VIII.4 Hydrogen to the Highways

Ronald Grasman
Chrysler Group LLC
800 Chrysler Drive
Auburn Hills, MI 48326
Phone: (248) 576-8220; Fax: (248) 576-7369
E-mail: ronald.grasman@daimler.com

DOE Technology Development Manager:
John Garbak
Phone: (202) 586-1723; Fax: (202) 586-9811
E-mail: John.Garbak@ee.doe.gov

DOE Project Officer: Doug Hooker
Phone: (303) 275-4780; Fax: (303) 275-4743
E-mail: Doug.Hooker@go.doe.gov

Contract Number: DE-FC36-04GO14285

Subcontractors:

- Daimler, Stuttgart, Germany
- BP America, Warrenville, IL
- Mercedes-Benz USA LLC, Montvale, NJ
- DTE Energy, Detroit, MI
- NextEnergy, Detroit, MI
- Automotive Fuel Cell Cooperation (AFCC), Vancouver, BC

Start Date: December 22, 2004
Projected End Date: September 30, 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/gge
- Demonstrate the safe installation of hydrogen fueling stations and fuel cell service facilities as well as the safe operation of all fuel cell vehicles.
- Raise public awareness of hydrogen technology and demonstration projects.
- Establish an initial hydrogen infrastructure network to support a small fleet of fuel cell vehicles.
- Develop codes and standards and implement rigorous safety processes.
- 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 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 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)
- **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)
- **Milestone 8**: Demonstrate the ability to achieve 250 mile range without impacting passenger cargo compartment. (4Q2008)
- **Milestone 10**: Validate FCV's 2,000 hour fuel cell durability using fuel cell degradation data. (4Q2009)

Accomplishments

- Continued mileage accumulation through customer operations with vehicles in service for over 5 years.
- Upgraded and operated Gen I vehicles with 70 MPa tank system as well as optimized and tested Gen II's computer processing unit (CPU) software to further improve fuel economy and start-up time.
- Submitted over 85 DVDs of raw data to National Renewable Energy Laboratory (NREL).
- Embraced DOE's "lighthouse" vision by relocating primary workshop from West Sacramento to Long Beach, California.

- Completed construction of City of Burbank station with infrared data acquisition (IRDA) communication as well as 35 MPa and 70 MPa fueling dispenser.
- Installed new electrolyzer and dispenser at the DTE Hydrogen Technology Park.
- Internally operated Gen II pre-production vehicles in a variety of driving patterns and weather conditions.

✧ ✧ ✧ ✧ ✧

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 fuel cell vehicles 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 is also providing data from Gen II vehicles under the similar operations as Gen I vehicles to compare technology maturity during program duration. All vehicles have been equipped with a data acquisition system that automatically collects statistically relevant data for submission to NREL, which monitors the progress of the fuel cell vehicles against the DOE technology validation milestones. The energy partners, BP, DTE, and NextEnergy, have installed an infrastructure to provide hydrogen to the Chrysler Team's FCVs and to 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. In addition, project safety was maintained through continued inter-team communication, vehicle and infrastructure training, employee and customer education, "tabletop" incident management drills and emergency responders training.

Results

Gen I Fuel Cell (F-Cell) Vehicles

Although the F-Cell fleet was originally intended for a 2-year operation, A-Class F-Cells have outperformed engineering expectations as the vehicles have been in full operation for over five years. Since the inception of the demonstration project, customers have driven over 300,000 miles, allowing the Chrysler Team to generate over 85 DVDs of raw data for submission to DOE. One fuel cell vehicle was deployed to NREL at Golden, Colorado for the laboratory's Advanced Technology Fleet Effort (see Figure 1).

To embrace DOE's "lighthouse" vision, the primary workshop was relocated from Sacramento to Long Beach, California. One service center remains in Palo Alto for Northern California customer support. The move to Southern California provided an impetus to more closely analyze the infrastructure landscape and station access for near-future fuel cell vehicle commercialization as well as for immediate need to fuel 70 MPa vehicles for testing and operating purposes.

Multiple Gen I A-Class F-Cells have been upgraded with new 70 MPa tank systems and corresponding components such as pipes, valves and tank controller units. The vehicles began internal operations in Southern California so that the 70 MPa Burbank hydrogen fueling station may be utilized and vehicle/infrastructure data may be collected and submitted to NREL.

Further progress was made toward the development of the start/stop software, designed to improve fuel economy by disconnecting the fuel cell stack during idle phase. Several Gen I vehicles were flashed with the start/stop software and were tested through extensive cycles. The test results clearly showed a positive effect on the vehicle's performance, especially on fuel consumption.

