VII.1 Hydrogen to the Highways - Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project

Ronald Grasman
Daimler AG, representing Chrysler LLC
800 Chrysler Drive
Auburn Hills, MI 48326
Phone: (248) 944-1113; Fax: (248) 576-2045
E-mail: ronald.grasman@daimler.com

DOE Technology Development Manager:
John Garbak
Phone: (202) 586-1723; Fax: (202) 586-2373
E-mail: John.Garbak@ee.doe.gov

DOE Project Officer: Doug Hooker
Phone: (303) 275-4780; Fax: (303) 275-4753
E-mail: Doug.Hooker@go.doe.gov

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Subcontractors:
- Daimler AG, Stuttgart, Germany
- BP America (BP), Warrenville, IL
- Mercedes Benz USA LLC, Montvale, NJ
- DTE Energy (DTE), Detroit, MI
- NextEnergy, Detroit, MI
- Automotive Fuel Cell Corporation (Ballard), Vancouver, BC

Start Date: December 22, 2004
Projected End Date: December 22, 2009

Objectives

- Record, collect and report data from fuel cell vehicles (FCVs) and the hydrogen fueling operations to validate 2009 Department of Energy (DOE) targets:
  - Fuel cell stack durability: 2,000 hours
  - Vehicle range: 250± miles
  - Hydrogen cost at the station: $3.00/gasoline gallon equivalent (gge)
- Demonstrate the safe installation of hydrogen fueling stations and fuel cell service facilities as well as the safe operation of all FCVs.
- Raise public awareness of hydrogen technology and FCVs.
- Establish an initial hydrogen infrastructure network to support a small fleet of FCVs across a metropolitan area.
- Conduct market research that will assist in the commercialization of next generation vehicles.
- Explore cost and commercial feasibility of renewable-based hydrogen generation.

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section (3.6.4) 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

(C) Lack of Hydrogen Refueling Infrastructure Performance and Availability Data

(D) Maintenance and Training Facilities

(E) Codes and Standards

(H) Hydrogen from Renewable Resources

Contribution to Achievement of DOE Technology Validation Milestones

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

- **Milestone 4:** Operate fuel cell vehicle fleets to determine if 1,000 hour fuel cell durability, using fuel cell degradation data, was achieved by industry. (4Q2006).

  The raw data validating this achievement has been provided to the National Renewable Energy Laboratory (NREL) for analysis. Furthermore, the Chrysler Team and three other industry partners continue to provide NREL with on-road vehicle data collected from FCVs operated under real world conditions. NREL is analyzing the fuel cell data and is publishing the composite data of the four industry teams at the Web site: http://www.nrel.gov/hydrogen/proj_learning_demo.html.

- **Milestone 7:** Validate vehicle refueling time of 5 minutes or less for a 5 kg of hydrogen (1kg/min) at 5,000 psi through the use of advanced communication technology. (4Q2007)

  Industry has achieved this milestone with 24% of the refueling events being greater than 1 kg/min for an average fueling rate of 0.79 kg/min which is monitored by NREL at the Web site http://www.nrel.gov/hydrogen/proj_demo.html (see Figure 1).

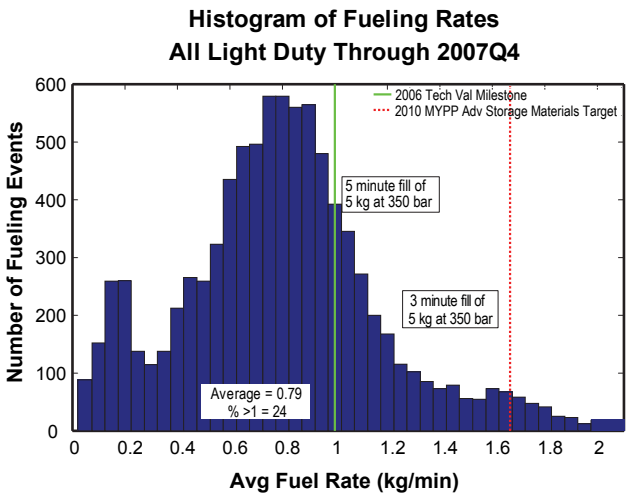

FIGURE 1. Fueling Rates Histogram

- **Milestone 8:** Fuel cell vehicles demonstrate the ability to achieve 250 mile range without impacting passenger cargo compartment. (4Q2008)

  This milestone is expected to be reached in the near future with Gen-II FCVs. Preliminary data will be provided to NREL to validate this progress.

