



# Research & Development for Off Road Fuel Cell Applications

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

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*IdaTech's Family of Reliable Fuel Cell Solutions*

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## 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**

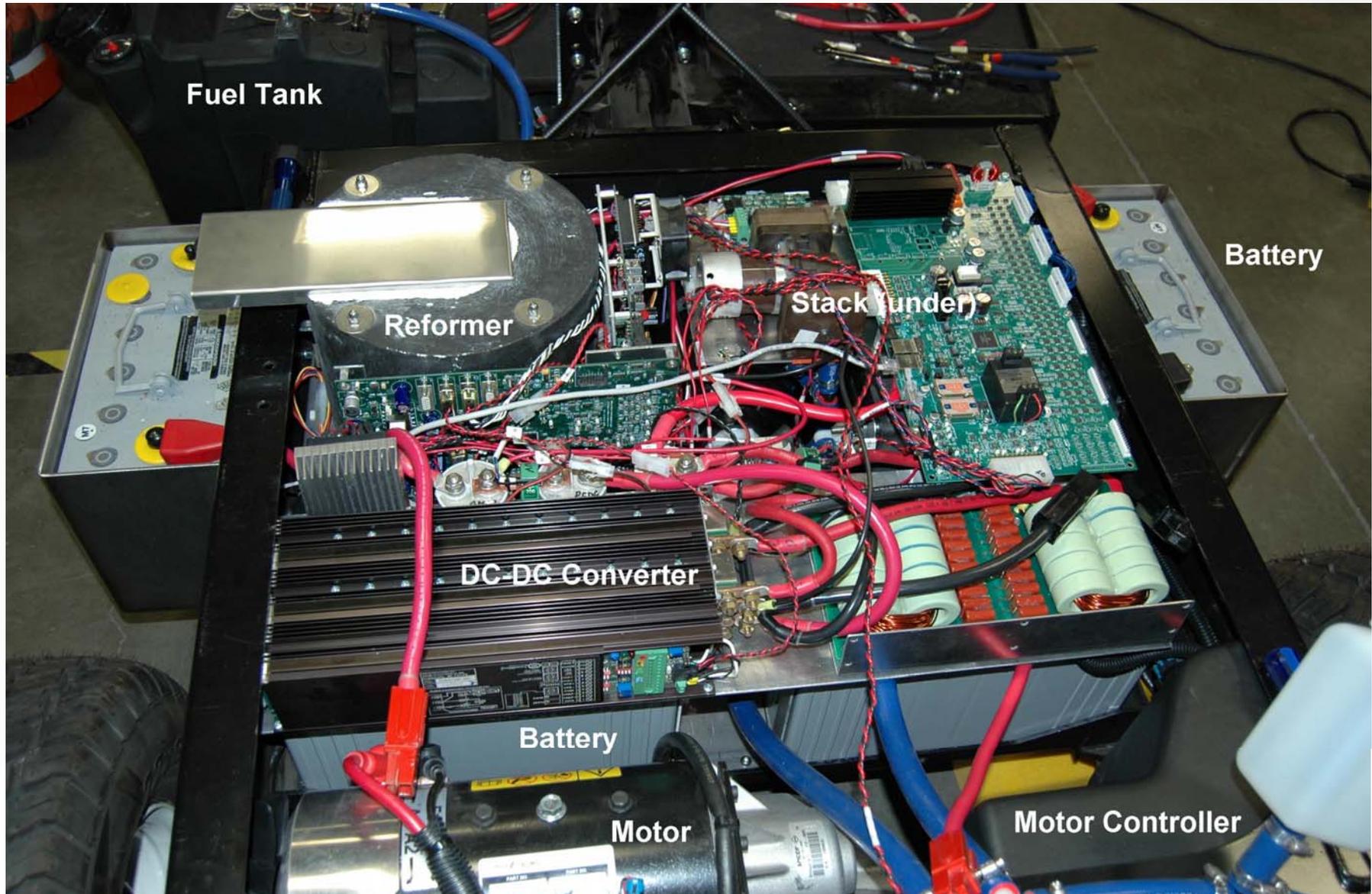
# Liquid-Fueled Fuel Cell Powered Toro Workman® Maintenance Vehicle



