VI.A.1 Hydrogen to the Highways

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Subcontractors:
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BP America, Warrenville, IL
Mercedes Benz USA LLC, Montvale, NJ
DTE Energy, Detroit, MI
NextEnergy, Detroit, MI
Ballard, Vancouver, BC, Canada

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Projected End Date: December 22, 2009

Objectives

- Record, collect, report and analyze data from fuel cell vehicles and hydrogen fueling operations.
- Validate 2009 performance 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.
- Establish an initial hydrogen infrastructure network to fuel small fleets of fuel cell vehicles across a metropolitan area.
- Develop retail compatible hydrogen refueling systems.
- Evaluate emerging hydrogen refueling and generation technologies that have the ability to meet Department of Energy (DOE) cost and performance targets.
- Explore cost and commercial feasibility of renewable-based hydrogen generation.

Technical Barriers

This project addresses the following technical barriers from the Technology Validation section (3.5.4.2) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(A) Vehicles
(B) Storage
(C) Hydrogen Refueling Infrastructure
(D) Maintenance and Training Facilities
(E) Codes and Standards
(H) Hydrogen from Renewable Sources

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 2: Demonstrate FCVs that achieve 50% higher fuel economy than gasoline vehicles (3Q 2005). This milestone has been achieved and the data has been sent to NREL for analysis.

Milestone 5: Operate fuel cell vehicle fleets to determine if 1,000 vehicle fuel cell durability, using fuel cell degradation data, was achieved by industry (4Q 2006). DaimlerChrysler, as well as three other industry teams, is providing the National Renewable Energy Laboratory (NREL) with on-road vehicle data collected from the fuel cell vehicles operated in various climatic regions. DaimlerChrysler is also providing NREL dynamometer testing data from a representative sample of hydrogen vehicles. NREL will publish and present composite data products that report on the progress of the technology made towards the DOE milestones.

Milestone 6: Validate vehicle refueling time of 5 minutes or less (4Q 2006). Due to regular use by customers, the fuel cell vehicles are being refueled on a consistent basis at a variety of fueling stations. Various technologies are being tested and demonstrated throughout the infrastructure network and results are reported within the project. This will support the continued improvement of refueling time. The permanent station utilizing electrolysis at the

DTE/BP station in Southfield, Michigan currently provides an average refueling time of less than 5 minutes. Although this refueling time is within the 5 minute objective, a target of less than 3 minutes is essential for customer friendly operation, even as filling volumes increase. With new technologies including pre-cooling and proper communication between the vehicle and fueling station, it is expected that this refueling time can be maintained or reduced.

Milestone 8: Demonstration (on a vehicle) 2.0 kWh/kg and 1.2 kWh/L compressed storage tanks (2Q 2008). The compressed hydrogen storage tank (5,000 psi) that is used in both the F-Cell and Sprinter fuel cell vehicles realize an energy density of 0.6 kWh/l.

Milestone 9: Validate FCVs with 250-mile range (by 2008), 2,000-hour fuel cell durability, and a hydrogen cost of $2.00-$3.00/gge (based on volume production) (4Q 2009). DaimlerChrysler is in the process of collecting raw data from the 30 fuel cell vehicles currently under daily operation. The data is provided to NREL which will share the composite data of four industry teams.

Milestone 12: Five stations and two maintenance facilities constructed with advanced sensor systems and operating procedures (4Q 2006).

- Maintenance Facility: DaimlerChrysler has established three service stations, one for each of three geographical areas (Northern California, Southern California, and Southeast Michigan). Detailed safety procedures and precautions have been implemented from initial design to continued operations. Maintenance facilities have undergone simulation modeling exercises and were upgraded with the appropriate sensors and safety equipment.
- Fueling Stations: The BP hydrogen station at NextEnergy in Detroit will comply with National Fire Protection Association (NFPA) 52 guidelines for fire and gas detection systems. Detailed safety procedures and processes have been implemented in the design and construction of the unit (i.e. HAZID, etc.). These rigorous safety analysis tools, including third party peer review, will also be applied for station commissioning.

Accomplishments

- All 30 vehicles are operational and equipped with onboard data collection devices to wirelessly transmit the collected data to local file servers which then make the data accessible to DaimlerChrysler via the internet.
- Emergency response plan and training programs are complete.
- Two hydrogen fueling stations, PG&E mobile refueler and DTE Energy, are operational. Of particular note is that the PG&E station is sited in a residential urban location. Two other BP stations, Los Angeles International Airport (LAX) and California Fuel Cell Partnership (CaFCP), are also operational and open for refueling DOE/DaimlerChrysler vehicles.
- UCLA and NextEnergy (Detroit) fueling stations are under development and/or construction.

