VI.A.9 Fuelcell Prototype Locomotive*

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Subcontractors:

- ECD Ovonic Hydrogen Systems, Rochester Hills, MI
- General Atomics, San Diego, CA
- Nuvera Fuel Cells Inc, Cambridge, MA
- Railway Technical Research Institute, Tokyo, Japan
- Transportation Technology Center, Inc., Pueblo, CO
- Modine Manufacturing Company, Racine, WI
- University Nevada – Reno, Reno, NV
- New York City Transit, New York, NY
- Regional Transportation District – Denver, CO
- Caterpillar Inc, Peoria, IL
- HERA USA, Ringwood, NJ
- Burlington Northern Santa Fe Railway, Fort Worth, TX
- Defense NTG & Rail Equipment Center, Ogden, UT
- Washington Safety Management Solutions, Aiken, SC

Project Start Date: July 1, 2005
Project End Date: June, 30 2007

*Congressionally directed project

Objectives

- Develop a locomotive powered by a fuel cell
- Develop ability to provide power-to-grid
- Facilitate commercialization of fuel cell power for large applications

Technical Barriers

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

(A) Lack of Fuel Cell Vehicle Performance and Durability Data

(B) Hydrogen Storage

Contribution to Achievement of DOE Technology Validation Milestones

This project will contribute to achievement of the following DOE Technology Validation milestones from the Technology Validation section of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

- **Milestone 15: Validate refueling time of 3 minutes for a 5 kg tank (1.67 kg/min) and durability of 1,000 cycles for solid state storage systems. (4Q, 2012).** Incorporating a complex heat exchange design, our metal-hydride system can refuel 14 kg in less than 15 minutes.

Accomplishments

- Validate and test metal-hydride fast-fill design
- Finalize power plant module design
- Fabricate 150 kW power plant
- Create space claim model

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Introduction

An international industry-government consortium is developing a fuel cell hybrid switcher locomotive for commercial railway applications and power-to-grid generation applications (Figure 1). This ongoing project is in its third phase and already has designed and tested a 150 kW power module and evaluated fast-fill metal hydride storage for large applications. The fuel cell hybrid switcher will address the feasibility of using fuel

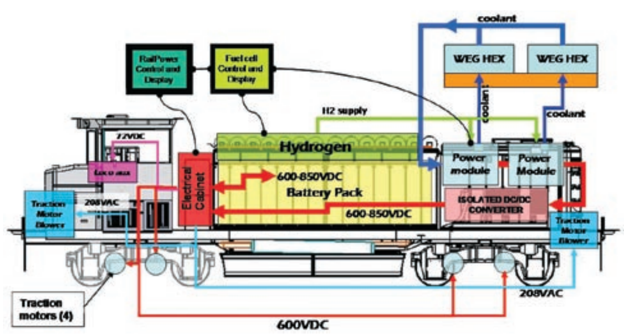

FIGURE 1. Fuelcell Hybrid Switcher Concept

cells for large industrial applications as well as hydrogen storage.

Approach

Based on previous industrial vehicle designs and consortia formation, Vehicle Projects, LLC evaluates state-of-the-art fuel cell and hydrogen storage technology and adapts the best technology for demonstration and potential commercialization. Where a technology is not commercially available, Vehicle Projects looks to assist in the development of such technology that will adapt easily to industrial vehicle applications.

This ongoing project takes a modular approach to design and development. Instead of developing a 1 MW powerplant, we are developing 150 kW modules which can then be ganged together in various combinations to meet the necessary power and voltage requirements. A similar approach is taken with the on-board hydrogen storage.

Results

During this phase of this multi-phase project, we developed and built a 150 kW prototype power module (Figure 2). Based on a previous design, Nuvera Fuel Cells integrated their cathodic water injection (CWI) Forza™ fuel cell stacks into a module that was installed into a test train and evaluated.

Testing of the 150 kW module resulted in multiple fuel cell stack failures. An inadequate purging scheme did not manage water on the anode side which caused flooding of the membranes. The end design also resulted in the prototype module being overweight, excessively large, and too costly. These are important factors for acceptance by end users.

Work was completed on a fast-fill metal-hydride storage system capable of storing 14 kg of hydrogen (Figure 3). This system will be used in a mine loader for evaluation. However, the resulting design does not appear scalable for larger systems such as the locomotive. The fast-fill portion of the system adds tremendous complexity and thus cost. Reliability is also questionable due to the high parts count.

Based on the above results, we changed our design methodology to incorporate more proven fuel cell and hydrogen storage technology. We also changed the base platform from a pure fuel cell locomotive to a fuel cell-battery hybrid locomotive in order to reduce capital costs. Our design is now based on Ballard Power Systems' Mark 902 P5, 150 kW proton exchange membrane (PEM) power modules used in the Citaro bus program in Europe. These modules have over 1.5 million km of proven reliability over 3 years. We also decided to incorporate Dynetek's 350 bar composite cylinders also used on the Citaro bus program. Though we initially looked to use metal hydride, the cost to develop a system capable of storing at least 70 kg of hydrogen was too great and no designs of this magnitude exists.

