X.6 Direct Methanol Fuel Cell Material Handling Equipment Demonstration

Todd Ramsden
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401
Phone: (303) 275-3704
E-mail: Todd.Ramsden@nrel.gov

DOE Manager
HQ: Peter Devlin
Phone: (202) 586-4905
E-mail: Peter.Devlin@ee.doe.gov

Subcontractor:
Oorja Protonics, Inc., Fremont, CA

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Fiscal Year (FY) 2011 Objectives

- Deploy and test fuel cell-powered material handling equipment (MHE) using renewable liquid fuels (in particular, methanol).
- Compile operational data of direct methanol fuel cells (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 business case and market viability of using DMFC technologies in material handling applications.
- In the longer term, help transform the market for the use of fuel cells in material handling applications.

Barriers

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

Technical Targets

No specific technical targets have been set.

FY 2011 Accomplishments

- Seventy-five DMFC systems were built, tested, and delivered to customer warehouse sites for real-world use and testing in Class III MHE (as of June 2011).
- DMFC systems underwent initial, beginning of life testing that will be used to provide a performance benchmark for the DMFC systems.
- Initial testing shows that DMFC systems used in Class III pallet jacks achieve 14 hours of operation on a single methanol fueling, compared to an average of less than 7 hours of autonomy for traditional battery-powered lifts.

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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.

DOE is currently demonstrating the potential benefits for hydrogen-fueled polymer electrolyte membrane (PEM) fuel cell-powered forklifts compared to 100% battery-powered forklifts. 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. (See Table 1 for an overview of the benefits of using DMFCs in material handling applications.)

TABLE 1. Benefits of DMFC Power for MHE Compared to Batteries

Expected DMFC Benefits Over Battery MHE	
Longer run times between fueling/charging	Estimated 12-14 hours of autonomy on one fill.
Increased battery and lift reliability	Maintaining state-of-charge and eliminating deep discharge of batteries should extend battery life.
Increased productivity	Reduced need for fills (versus charging) and reduced time for fills (versus charging).
Lower greenhouse gas emissions	Compared to charging batteries using a typical electricity grid mix.
Low-cost infrastructure	Liquid alcohol fuels such as methanol offer low storage and dispensing costs.
Low cost of ownership	Productivity, reliability, and battery life gains expected to enable lower overall cost.

Approach

NREL has partnered with Oorja Protonics on a two-year 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 15 months, with 5,000 total operational hours expected on each unit. The demonstration includes the use of renewable, bio-derived methanol to characterize the impact on DMFC systems of using renewable methanol fuel.

As part of the project, Oorja built, tested, and deployed pallet jacks using its OorjaPac Model 3 DMFC power pack, which delivers an output power of approximately 1.5 kW and includes a 12-liter methanol storage tank expected to provide 12-14 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 is compiling and analyzing these data and is providing a third-party assessment on the performance of DMFCs used in material handling applications.

FIGURE 1. The OorjaPac Model 3 DMFC System

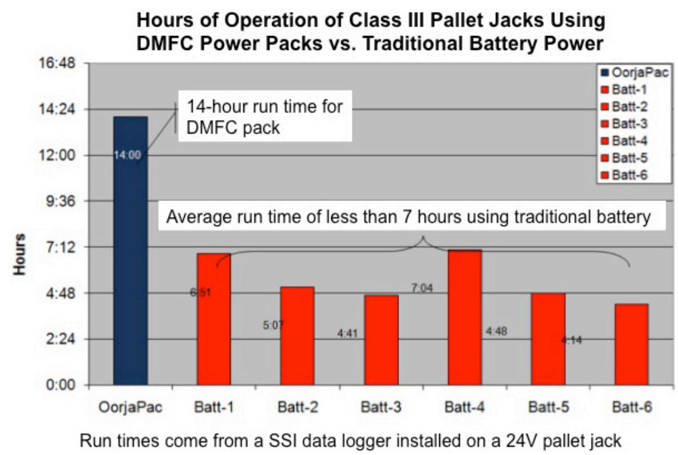

FIGURE 2. Run Time for DMFC Class III MHE Compared to Battery-Powered MHE

Results

Until recently, the primary target use for DMFCs has been for portable power applications, particularly micropower applications. In FY 2011, NREL investigated companies developing DMFC systems that produced output power above 1 kW and were capable of powering Class III MHE. Based on this, NREL released a competitive request for proposals to demonstrate DMFCs to power MHE in commercial warehouse operations. In early 2011, NREL awarded a subcontract to Oorja Protonics to build, test, and deploy 75 DMFC-powered Class III pallet jacks in four commercial food warehousing and distribution centers.

The OorjaPac Model 3 DMFC power packs that are 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. Figure 1 shows the OorjaPac DMFC system, on its own (left), and integrated with a Class III pallet jack and its battery (right). Initial testing of these DMFC systems show that the OorjaPac needs to be fueled with methanol (with fills expected to take 1-2 minutes) after 14 hours of operation, compared to average run times of less than seven hours for traditional battery systems (see Figure 2). Initial testing using data loggers on operating pallet jacks showed the OorjaPac DMFC system maintained a more consistent state-of-charge on the battery packs and avoided deep discharges of the batteries.

The specific configuration of the OorjaPac DMFC system was built to meet customer performance needs. To accomplish this, Oorja performed testing using data loggers of MHE at all four customer sites under this deployment project to benchmark the necessary performance. This information was used to determine the specific fuel cell count in the OorjaPac as well as the hybridization algorithms needed to provide sufficient performance and run times to meet customer needs. Based on this benchmark testing, Oorja built DMFC systems for use at all four demonstration sites. Prototype systems were tested on target customer Class III pallet jacks to ensure proper electrical and mechanical linkage, as well as proper safety, ergonomics, and counterbalance.

Individual DMFC systems underwent performance, reliability, and emissions testing. Beginning of life performance testing of the OorjaPac DMFC systems showed a maximum power output of 1.65 kW. Emissions testing at the anode and cathode sides of the DMFC pack showed overall carbon dioxide emissions to be well below OSHA limits of 200 ppm. Vibration table testing showed minimal impact on system performance from vibration.

Environmental testing showed that operation in higher temperature environments tended to lower overall system efficiency because of higher parasitic power requirements needed to maintain thermal balance. Improved system controls were developed to avoid any freezing of system components during lower temperature use.

Conclusions and Future Direction

- Seventy-five OorjaPac DMFC systems were built, tested, and delivered to customer warehouse sites for real-world use and testing (as of June 2011).
- DMFC systems underwent beginning of life testing that will be used to provide a performance benchmark for the systems.
- Data from these DMFC systems based on real-world use in providing power to Class III pallet jacks are being collected by Oorja and compiled by NREL.

In the next year, NREL will use real-world operating data to characterize the performance of DMFC systems used in material handing applications, including characterization of:

- Site Operations – hours of DMFC forklift use, amount of methanol dispensed, number of fueling events.
- Infrastructure Performance – average fueling time, average fueling rate, number of safety incidences, maintenance required.
- DMFC Performance – hours of operation between fuelings, hours of operation per gallon of methanol, average battery life, battery state-of-charge.

The analysis of real world data will be used to develop a total cost of ownership estimate of DMFC systems, including any productivity improvements, for comparison to battery MHE.

FY 2011 Publications/Presentations

1. Todd Ramsden, “Direct Methanol Fuel Cell Material Handling Equipment Demonstration,” DOE Fuel Cell Technologies Program Annual Merit Review, May 10, 2011.

References

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