Introduction

The primary goal of this project is to demonstrate the use of fuel cell vehicles under real world conditions utilizing multiple sites with varying climates and sources of hydrogen. The work to be performed for this project consists of testing, demonstrating and validating performance of (1) hydrogen fuel cell vehicles (2) infrastructure and (3) vehicle and infrastructure interfaces. Specifically, the 5-year project will identify the status of the performance targets of $3.00/gge hydrogen production cost, 250 vehicle mile range and 2,000-hour fuel cell durability. Vehicle and infrastructure data will be collected to monitor the progress toward the aforementioned performance targets of the hydrogen vehicles and infrastructure.

Approach

To meet the project's objectives, DaimlerChrysler's approach is to deploy 30 first generation (Gen I) vehicles for real-world operation into three regions of the United States. The selected locations are Southern California for hot climate, northern California for moderate weather, and southeast Michigan for a cold environment. These vehicles will maintain continued customer operation and will be utilized in day-to-day operation in diverse driving conditions, terrain and temperature.

All vehicles within the DOE demonstration project will be equipped with a customer friendly data acquisition system that will automatically collect statistically relevant data for submission to NREL as well as for internal analysis for technology improvement. DaimlerChrysler is creating a broad database so that NREL may thoroughly evaluate the progress of fuel cell vehicles and hydrogen infrastructure against the DOE technology validation milestones.

The energy partners, BP, DTE Energy and NextEnergy, are installing the necessary infrastructure to support the vehicles in each geographical area and to evaluate the technologies which have the potential to achieve the DOE hydrogen cost targets.

Results

Vehicle Operation and Fleet Customers

The project is now in full operation. Altogether, 30 fuel cell vehicles were assembled and delivered to the United States including 28 A-Class "F-Cell" and two Sprinter delivery vans. All fuel cell vehicles within the DOE project have completed the initial "pre-customer operation" test and are under daily operation by customers located in the three regions (see Figures 1 and 2). The 18 DOE-DCX fleet customers are shown on Table 1.

Data Reporting - Fleet Data Acquisition

In order to evaluate the progress made toward the DOE Milestones, all 30 fuel cell vehicles have been equipped with data recording equipment and software that allow the constant recording of numerous data points and conditions during operation. To accommodate the size and complexity of the data, DaimlerChrysler has developed a Fleet Data Acquisition (FDA) system that wirelessly transmits the data from each vehicle to local file servers which then make the data accessible to test engineers via the internet. This process allows for timely submittal of all performance data to NREL. Thus far, thirteen local file servers have been installed and 14 CDs of vehicle data have been provided to NREL.

DaimlerChrysler has also completed two semi-annual dynamometer and acceleration tests. Cooperative testing analysis was performed between NREL, DaimlerChrysler and EPA representatives to ensure that all tests were successful and that the desired results were attained.

The data was not only incorporated into the R&D process to continually improve the F-Cell performance, but was also used to monitor the progress of the DOE validation milestones. DaimlerChrysler utilized the data in the design of four software upgrades that directly improved the reliability and performance of the F-Cell vehicles. NREL is utilizing the data to monitor DaimlerChrysler's progress toward the DOE milestones such as the vehicle range, fuel cell durability and energy density of storage tanks.

FIGURE 1. DaimlerChrysler Fuel Cell Vehicles in Operation

FIGURE 2. Energy Partners, BP and DTE Energy, Providing Fueling Needs for Fuel Cell Vehicles

TABLE 1. DaimlerChrysler Fleet Customers

Government Agencies
Bay Area Air Quality Manangement District
California Air Resource Board
California Department of General Services
California Department of Transportation
California Energy Commission
California Fuel Cell Partnership
City of Farmington Hills
Sacramento Municipal Utility District
Non-Profit Organization
SRI International
University of California at Berkeley
University of California at Los Angeles
Wayne State
For Profit Organization
DaimlerChrysler
Inergy Automotive Services
Los Angeles World Airport
Pacific Gas & Electric Company
Southern California Edison
United Parcel Service

Service Facilities

Three regional facilities have been established to service the 30 vehicles operated in the three validation regions. All three regional facilities have the tools, equipment and infrastructure required to ensure that all customer service needs are met and that all vehicle maintenance and data collection can be performed in a timely fashion.

DaimlerChrysler is among the first to build a cost effective hydrogen safe maintenance facility utilizing computational fluid dynamic (CFD) modeling. The Southern California (Long Beach) facility was constructed specifically for hydrogen vehicles and allows service of the vehicles with full hydrogen tanks. Prior to the construction of this facility, all fuel cell vehicles had to be completely defueled prior to servicing in this maintenance site. DaimlerChrysler shared the innovative methodology and recommendations with the DOE through a demonstration tour as well as a 12 page summary report.

