IX.1 Direct Methanol Fuel Cell Material Handling Equipment Demonstration

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Subcontractors:
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Project End Date: March 31, 2013

Overall Objectives

- Operate and maintain fuel-cell-powered material handling equipment (MHE) using direct methanol fuel cell (DMFC) technology.
- Compile operational data of DMFCs and validate their performance under real-world operating conditions.
- Provide an independent technology assessment that focuses on DMFC system performance, operation, and safety.
- Evaluate the market viability of using DMFCs in material handling applications.

Fiscal Year (FY) 2013 Objectives

- Complete regular analysis of operation data through December 2012.
- Complete validation of operation against the operational project target for calendar days and hours of operation per unit.
- Complete durability and reliability analyses of units.
- Complete value proposition analysis of DMFCs MHE technology.

Barriers

This project addresses non-technical issues that prevent full commercialization of fuel cells.

Technical Targets

No specific technical targets have been set.

FY 2013 Accomplishments

- Analyzed 251,000 hours of operation from 131 units operating at five sites.
- Completed operation analysis against calendar time and hours (median hours of DMFC unit operation was 1,391).
- Completed durability analysis of DMFC units.

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INTRODUCTION

The National Renewable Energy Laboratory (NREL) and the U.S. Department of Energy (DOE) are interested in supporting the development of early market applications for fuel cell technologies. A study by Battelle Memorial Institute, "Identification and Characterization of Near-term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets," showed that fuel cells have the potential to power material handling equipment (also known generically as forklifts) at a lower overall cost than lead-acid batteries for certain types of operations [1]. Battery-powered forklifts typically use lead-acid batteries that can only provide enough power for one 8-hour shift. Multi-shift operations therefore generally require additional battery packs and battery change-outs, which reduces productivity and increases costs of operation.

NREL and DOE are currently evaluating the benefits of hydrogen-fueled polymer electrolyte membrane (PEM) fuel cells for MHE and have found that PEM fuel-cell-powered MHE can have a lower total cost of ownership compared to battery-powered forklifts [2,3]. As a supplement to the hydrogen-fueled PEM fuel-cell-powered forklift deployment testing, NREL is investigating the use of DMFC technologies in material handling applications. DMFCs, which use a liquid methanol fuel, hold promise to deliver many of the same operational benefits of hydrogen-powered fuel cell MHE, including long run times, short fueling times, and increased productivity. Liquid alcohol fuels such as methanol offer reduced infrastructure costs, high energy density, and low overall fueling costs.

APPROACH

NREL has partnered with Oorja Protonics on a project to demonstrate and evaluate DMFCs to provide power for MHE in four commercial wholesale distribution centers. In total, 75 DMFC-powered Class III pallet jacks have been deployed in warehouses operated by Unified Grocers, Testa Produce, and Earp Distribution. DMFC lifts are being operated two shifts per day for a 15-month deployment, with 3,500 to 5,000 total operational hours expected on each unit.

As part of the project, Oorja built, tested, and deployed its OorjaPac Model 3 DMFC power pack into Class III pallet jacks. The DMFC system delivers an output power of approximately 1.5 kW and includes a 3-gallon methanol storage tank expected to provide approximately 12 hours of autonomy between fuelings. Methanol fuel is being dispensed to the DMFC MHE using the OorjaRig methanol dispenser, which is designed to meet all relevant fire and safety codes for indoor methanol dispensing. Oorja is collecting data on both the DMFC systems and the supporting methanol fueling infrastructure. NREL has compiled and analyzed these data and is providing a third-party assessment on the performance of DMFCs used in material handling applications. As part of the 15-month deployment, DMFCs lifts were operated for two shifts per day, with a total operational target of 3,500 hours of use for each unit.

RESULTS

In total, the DMFC MHE fleet had more than 251,000 hours of operation as of December 2012. DMFC systems had significant usage, with over half of the units logging more than 1,500 hours of operation, and nearly 25% of the systems reaching more than 2,370 hours (see Figure 1). A few systems have surpassed the minimum operational target of 3,500 hours.