- **Milestone 10:** Validate FCV's 2,000 hour fuel cell durability using fuel cell degradation data. (4Q2009)

  The Chrysler Team will continue to provide NREL data from daily operation of the FCVs. In addition, data will be submitted from Gen-II which will be operational in 2009. Data collected from a test bench is used to perform an accelerated durability test on the fuel cell system. This data will provide information on the degradation behavior of the next generation stack.

Accomplishments

- Thirty Gen-I FCVs were operated under real world conditions by different customers that continued to accumulate mileage under different climate and driving conditions.
- Over 69 DVDs of vehicle and infrastructure data were submitted to NREL for continuous evaluation of the technology.
- Emergency Response Plan and Training Programs were finalized and implemented.
- More than 1,960 vehicle refills were conducted since the beginning of the project at the NextEnergy, DTE Energy, Los Angeles International Airport (LAX), and Pacific Gas and Electric Company (PG&E) hydrogen fueling stations.
- Approximately 100 media/outreach events were organized in 2007 and 2008 to raise public knowledge of hydrogen technology and demonstration project.
- The development of the Burbank fueling station has been finalized with a scheduled commissioning date of November 2008.

Introduction

The primary goal of this project is to validate fuel cell technologies for infrastructure, transportation as well as assess technology/commercial readiness for the market. The Chrysler Team, together with its partners, have been testing the technology by operating and fueling hydrogen FCVs under real world conditions in varying climate, terrain and driving conditions. Vehicle infrastructure data has been collected to monitor the progress toward the 2009 hydrogen vehicle and infrastructure performance targets of $2.50–3.00/gge hydrogen production cost and 2,000-hour fuel cell durability. Furthermore, progress is being made to validate a greater than 250-mile range without impacting the passenger or cargo compartments. Finally, to prepare the public for a hydrogen economy, outreach activities have been designated to promote awareness and acceptance of hydrogen technology.

Approach

To achieve the project goals, the Chrysler Team deployed 30 Gen-I vehicles into customer hands for real-world operations in three climatic regions of the United States. The team will also provide data from Gen-II vehicles gathered under the same real-world operations as Gen-I to compare technology maturity during project duration. All vehicles have been equipped with data acquisition systems that automatically collect statistically relevant data for submission to NREL, who monitors the progress of the FCVs against the DOE Technology Validation milestones. The energy partners, BP, DTE, and NextEnergy, have installed infrastructure to provide hydrogen to the Chrysler Team FCVs and evaluate the technologies which have the potential to achieve the DOE hydrogen cost targets.

To raise public awareness of hydrogen technology and demonstration projects, the Chrysler Team aligned its communication activities with the goals of the DOE. To implement a safety process for hydrogen stations and fuel cell vehicles, the Incident Management Plan was developed. Finally, a market research study was conducted to understand the driver's perception, attitudes and usage of FCVs with partner organizations in California and Michigan.

Results

Gen-I FCVs

Throughout the year, customers continued to operate Gen-I FCVs in a variety of terrain, traffic and climatic conditions. All vehicles continued to be equipped with a data acquisition system that telematically collected vehicle data for submission to NREL. Since the inception of the Demonstration Project, over 69 DVDs of vehicle data have been submitted to NREL and mileage continues to be accumulated by Gen-I drivers in Michigan, Northern and Southern California. As customers gained driving and fueling experience, drivers have doubled accumulated mileage from 2006 to 2008.

Although the Chrysler Team has successfully completed its two-year commitment of operating 30 Gen-I vehicles, internal and external operations of these FCVs will continue until the end of the DOE project. While approximately 20 customer contracts have been extended for further Gen-I operations, one vehicle will be operated at the NREL facility. Although the remaining vehicles will be driven outside the DOE project, the Chrysler Team will continue to provide NREL data from these FCVs until the end of the DOE project.

In 2007, the Chrysler Team completed the requested DOE tests for its first generation vehicle. This included four dynamometer and two acceleration tests for each of the three designated vehicles from Michigan, Northern and Southern California (see Figure 2). In addition, gradeability and "power at 40°C" testing were successfully performed.

Furthermore, many technology improvements were made in 2007. Of particular note is the 60% improvement in vehicle range. In addition, a 10% fuel economy improvement was realized through a software optimization scheme.

Gen-II Technical Accomplishments

As the Chrysler Team finalized all required testing for Gen I vehicles, engineers are currently validating the second generation FCV, the B-Class F-Cell. To expeditiously provide DOE with data generated from the fuel cell system designed for the second generation vehicle, the Gen-II fuel cell system has been evaluated on a test bench whereas the FCVs have been internally driven by test operators. To date, B-Class F-Cell vehicles have been internally operated accumulating mileage in cold weather conditions (see Figure 3). In addition, the Chrysler Team has completed 50% of the test bench bogey, including 900 hours of implementation ready and 100 hours of design verification testing on the fuel cell system. In addition, 400 hours of processed data has been submitted to NREL.

