V.J.4 Research & Development for Off-Road Fuel Cell Applications

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Contract Number: DE-FC36-04G014303

Subcontractors:
- The Toro Company, Bloomington, MN
- University of California (UC Davis), Davis, CA

Project Start Date: August 9, 2007
Project End Date: June 9, 2010

Objectives

- Develop system to allow proton exchange membrane (PEM) fuel cells to operate in off-road applications.
- Evaluate air-filtration technologies for off-road applications.
- Conduct a program of study, evaluation and laboratory testing needed to establish a comprehensive set of PEM fuel cell system requirements for turf and grounds maintenance vehicles.
- Fully integrate prototype PEM fuel cell system in a Toro Workman® e2065 – series utility vehicle for field trials.
- Conduct field trials utilizing two vehicles.
- Demonstrate vehicle at various venues.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Durability

Technical Targets

Conduct field trials at River's Edge Golf Course and The High Desert Museum (HDM) Wildlife and Living History.

Accomplishments

- Measured the shock, and vibration spectrum for golf course maintenance vehicles.
- Gathered information on the air contaminants that may have an effect on fuel cell operation and developed an air filter for fuel cell systems.
- Developed the Workman® e2065 lawn tractor equipped to operate on direct current (DC) voltages, and had accelerometers installed and evaluated shock and vibration.
- Measured the power load profiles on two golf courses.
- Designed and installed an IdaTech liquid-fueled fuel cell system in a Toro Workman® e2065 light-duty maintenance truck.
- Re-designed and installed an IdaTech liquid-fueled fuel cell system in a Toro Workman® MDE light-duty maintenance truck.
- Continue field trials with two vehicles.

Introduction

Nearly no practical work has been performed by the fuel cell industry, and its suppliers and trade associations on the subject of off-road fuel cell operation. The environments encountered in off-road applications could adversely affect fuel cell performance and life, requiring re-designing for the harsher environment.

One of the recognized challenges in fuel cell systems air purification is in providing a highly efficient particulate and chemical filter with minimal pressure drop. PEM integrators do not want additional parasitic loads added to the system as compensation for a highly efficient yet highly restrictive filter. Additionally, there is challenge in integrating multiple functions into a single air intake module tasked with efficiently and effectively filtering high dust loads, diesel soot, pesticides, ammonias, high frequency noise, and other anticipated off-road contaminants.

It is one key project objective to develop a strategy, and through it a solution, for achieving clean cathode inlet air. Other off-road concerns are related to fuel cell power requirements and the effect of shock and vibration.

Approach

- Measure the air quality for off-road application and develop an air filter.
- Measure the shock and vibration spectrum for off-road vehicles, and then subject an IdaTech fuel cell system to the spectrum.
- Design, assemble, and test a Toro Workman® e2065 light-duty maintenance truck with an IdaTech liquid-fueled (methanol/water) fuel cell system incorporating the developed air filter.

Results

An IdaTech liquid-fueled fuel cell system was assembled, tested at IdaTech, delivered to UC Davis and demonstrated at UC Davis. Shake and vibration testing has begun at UC Davis and six of eight tasks completed.

Toro has determined the fuel cell systems specification for the Workman® e2065 and IdaTech's FCS 3000 system meets the specifications and incorporates the developed air filter. A Toro Workman® e2065 light-duty maintenance truck was received, and designated test vehicle (TV)-1.

Three fuel cell systems were assembled and all three passed operational testing. One unit while sitting next to the vehicle was used to charge the battery configuration. The unit was reconfigured and installed into the vehicle. The vehicle has accumulated 63.5 hours of off-road operation at the River's Edge Golf Course. A photo of TV-1 on the golf course is shown in Figure 1. During the summer of 2008, TV-1 accumulated 62 hours of maintenance duties. During the winter an upgrade was performed on the fuel cell system. Wiring connections were reduced, a smaller lighter DC to DC converter on a studier sheet metal support and onboard data acquisition were incorporated. Every ten seconds data is stored on a replaceable memory card. The installed upgraded fuel cell system is shown in Figure 2. TV-1 has accumulated the following statistics:

Fuel Cell Run Time = 171 hours
Total Fuel Feed = 465 liters
Total Energy = 353 kW/hr
Total Thermal Cycles = 165

A second vehicle, designated TV-2, was procured from Toro which Toro has designated as an MDE model (mid-duty electric). The new vehicle design incorporates front wheel shocks and an accessible area under the front hood. An upgraded fuel cell system was installed in the vehicle. The batteries were placed two in front and two in the rear compartment. This eliminated the "saddle bag" batteries external to the rear compartment in the first vehicle. The vehicle rear compartment was modified to provide ease of removal of the whole

FIGURE 1. TV-1 on Golf Course

FIGURE 2. Upgraded IdaTech Liquid-Fueled Fuel Cell System Installed in TV-1

system for maintenance. Onboard data acquisition was added. Every ten seconds data is stored on a replaceable memory card. The fuel cell system installed in TV-2 is shown in Figure 3. The second vehicle was deployed at HDM south of Bend, Oregon. This field trial differs in that the terrain is flatter, the operators more educated and the vehicle will accumulate more operating hours. The vehicle in front of the HDM is shown in Figure 4. TV-2 has accumulated the following statistics:

Fuel Cell Run Time = 315 hours
Total Fuel Feed = 77 liters
Total Energy = 42 kW/hr
Total Thermal Cycles = 51

The present systems have four generic printed circuit boards installed. Many of the functions on the boards are not used with the present system. Many wires could be eliminated by consolidating the four boards onto one board. We have contracted with Etrix Group Inc. a local electronic design company, to consolidate the needed functions onto one board.

FIGURE 3. IdaTech Liquid Fueled Fuel Cell System Installed in TV-2

FIGURE 4. TV-2 at the High Desert Museum

Conclusions and Future Directions

The work conducted so far shows that an IdaTech liquid-fueled fuel cell system can be integrated into an off-road vehicle. Operation on a real golf course atmosphere was successful; however, improved reliability is required. Some example of faults and corrections:

- System over-heated on very hot day – added cooling fan.
- Thermocouple shorted – added restraint.
- Wires fell off coolant switch – restrained wires.
- Fuel pump slowed down, dirt was cause – sealed pump gearbox opening.
- Fuel line dry – removed tank dip tube and place exit at tank bottom.
- Inverter not ramping up – installed improved inverter and improved firm ware.
- Troubleshooting faults takes too much time – added onboard data acquisition.
- Multiple printed circuit boards with unused capability and extra connectors increase wiring breakage – consolidation of board recommended.

Field trials will continue for both vehicles. Demonstrations of the vehicles will be scheduled for the rest of the project.

FY 2009 Publications/Presentations

1. Annual Merit Review: fcp_03_lawrance