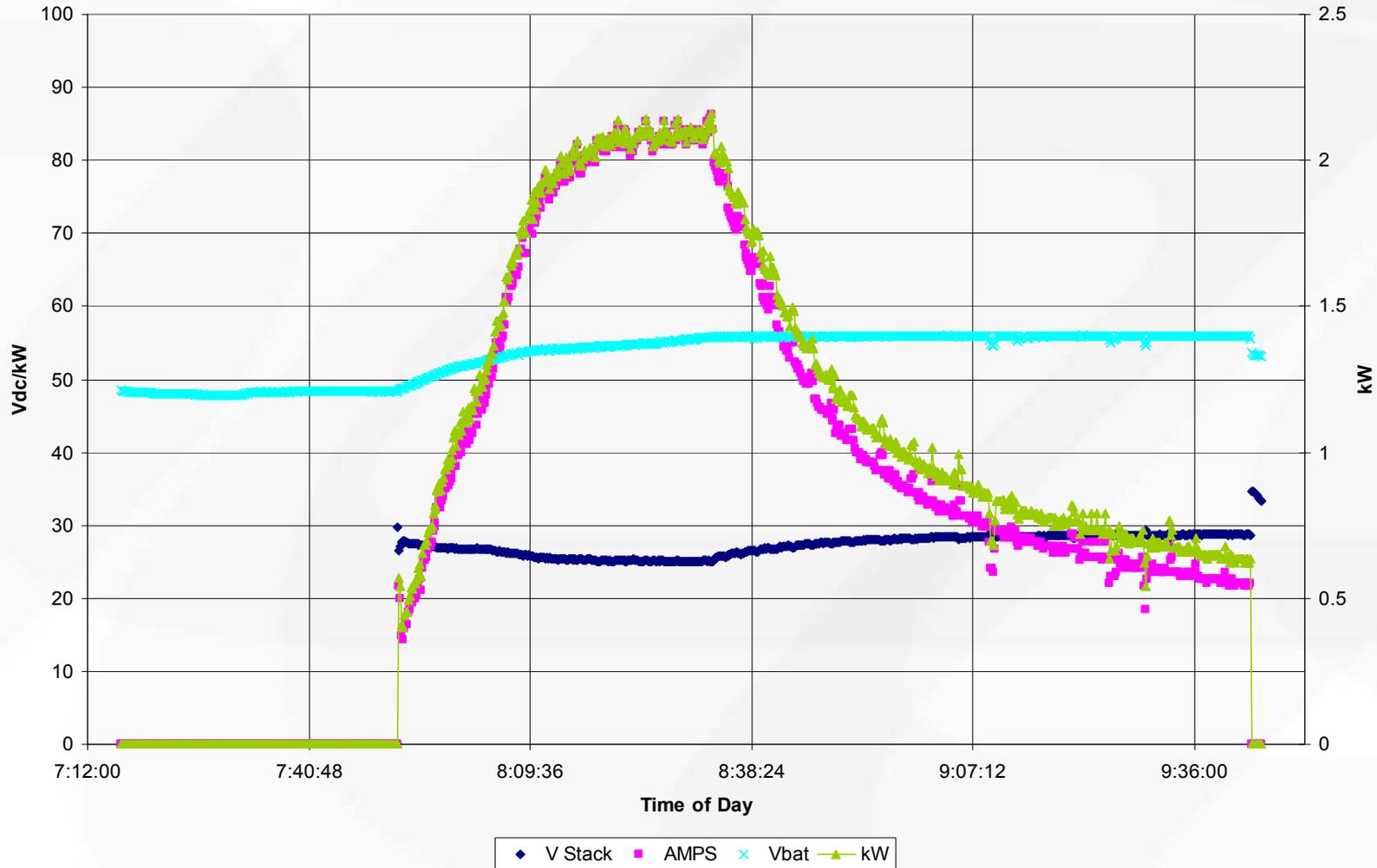
- Purchased test platform a Workman® e2065 Golf Course Maintenance Vehicle
- Modified three 1 kW Fuel Cell Systems (FCS) to produce 2.5 to 3.5 kW each
- Deliver FCS to UC Davis for S&V testing
- Installed FCS in vehicle
- Performed field trials of Golf Course Maintenance Vehicle at River's Edge Golf 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