Codes and Standards

The *Hydrogen Safety Best Practices* manual was published to integrate extensive historical experience and leanings from the Hydrogen Safety Panel work and other practices. Within these documents, safety event records from H2incidents.org provide lessons learned that are linked to web-site content.

Other hydrogen codes and standards accomplishments include:

- Society of Automotive Engineers TIR J2719-V2 was published to address hydrogen fuel quality for FCVs. SB76, a California requirement, is in alignment with J2719-V2.
- Canadian Standards Association (CSA) America
  - Hydrogen Gaseous Vehicle 4.x standards for hydrogen fueling devices and hardware have

FIGURE 2. Gen-I Dynamometer Testing

FIGURE 3. Gen-II F-Cell Vehicle Cold Weather Operation

been completed and are now under ballot by the CSA Automotive Tech Council.
  - Draft and public comments have been completed for HPRD1, a standard developed for hydrogen pressure relief devices. The work group is currently responding to all public comments.
- ASTM – Construction of the 70 MPa fueling device has been completed. The sampling device will be tested at Powertech Labs in Vancouver, BC during the third quarter of 2008. The operational manual and testing results will be used to draft a standard for the sampling of hydrogen in high pressure environments.
- International Code Council (ICC) – International Fire Code now includes fueling pad requirements that eliminate the need for cable grounding of vehicles.

In addition, the Michigan Hydrogen Storage and Dispensing Rules that address the storage and dispensing of hydrogen in Michigan was successfully completed. These rules were developed in conjunction with fire marshals, code officials, specialty gas provides, energy companies, non-governmental organizations (Next Energy) and standards development organizations (CSA, National Fire Protection Agency, ICC). The rules have been promulgated and are now in effect in Michigan.

Safety and Health

On-going safety and health programs were maintained during this reporting period with no major hydrogen related events to report. The Chrysler Team, in conjunction with energy partner BP and City of Burbank, began risk assessment activities that included a Hazard Operational Analysis (HAZOP) and a Hazard Identification (HAZID) for the 350/700 bar station to be constructed in Burbank, California. Information gathered during the risk assessment process has been incorporated into the National Environment Policy Act (NEPA) and California Environmental Quality Act (CEQA) where applicable.

DOE Project Fleet Vehicle Incident Management Plan was updated and distributed to the Incident Management leaders and commanders which are identified within the document. In conjunction with the commissioning of the Detroit NextEnergy hydrogen fueling station, emergency responder training was conducted with Wayne State University security, Detroit Police personnel, and Detroit fire fighters.

Outreach and Media

The Chrysler Team developed a marketing strategy to better align its communication activities with DOE goals. To promote awareness of hydrogen technology and FCVs, the Chrysler Team and fleet partners participated in over 100 media and outreach events. Examples of such events include the University of California Berkeley Drive Kick-Off Media Event, EVS-23 in Anaheim, and the National Hydrogen Association (NHA) Annual Hydrogen Conference in Sacramento, CA (see Figures 4 and 5). To raise public knowledge of the hydrogen demonstration project, the Chrysler Team created new promotional materials and educational tools. These materials included display banners that describe the DOE program and F-Cell customers, and flyers which highlight the DOE's hydrogen and fuel cell technology efforts and its collaboration with the Chrysler Team. These materials were displayed and/or distributed at a variety of on and off-site events.

Fueling Stations and Co-Production Facilities

The Burbank hydrogen fueling station is under development and has a projected start-up date of November 2008. Long lead-time equipment has been ordered, and the project survey and station layout has

FIGURE 4. University of California, Berkeley Media Event

FIGURE 5. 2008 NHA Daimler Display

been completed and approved. HAZOP, HAZID and other project safety reviews are on-going, the CEQA/NEPA processes are being implemented, and local permitting requirements are in-process. In addition, the legal agreement with City of Burbank has been completed.

The Burbank station will have on-site steam methane reformer hydrogen production of 240 kg/day and up to 108 kg/day storage capacity. Additionally, the station will be able to deliver hydrogen at 35 MPa and 70 MPa (see Figure 6). The site will be open for all FCVs and City of Burbank's fuel cell bus will utilize approximately 10 kg/day of hydrogen.

In Michigan, the NextEnergy Center and DTE have been providing hydrogen to DOE customers. In California, California Fuel Cell Partnership, PG&E and LAX stations have been servicing FCVs on a regular basis.

Conclusions and Future Directions

Future Work

- Maintain smooth operation of the FCVs with on-going service, maintenance and customer support.
- Accumulate more miles in different ecosystems to validate status to the DOE Performance Targets.