Safety Training

DaimlerChrysler worked with its energy partners DTE Energy, FTI (Fueling Technologies Inc.), Air Products and BP to develop a failure mode effects analysis (FMEA) for the interface between the vehicle and the DTE hydrogen fuelling station. The FMEA information was later transferred into BP's HAZID for the NextEnergy hydrogen facility located in Detroit, Michigan. Key findings and lessons learned include:

- The nozzle/receptacles need to be certified to SAE J2600.
- Hydrogen stations need a conventional grounding surface to ground vehicles through the tires (API RP 2003).
- Future vehicle-to-station communication should utilize infrared.

Throughout the year, DaimlerChrysler completed an Incident Management Plan outlining instructions, advice and recommendations for all employees directly involved in the use of fuel cell vehicles for different levels of incident (high/medium/low). DaimlerChrysler also developed the following training programs:

- Service employee training
- Customer training
- General training (F-Cell 101)
- Infrastructure training
- Emergency response training

Fueling Stations and Co-Production Facilities

Two DaimlerChrysler/DOE partially funded hydrogen fueling stations are currently in operation while two other stations are either under development or construction. The operating stations include DTE Energy located in Michigan and PG&E in Northern California. PG&E was installed and commissioned at an ideal downtown San Francisco location. To foster public acceptance for hydrogen, BP has been involved in locating the PG&E station within an urban environment. The CaFCP and LAX stations, although not funded by DOE, are also providing hydrogen to DOE customers.

A new station is being built in Detroit. BP and NextEnergy identified an optimal site located in downtown Detroit. All legal agreements with NextEnergy and Air Products are finalized. BP coordinated comprehensive safety processes and analysis with NextEnergy. In addition, a successful community outreach program was developed.

A new station is also planned for the Los Angeles area. BP and an industrial gas company have selected and evaluated a suitable site on UCLA property. Legal agreement, technical assessment and environmental impact of the station are under review. The station will utilize on-site hydrogen production technologies.

Note: Data from this demonstration project is reported as part of the composite results presented in project report VI.G.1.

Conclusions and Future Directions

Conclusions

- DaimlerChrysler deployed 30 Gen I vehicles into customer hands in three different regions.
- The FDA infrastructure was developed to wirelessly and automatically collect data from each vehicle to file servers for customer friendly operation.
- Three regional service facilities were established to support vehicle maintenance, data collection and customer needs.
- Two DOE hydrogen fueling stations (PG&E mobile refueler and DTE Energy)are operational in addition to the LAX and CaFCP stations.
- An innovative approach was utilized to design and construct a hydrogen safe service facility.
- BP and DTE energy provided hydrogen refueling requirements to fleet customers in three locations.
- DaimlerChrysler developed an Incident Management Plan, education programs, and outreach activities as well as participating in codes & standards development activities.

Future Work

- DaimlerChrysler will accumulate more miles with fuel cell vehicles operated by customers.
- Customer relations will be cultivated with ongoing service, maintenance and performance outreach.
- BP will finalize the construction and commission of the NextEnergy station located in Detroit, Michigan.
- BP will continue the site preparation and permitting process for UCLA. DaimlerChrysler will add a Linde mobile refueler at Long Beach, California facility.
- Project safety will be maintained through continued FMEA updates, vehicle and infrastructure training, education, emergency responders training and emergency response drills.
- The FDA infrastructure will be expanded from 13 to 17 local file servers.
- DaimlerChrysler will continue to generate performance data from daily vehicle operations as well as acceleration, gradeability and dynamometer testing.

FY 2006 Publications/Presentations

1. Bonhoff, Klaus "Fuel Cells Enabling the Mobility of the Future – DaimlerChrysler's Worldwide Fuel Cell Activities," World Hydrogen Technologies Convention 2005, Singapore, October 2005.

2. Bonhoff, Klaus "Comments on WtW-Study Reports & Future Outlook for FCV and Hydrogen Economy," JHFC Seminar – Workshop on WtW Efficiency Analysis, Tokyo, Japan, March 2006.

3. Bonhoff, K., Docter, A., Rau, W. "Fuel Cell Market Development," Challenge Bibendum, Kyoto, Japan, June 2005.

4. Lamm, W. Rau "Technical Status and Future Prospectives for PEM Fuel Cell Systems at DaimlerChrysler," Grove Fuel Cell Symposium, London, England, October 2005.

5. Schneider, Jesse "Development of Fueling Performance Targets for 70 MPa Gaseous Hydrogen Storage Containers," Long Beach, California, March 2006.

6. Tran, Doanh "DaimlerChrysler Global Fuel Cell Operations," Palm Springs, California, November 2005.