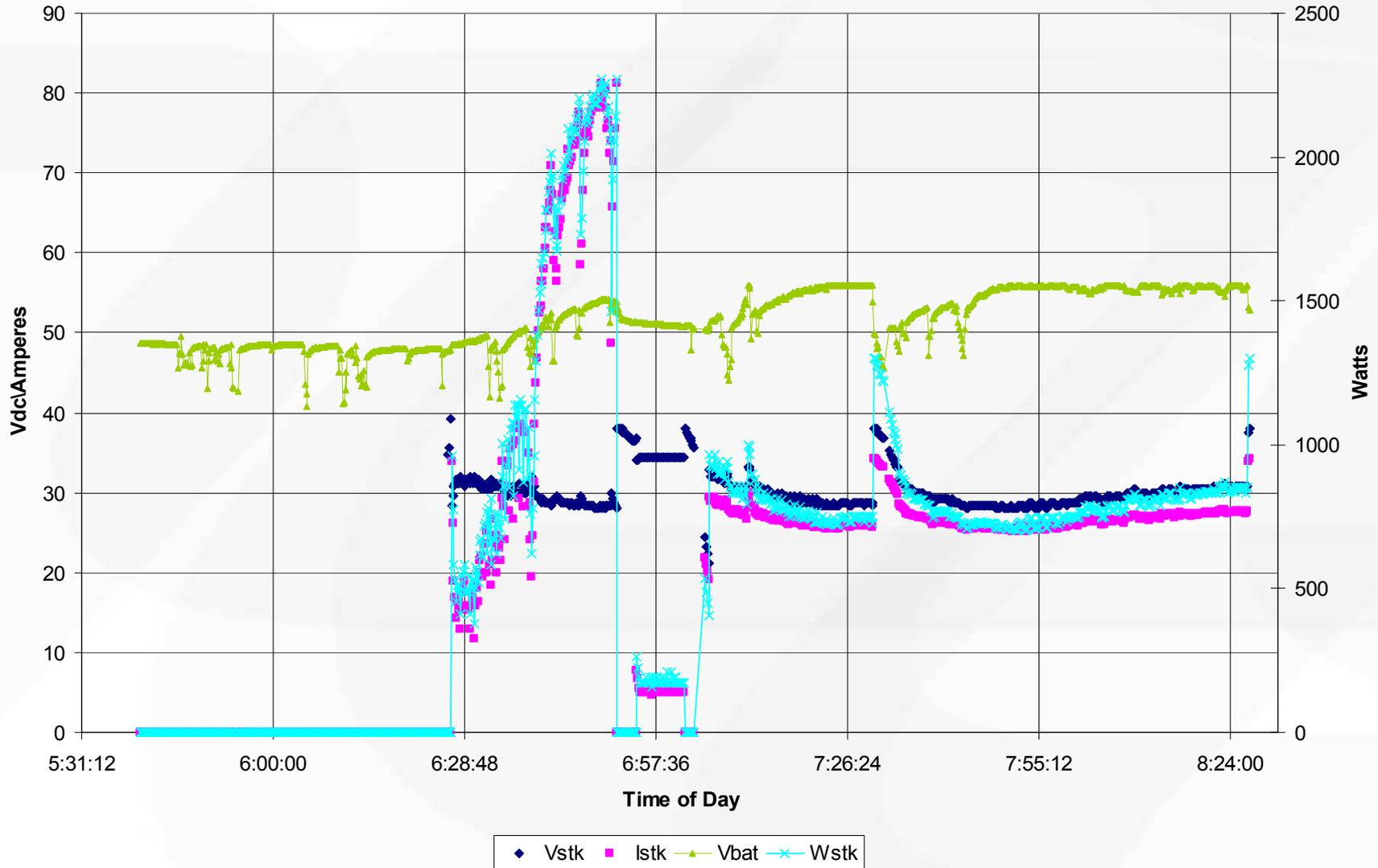
### Fuel Cell Powered Golf Course Maintenance Vehicle on Rivers Edge Golf Course



