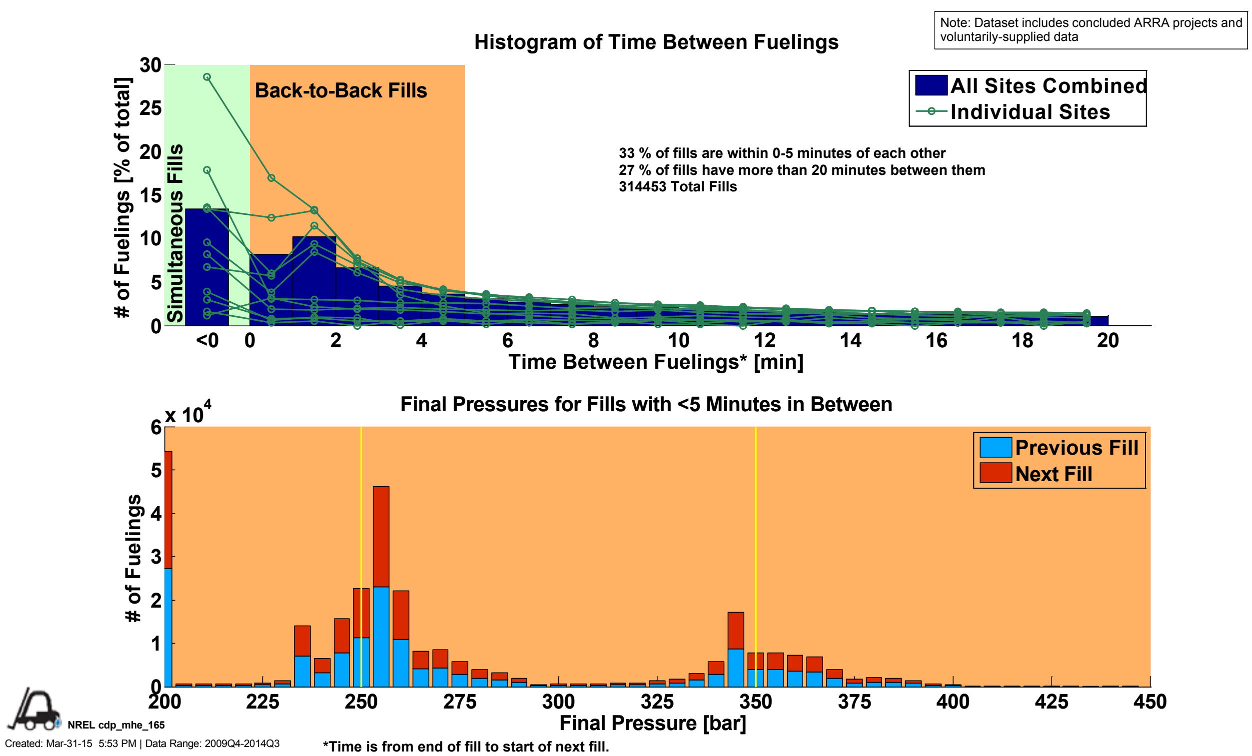

FIGURE 4. Histogram of time between fuelings, relative to the dispensers (cdp_mhe_165)

FY 2015 PUBLICATIONS/PRESENTATIONS

1. Ainscough, C., Kurtz, J., *ARRA Material Handling Equipment Composite Data Products: Data through Quarter 3 of 2014*, Golden, CO: The National Renewable Energy Laboratory, 2015.

2. Ainscough, C., *Material Handling Equipment Data Collection and Analysis,* Washington, DC: U.S. Department of Energy, 2015.

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1. *Highlights from U.S. Department of Energy's Fuel Cell Recovery Act Projects*. Washington, DC: U.S. Department of Energy, February 2014. http://energy.gov/eere/fuelcells/downloads/highlights-us-department-energys-fuel-cell-recovery-act-projects.

2. *Fuel Cell and Hydrogen Technology Validation*. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/hydrogen/proj_tech_validation.html.

3. Kurtz, J., *Forklift and Backup Power Data Collection and Analysis*. Washington, DC: U.S. Department of Energy, 2014, http://www.hydrogen.energy.gov/pdfs/progress14/vii_a_6_kurtz_2014.pdf.

4. Ramsden, T., *An Evaluation of the Total Cost of Ownership of Fuel Cell-Powered Material Handling Equipment*. Golden, CO: National Renewable Energy Laboratory, April 2013.

5. Kurtz, J., et al., *ARRA Material Handling Equipment Composite Data Products: Data through Quarter 4 of 2013*. Golden, CO: National Renewable Energy Laboratory, June 2014. http://www.nrel.gov/docs/fy14osti/62130.pdf.