FIGURE 1. Gen I F-Cell Utilized by NREL

Gen II Technical Accomplishments

Start/stop software improvements were also developed for second generation vehicles, or B-Class F-Cells. The new Gen II start/stop algorithm optimized the interface between the fuel cell and energy management system, thereby decreasing the time to restart the fuel cell system after being disconnected. This software has already been integrated into the design and verification process.

To expeditiously provide DOE with data generated from the fuel cell system designed for the second generation vehicle, Gen II fuel cell vehicles were tested on a dynamometer so that fuel economy and range could be verified. In addition, Gen II fuel cell systems were evaluated on a test bench to simulate 2,000 hours of real world driving conditions. The fuel cell system performed well under the stringent test conditions and the processed data has been submitted to NREL for analysis.

To complement the fuel cell system testing, internal Gen II vehicle operations were performed under a wide range of terrain and climate conditions, including diverse temperature, humidity and ambient air pressure (see Figures 2 and 3). For example, Gen II vehicles were driven in extreme cold weather conditions with temperatures as low as -26°C and met all engineering requirements, including reliability and durability. In addition, the Chrysler Team internally operated Gen II vehicles in the hot and dry conditions of Death Valley. While the vehicles performed up to customer expectations, valuable insight was gained and a variety of on-road vehicle data was collected. Raw data from internal operation in Death Valley, as well as other locations, have been submitted to NREL. This allowed the research facility to validate the 2009 DOE targets.

FIGURE 2. Gen II Fuel Cell Vehicles Operated in Cold Weather

FIGURE 3. Hot Weather Testing of Gen II B-Class

Codes and Standards

The Chrysler Team participated in various working groups to support and assist with the development of codes and standards. Of particular note is Society of Automotive Engineers (SAE) J2578 ("Recommended Practice for General Fuel Cell Vehicle Safety") and SAE J2579 ("Technical Information Report for Fuel Systems in Fuel Cell and Other H2 Vehicles") that have been discussed in the SAE Safety Working Group and have been revised for publication. The draft of SAE J2601, which provides fueling protocol methodology for pressures up to 70 MPa, will be published in 2009 so that it may replace the document commonly known as Next Energy Release A document. The U.S. National Highway Traffic Safety Administration will modify the Federal Motor Vehicle Safety Standards (FMVSS) to ensure that safety practices adhered by fuel cell vehicle manufacturers are consistent with the processes specified in FMVSS 305.

NextEnergy Center held its Hydrogen Codes and Standards Conference which attracted first responders, local officials, hydrogen industry experts, and national code development organizations that provided updates on the latest developments of national and international hydrogen codes and standards. This conference featured updates from such organizations as SAE, American Society of Mechanical Engineers, Canadian Standards Association America, Compressed Gas Association, International Code Council, and International Organization for Standardization.

Safety and Health

On-going safety and health programs were maintained with no major hydrogen-related events to report. The 2008 to 2009 reporting period began with emergency responder training in Santa Clara County and commissioning of the Palo Alto maintenance facility as well as hydrogen training for all on-site staff. In addition, the vehicle lift grounding system was updated at all maintenance facilities.

The Chrysler Team, in conjunction with City of Burbank, finalized the risk assessment activities including Hazards and Operational Safety Analysis/ Hazard Identification Analysis studies for the 70 MPa Burbank hydrogen fueling station in California. Information gathered during the risk assessment process was incorporated into the National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) process where applicable.

Outreach and Media

Early in the year, the Chrysler Team participated in traditional outreach events such as the SAE World Congress in Detroit and the National Hydrogen Association meeting in Sacramento where the F-600 cutaway model and a newly designed well-to-wheels kiosk were displayed. Other customary events of which the Chrysler Team was a part included the ride-n-drive at the Fuel Cell Seminar in Phoenix, and the Electric Drive Transportation Association (EDTA) Exposition in Washington, D.C. where the upgraded 70 MPa A-Class F-Cell was on display, together with banners describing the Chrysler Team's partnership with the DOE. The largest outreach event in 2008 was the Hydrogen Road Tour spearheaded by the Department of Transportation.