The new overall design will now use a RailPower battery hybrid Green Goat™ as the locomotive platform (Figure 4). Keeping the existing lead-acid batteries, we will replace the 205 kW diesel gen-set with 225 kW of fuel cell net power, remove the diesel fuel tank, and place 14 compressed hydrogen cylinders, capable of storing 70 kg of hydrogen at 350 bar, on the roof (Figure 5).

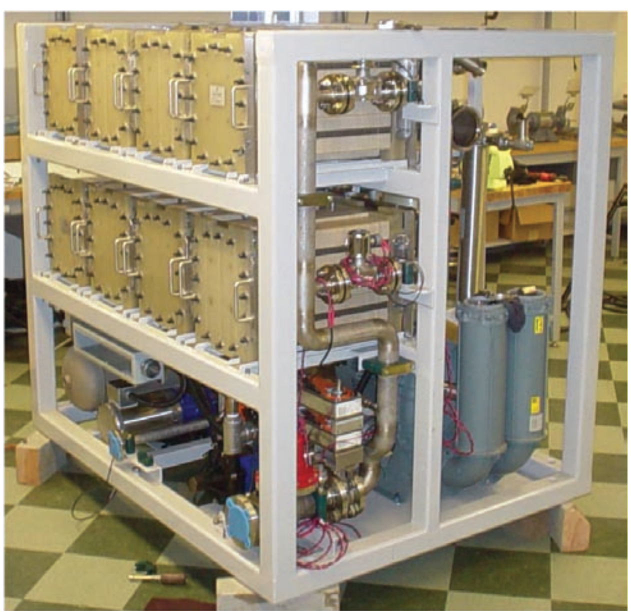

FIGURE 2. Prototype 150 kW Power Module

FIGURE 3. Fast-Fill Metal-Hydride Storage

FIGURE 4. Green Goat™ Locomotive Platform

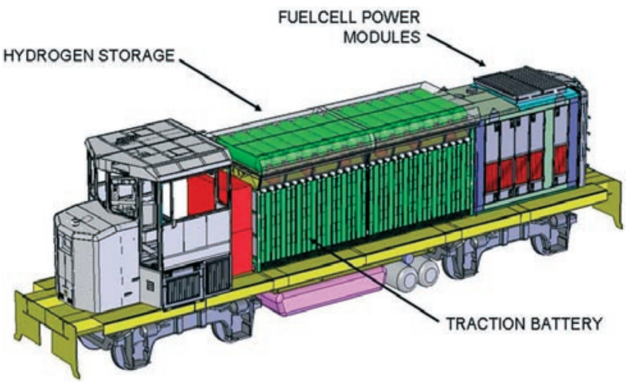

FIGURE 5. Fuelcell Hybrid Switcher Locomotive Design

Conclusions and Future Directions

- For large system applications, metal hydride storage designs are not sufficiently developed and are excessively expensive with unknown reliability.
- For large vehicle applications a modular approach to system design incorporating proven hardware reduces capital costs and minimizes risk.
- System designs reducing weight and volume are critical even for large vehicle applications.
- A Green Goat™ hybrid switcher locomotive will be modified using Ballard fuel cell power modules and Dynetek 350 bar composite cylinders. Vehicle Projects will complete system design and balance of plant design. The locomotive will be demonstrated in the LA basin area.

FY 2007 Publications/Presentations

1. System Design of a Large Fuelcell Hybrid Locomotive, Arnold R. Miller, David L. Barnes, Kris S. Hess, Tim L. Erickson, ASME Fifth International Fuel Cell Science, Engineering & Technology Conference, New York City, New York, 18–20 June 2007.

2. Fuelcell Locomotives for Seaports and Power-to-Grid Applications, Arnold R. Miller, David L. Barnes, Kris S. Hess, Tim L. Erickson, Second European Ele-Drive Transportation Conference (EET 2007), Brussels, Belgium, 30 May – 1 June 2007.

3. Fuelcell Hybrid Switcher Locomotive for Seaports, Arnold R. Miller, David L. Barnes, Kris S. Hess, Tim L. Erickson, Hydrogen and Fuel Cells 2007, Vancouver, British Columbia, 29 April – 2 May 2007.

4. Fuelcell Hybrid Switcher Locomotive, Arnold R. Miller, David L. Barnes, Kris S. Hess, Tim L. Erickson, Locomotive Maintenance Officer's Association Meeting, Omaha, Nebraska, 22–23 March 2007.

5. Fuelcell Locomotives for Urban Rail Applications, Arnold R. Miller, Faster Freight Cleaner Air, Long Beach, California, 26–28 February 2007.

6. Variable Hybridity Fuelcell Locomotive, Arnold R. Miller, H_2Expo International Conference and Trade Fair on Hydrogen and Fuel Cell Technologies, Hamburg, Germany, 25–26 October 2006.

7. Ammonia Fuel for Rail Transportation, Arnold R. Miller, Ammonia Conference 2006, Denver, CO, 9–10 October 2006.