Research & Development for Off Road Fuel Cell Applications

DOE Annual Merit Review & Peer Evaluation
May 18-22, 2009
Arlington, VA

IdaTech’s Family of Reliable Fuel Cell Solutions

This presentation does not contain any proprietary, confidential, or otherwise restricted information
# DOE Off Road Project - Overview

## Timeline
- Start date: Sept 2004
- End date: June 2010
- Percent complete: 60%

## Budget
- Total project funding
  - DOE share $1,084,488
  - Contractor share $464,780
- Funding received in FY08 $278,510
- Funding for FY09 $250,400

## Barriers
- Air-filtration for off-road applications
- Impact of Shock & Vibration (S&V)

## Partners
- The Toro Company (Minneapolis, MN)
- University of California – Davis
- Rivers Edge Golf Course (Bend, OR)
Task -2 Shock & Vibration (S&V)

Task - 5
– Install PEM Liquid Fueled Fuel Cell System in Golf Course Maintenance Vehicle
– Perform Field Trials

Task – 6 Show Vehicle at Exhibits
DOE Off Road Project

Liquid-Fueled Fuel Cell Powered Toro Workman® Maintenance Vehicle
DOE Off Road Project – FY 2008 Milestones

- Purchased test platform a Workman® e2065 Golf Course Maintenance Vehicle
- Modified three 1 kW Fuel Cell Systems (FCS) to produce 2.5 to 3.5 kW each
- Deliver FCS to UC Davis for S&V testing
- Installed FCS in vehicle
- Performed field trials of Golf Course Maintenance Vehicle at River’s Edge Golf Course for four months with course crew using vehicle
- Completed shock and vibration initial testing successfully

FY 09 Milestone Plan
- Develop second prototype with upgraded design based on field trials and S&V results
- Continue field trials at Rivers Edge Golf Course and start field trials at The High Desert Museum (Bend, OR)
- Demonstrate vehicle at selected venues
DOE Off Road Project Fuel Cell System Installed

Fuel Tank

Reformer

Stack (under)

DC-DC Converter

Battery

Motor

Motor Controller
Fuel Cell Powered Golf Course Maintenance Vehicle on Rivers Edge Golf Course

Time of Day

Vdc/kW

V Stack • AMPS × Vbat — kW

Contains No Confidential or Proprietary Information
Vehicle on Golf Course 08/04/2008 Back Nine Twice

Contains No Confidential or Proprietary Information
Field Trials

• River’s Edge golf course is owned by the Riverhouse Hotel and Convention Center in Bend, OR
• The Riverhouse President and Director of Marketing are enthusiastic about a green vehicle on the course.
• The course Maintenance Supervisor and crew have commented positively about the vehicle for it’s low noise, smooth operation, and environmental friendliness.
• The vehicle is showing a peak efficiency of 40%
Field Trials

• **Fuel Cell System**
  • Run Time = 465 hrs
  • Liters consumed = 428
  • Thermal Cycles = 140
  • kW-hr = 262
  • Fuel Cell Hours = 303
  • kW-hr/Liter = 0.612

• **Vehicle Experienced:**
  – Rough terrain
  – Dirt, dust, grass clippings, fertilizer, sand, and high temperatures
  – No degradation in performance
  – Air filter replaced at end of Summer
Independent Evaluation

- Toro’s Director of R&D visited IdaTech and drove the fuel cell vehicle on the River’s Edge Course for a day with a battery-only powered vehicle for comparison.
- Toro – “Over all, the fuel cell prototype exhibited satisfactory performance, it had a few performance ‘glitches’ which IdaTech is addressing.”
• Toro provided load profiles (accelerations or “g forces”) of Workman vehicle in golf course (2005 trials)
• An IdaTech FCS was S&V tested at UC Davis on a vibration table
• Finished and ongoing testing on the frequencies reported by the load profiles and on additional frequencies due to implements such as rotary mowers (3 to 500 Hz range)
• Literature review has indicated that simulated load profiles are adequate representation of expected off-road vibration
• Testing includes sinusoidal and random excitations; responses are measured using accelerometers placed on main components and throughout the fuel cell stack
• Some of the S&V issues observed on the FCS have already been solved by IdaTech by modifying the layout of the components, so they can be incorporated into the vehicle.

• Modal analysis is being performed so possible resonances can be identified and avoided in the second prototype.

- Figures show 3D image of the fuel cell stack. Computational tools are used to identify resonant frequencies.

- It was found that frequencies in the 21-22 Hz range might induce torsion stress in the fuel cell stack.
FY 09

- Complete S&V testing
- Complete second prototype updated with S&V, field trials results, and design for manufacturing.
- Demonstrate vehicles at selected venues.
- Install full-time data acquisition capability
- Improve system for ease of manufacturing
- Continue Field Trials with both vehicles
  - Emphasis on more difficult course tasks
DOE Off Road Project - Summary

Accomplished:

- Installed liquid fueled-FCS system in a Workman® e2065 Golf Course Maintenance Vehicle. Provided required energy during field testing. Needs improvement, however, acceptable for most course tasks.
- Function under S&V loads, survived Summer on a very rough golf course with minor problems. None related to S&V.

Improvements:

- Increase FCS power output to meet more arduous tasks.
- Add data acquisition for improve diagnostic and to record full time activity
- Continue field trials at two locations.
- Eliminate all faults for improved reliability
- Improve manufacturability