Fueling Stations and Co-Production Facilities

Burbank Station

With significant cooperation from a wide variety of partners, including the City of Burbank, California Air Quality Management District and DOE, the Chrysler Team fulfilled its commitment to complete the construction and commissioning of the Burbank hydrogen fueling station (see Figure 4). Not only were the NEPA/CEQA, local permitting requirement and legal agreement with the City of Burbank completed, but all the functionality of all components, including the steam methane reformer, was confirmed. The fueling system was filled with hydrogen from a tube trailer, and is presently filling 35 MPa cars that the City of Burbank operates. In addition, several 70 MPa vehicles with an IRDA system were fueled to full capacity.

DTE Hydrogen Technology Park

To keep up with the cold weather demands of Michigan, the electrolyzer and dispenser of the fueling station were replaced. The dispenser was modified to accept 70 MPa vehicles for communicated fills. While the manufacturer completed installation, testing and start up during the fourth quarter of 2008, Michigan

FIGURE 4. Burbank Hydrogen 35 MPa and 70 MPa Fueling Station

Department of Environmental Quality final inspection was finalized during the third quarter of 2009. The DTE Energy Hydrogen Technology Park is currently up and running doing vehicle fueling.

Los Angeles International Airport (LAX)

While the site had not been funded under the current DOE grant, it regularly served Daimler/ Chrysler/DOE customers as well as Ford, Toyota and Honda. BP terminated its operation of the Praxair LAX station during the third quarter of 2008. BP de-branded the station and the site remained available to customers that had contracts with Praxair until the second quarter of 2009.

NextEnergy

BP and its partners have agreed to transfer the station assets and operating responsibility to NextEnergy. The station is open and functioning well. NextEnergy Center presently has fueling agreements with several original equipment manufacturers (OEMs) to refuel hydrogen vehicles.

Critical Infrastructure Next Steps

As fuel cell vehicles transition from a demonstration phase to commercialization, the development of well established hydrogen fueling station network is critical and, as a result, the following recommendations are made:

- More funding must be devoted toward long-term infrastructure development.
- Forty hydrogen stations need to be placed in the Los Angeles area by 2010.
- Station deployment should consider the needs of all fleets operating under the program.

- All new stations must meet the performance specifications outlined in the NextEnergy Release A document.
- To ensure maximum vehicle utilization, fuel costs must be considered.

Summary and Future Directions

Summary

- Completed construction of City of Burbank 70 MPa station.
- Installed new electrolyzer and dispenser at DTE Station.
- Internally operated Gen II pre-production vehicles.
- Upgraded and operated vehicles with 70 MPa tank system and new CPU software.
- Continued mileage accumulation of Gen I vehicles.

Future Work

- Prepare for next generation demonstrations.
- Work with DOE to ensure existing hydrogen stations remain open and available.
- Finalize decision and plan for project extension.
- Maintain smooth operation of Gen I fuel cell vehicles with on-going service, maintenance and customer support.
- Continue internal operations of Gen II vehicles.
- Maintain the high quality of technical vehicle and infrastructure data reporting to NREL/DOE.
- Pursue novel approaches toward outreach and media events to raise public knowledge of hydrogen technology and demonstration projects.

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:

- OEM and energy company coordination is important for optimal selection of sites.
- Funding for long-term operation needs to be discussed.
- Reformer supplied facilities were much more complex and required larger footprint than anticipated.
- Early coordination with officials to establish relationships is critical.
- Additional documentation and unexpected requirements from permitting officials are not unusual.
- NEPA/CEQA process can be very lengthy and interfere with budget deadlines.
- Legal contracts often take much longer than expected.
- Reliability of equipment needs to be improved.
- A better set of analytical test methods is needed to ensure hydrogen quality.

Publications/Presentations

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

Fuel Cell 2008; Long Beach, CA	05/08
Memorial Day Parade; Scotch Plains, NJ	06/08
Turner Logistics Tradeshow; Long Beach, CA	07/08
Aspen Ideas Festival; Aspen, CO	07/08
Semicon West; San Francisco, CA	07/08
John Mayer Concert; Jones Beach, NY	08/08
Butterfly Festival; Trenton, NJ	08/08
Hydrogen Drive; Maine to California	10/08
California Science Teacher's Association Conference; San Jose, CA	12/08
EDTA Conference and Expo; Washington, DC	04/08
World Mobility Forum; Stuttgart, Germany	01/09
Firehouse World; San Diego, CA	02/09
Washington DC Auto Show; Washington , DC	02/09
Alternative Fuels Symposium – 2nd annual Meeting; Paris, France	03/09
20th NHA Conference and Hydrogen Expo; Columbia, SC	03/09
NAFA Annual Convention; New Orleans, LA	04/09
NAFA March Meeting; New York, NY	05/09
EVS-24: The International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium; Stavanger, Norway	05/09