The OorjaPac Model 3 DMFC power packs used in this deployment project act in concert with traditional MHE battery systems. Unlike traditional battery systems that have limited run time and require frequent battery changes and charging from the electricity grid, the OorjaPac DMFC system acts as an onboard battery charger, maintaining the battery pack state-of-charge and eliminating electric-grid-based battery charging. Under this configuration, actual DMFC operation time depends on the battery state-of-charge. With a high charge level, the DMFC system may turn off while the pallet jack continues to be used. Hence, the operation hours noted above reflect actual run-time of the DMFC systems but may underestimate actual MHE hours of operation.

The DMFC Class III pallet jacks are deployed in warehouses operating two shifts per day. Data provided indicate that DMFC systems are typically operated 7 to 12 hours per day (with actual MHE operation hours potentially higher). NREL found that DMFC systems operate for an average of 8.7 hours between methanol fuelings (see Figure 2). Thus, the DMFC systems can easily operate for a full shift on a single methanol fill, and given their typical

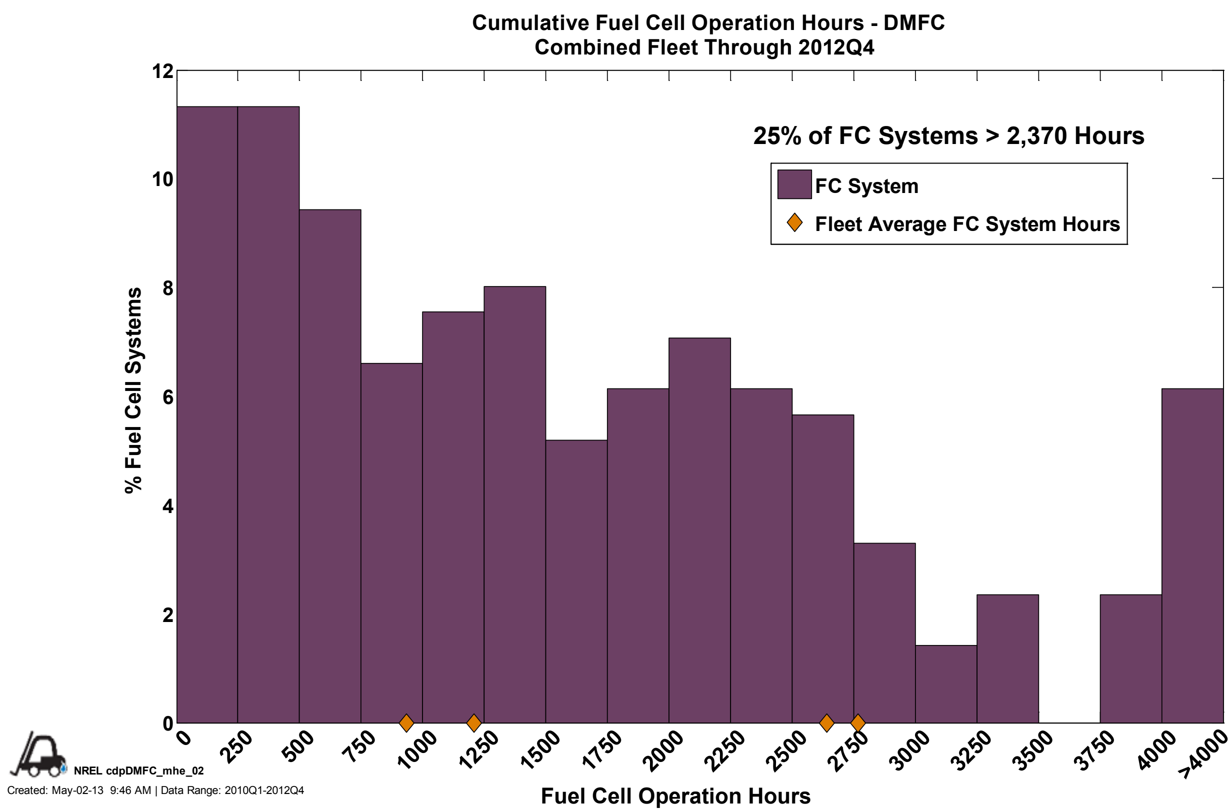

FIGURE 1. Fuel Cell Unit Operational Hours

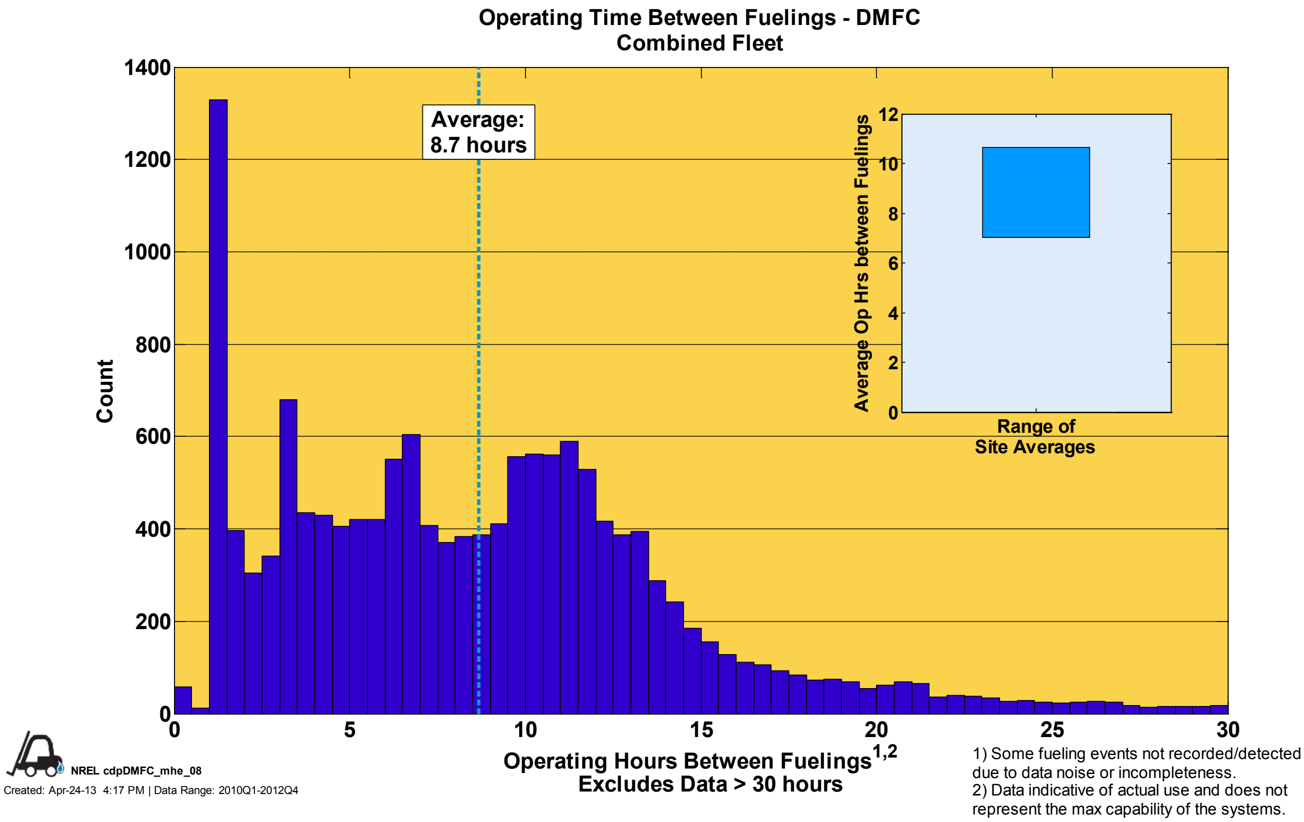

FIGURE 2. DMFC Operation Hours between Fuelings

use pattern, they can often operate for a complete two-shift day on a single fill. Reflecting this, analysis of the methanol fueling data shows that the DMFC systems are filled one time per day on average.