# Fuel Cell Power On Golf Course



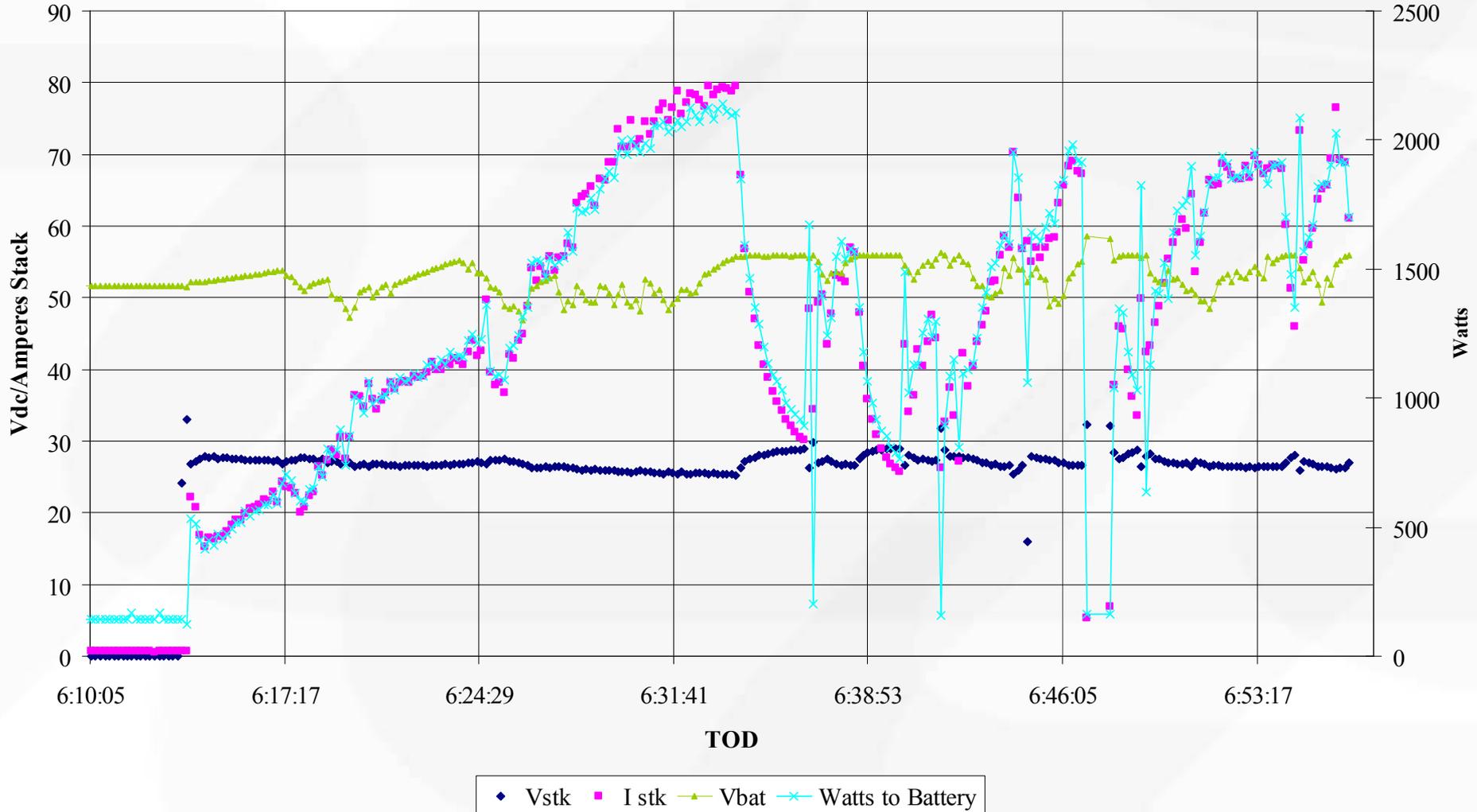
On Course August 1, 2008



# Fuel Cell Maintains Full Battery Charge



Vehicle on Golf Course 08/04/2008 Back Nine Twice





Dirt and Dust, Rough



Rough Path, Note Fence Shadow



Elevation Change 300 feet



Rough Fairways  
Vehicle Has No Suspension

- 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 its low noise, smooth operation, and environmental friendliness.
- The vehicle is showing a peak efficiency of 40%