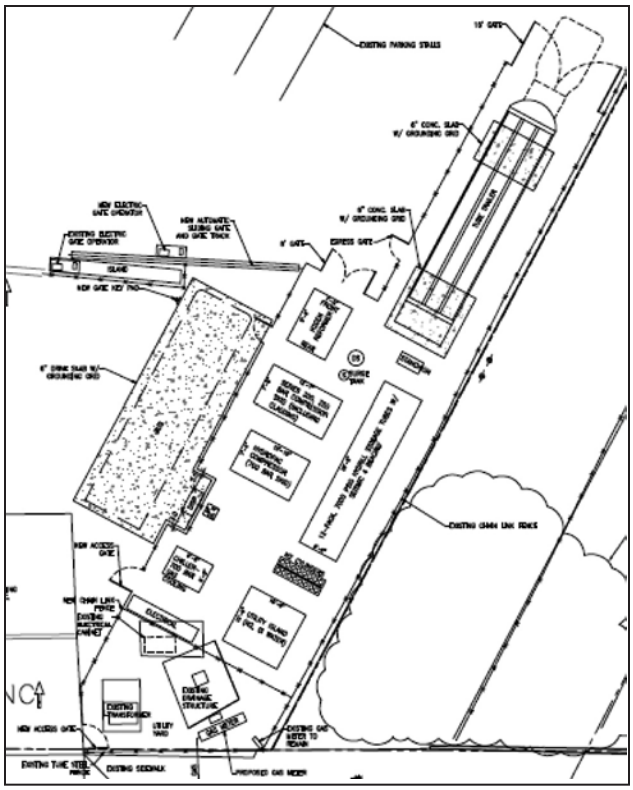

FIGURE 6. Burbank Hydrogen 35 MPa and 70 MPa Fueling Station

- Finalize technical and operational development of the 70 MPa fuel tank upgrade and Gen-II activities.
- Continue operations of the DTE, NextEnergy, LAX and PG&E sites until end of contract. Assure safety processes and risk assessment activities are maintained for all sites.
- Complete site development of the City of Burbank 70 MPa hydrogen station.
- Maintain project safety through continued inter-team communication, vehicle and infrastructure training, employee and customer education, "tabletop" incident management drills and emergency responders training.
- Maintain the high quality of technical vehicle and infrastructure data reporting structure to NREL/DOE.
- Continue pursuit of novel approaches toward outreach and media events in order to raise public knowledge of hydrogen technology and demonstration projects.
- The Chrysler Team's Wayne State University vehicle lease ended during the first quarter of 2008 and this vehicle is no longer part of the DOE project. The Chrysler Team currently does not have a vehicle in Michigan.

Hydrogen Stations

Placing a hydrogen fueling station is a unique experience that breaks new ground. Based on the experiences and lessons learned from the City of Burbank station, the following conclusions and recommendations are made:

- Significantly lengthen the amount of time planned for design, manufacture, construction and commissioning due to multiple parties involved and multiple layers of approval that must be maintained.
- There are at least two, and sometimes more, layers of responsibility within the same AHJ (Authority Having Jurisdiction) and each has a different set of concerns and needs to be addressed uniquely. The needs of all must be clearly understood and satisfied.
- Early and frequent discussions with the AHJs, general public and stakeholders helps ensure a smooth permit approval process.
- Engaging local contractors, familiar with city, state and federal approval processes, is invaluable. The approval process is the most uncertain aspect of the project to schedule.

FY 2008 Publications/Presentations

Below is a list of presentations made by the Chrysler Team:

1. Wolfsteiner, Matthias "Experiences with Daimler's Worldwide Fuel Cell Passenger Car Fleet", EVS 23, December 2007.

2. Friebe, Peter "DaimlerChrysler's Fuel Cell Vehicle Operation Within the California Hydrogen Infrastructure Network", EVS 23, December 2007.

3. Kentzler, Monika "Development of a Standardized Refueling Process for Vehicles with Compressed Hydrogen Tanks", 2008 NHA Annual Hydrogen Conference, April 2008.

4. Friebe, Peter "Moving Hydrogen Vehicles Into Commercialization", 2008 NHA Annual Hydrogen Conference, April 2008.

5. Froeschle, Peter "Optiresource – Daimler's 'Well-to-Wheel' – Optimizer, 2008 NHA Annual Hydrogen Conference, April 2008.

6. McGuire, Tim "Utilizing Data Analysis to Facilitate Fuel Cell Vehicle Technology towards Commercialization", 2008 SAE World Congress, April 2008.

7. Grasman, Ronald "Hydrogen to the Highways", 2008 Annual DOE Hydrogen Program Review, June 2008.