NREL analyzed individual DMFC systems to characterize system voltage, current, and power; maximum voltage and power over time; and stack voltage decay. A voltage and power degradation analysis is completed for each unit and fleet. The degradation analyses are projected times to 10% voltage degradation and a lower power limit. Actual results not published because the results are proprietary.

TABLE 1. Performance Summary of the Oorja DMFC Systems

Sites	5
Number of fuel cell forklift power units analyzed	131
Total hours of operation	251,000
Total methanol fueling events	>14,000
Average hours of operation between fueling	~9
Average daily hours of operation per system	8-10
Average daily methanol fills per system	~1
Median DMFC system hours of operation	1,391

NREL has completed the technology durability analysis. The technology reliability and MHE value proposition analyses are not completed due to insufficient data.

CONCLUSIONS AND FUTURE DIRECTION

Overall, although NREL received a great deal of stack-level DMFC system data, NREL received very limited data from Oorja on maintenance and costs. Due to this, NREL cannot provide a thorough verification of maintenance and infrastructure costs. Based on the limited summary data provided, it appears that DMFC units that had been upgraded with system improvements had 40% fewer unscheduled maintenance events compared to the initial generation of DMFC systems that were deployed as part of this demonstration. Methanol infrastructure costs appear to be on the order of $75,000 per site. In comparison, hydrogen infrastructure costs to support PEM fuel cell MHE are expected to be in the range of $500,000 to $1M per site.

Suggested DMFC research and development pathways to address improving DMFC durability:

- Improve anode catalyst durability by minimizing Ru loss. PtRu alloy is the state-of-the art DMFC anode catalyst but performance degrades over time because of the loss of Ru. Furthermore, some Ru crosses over from anode to cathode via the membrane and lowers the cathode performance.

- Higher methanol tolerant membrane, that is also durable, conductive and low cost, is needed to minimize mixed potential issue when methanol solution crosses over from anode to cathode. This lowers the fuel cell voltage, fuel utilization and overall fuel cell performance over time. Higher methanol tolerant membrane will also enable higher methanol concentration fuel to be used and result in smaller methanol fuel storage. This could save space in fueling station and cost.
- Methanol tolerant cathode catalyst. Cathode catalyst that does not oxidize the methanol that crosses over from the anode would improve fuel cell performance and durability.
- Engineer DMFC systems to operate over a range of environmental temperatures, including below freezing to 100°C.
- Optimize the DMFC system to have good water and methanol concentration management. This will increase fuel cell voltage, fuel utilization & performance, along with lower maintenance cost.

FY 2013 PUBLICATIONS/PRESENTATIONS

1. Ramsden, T., Ulsh, M., Kurtz, J., Sprik, S., Ainscough, C., "Direct Methanol Fuel Cell Material Handling Equipment Deployment," DOE Hydrogen and Fuel Cells Program Annual Merit Review, May 16, 2012, Washington, D.C.

REFERENCES

1. K. Mahadevan et al., "Identification and Characterization of Near-Term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets," Battelle. April 2007.

2. National Renewable Energy Laboratory, "Hydrogen and Fuel Cells Research: Early Fuel Cell Market Demonstrations." http://www.nrel.gov/hydrogen/proj_fc_market_demo.html.

3. National Renewable Energy Laboratory, Hydrogen Technologies and Systems Center's Technology Validation Program, "Total Cost of Ownership for Class I, II, & III Forklifts," March 2012. http://www.nrel.gov/hydrogen/cfm/images/cdp_mhe_58_totalcostofownership.jpg.