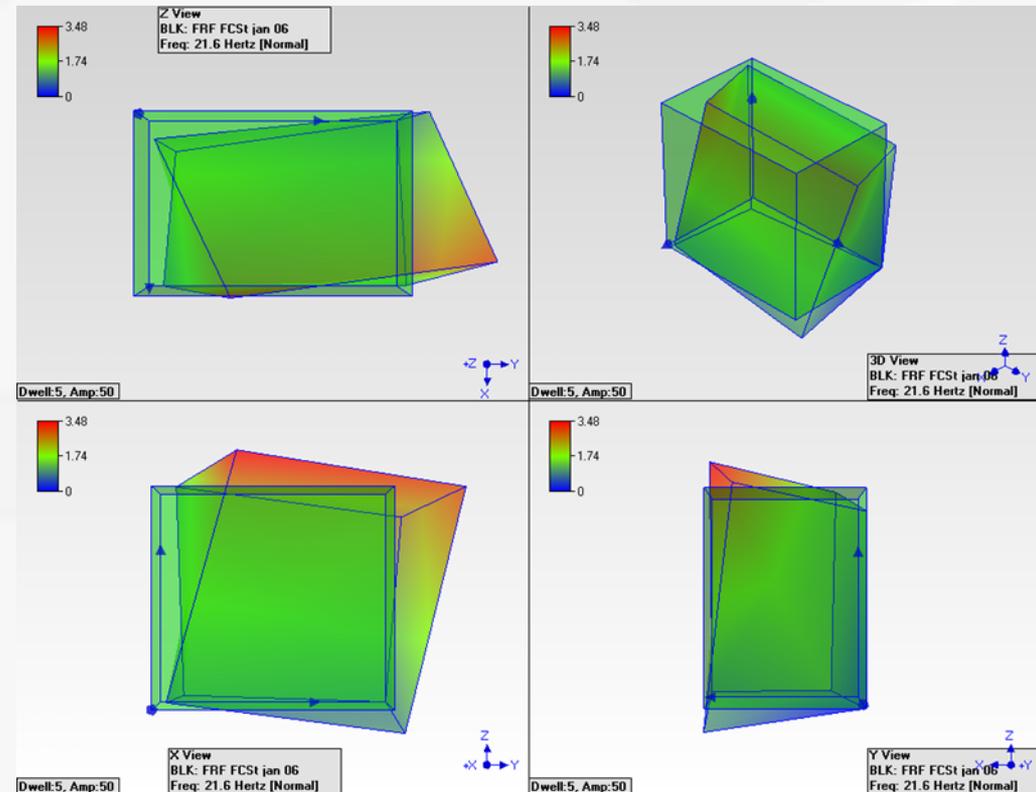
- Fuel Cell System
  - Run Time = 465 hrs
  - Liters consumed = 428
  - Thermal Cycles = 140
  - kW-hr = 262
  - Fuel Cell Hours = 303
  - kW-hr/Liter = 0.612
- Vehicle Experienced:
  - Rough terrain
  - Dirt, dust, grass clippings, fertilizer, sand, and high temperatures
  - No degradation in performance
  - Air filter replaced at end of Summer

- 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

## 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