VI.A.2 Ford & BP Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project

Gregory Frenette (Primary Contact), Gerry Brooks
Ford Motor Company
Fuel Cell Center
1201 Village Rd.
Dearborn, MI 48121
Phone: (313) 390-2505; Fax: (313) 845-7453
E-mail: gfremett@ford.com

DOE Technology Development Managers:

Sigmund Gronich
Phone: (202) 586-1623; Fax: (202) 586-9811
E-mail: Sigmund.Gronich@ee.doe.gov

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) 275-4753
E-mail: Doug.Hooker@go.doe.gov

Contract Number: DE-FC36-04GO14287

Subcontractor:
BPAmerica Inc., Naperville, IL 60563

Start Date: November 17, 2004
Projected End Date: June 2009

Objectives

- DOE: By 2009, validate hydrogen vehicles that have greater than 250-mile range, 2,000 hour fuel cell durability, hydrogen infrastructure that results in a hydrogen production cost of less than $3.00/gge (untaxed), and safe and convenient refueling by trained drivers
- Ford:
  - Gain vehicle operational data in differing climates, to direct and augment future design efforts
  - Provide input to the industry-government efforts to define a future hydrogen economy
- BP:
  - Establish an initial hydrogen infrastructure network to fuel small fleets of fuel cell vehicles across a metropolitan area
  - Develop retail compatible hydrogen refuelling systems
  - Evaluate emerging hydrogen technologies that have the ability to meet 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 & Standards

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 Fuel Cell Vehicles (FCVs) that achieve 50% higher fuel economy than gasoline vehicles (3Q 2005). Progress to date: Dynamometer vehicle testing has been completed on the Phase I Ford Focus FCV prior to fleet deployment, and resulting data that supports this milestone has been provided to NREL. Additional dynamometer test data from field test units has also been provided in quarterly data reporting to NREL.

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). This milestone has been addressed with data generated from the first engineering test vehicles in accelerated on-road durability testing. Fleet use data is being accumulated for ongoing reporting. Fuel cell parameters are being monitored, collected and reported to NREL in quarterly data reports. To accelerate the collection of pertinent data to support this milestone, efforts have also been made to ensure that all vehicles are being used optimally, and reassignments to more active customer applications are underway along

with project guideline revisions to expand driving opportunities for customers.

Milestone 6: Validate vehicle refueling time of 5 minutes or less (Year-End 2006). Progress to date: On the Focus models, a full fill of hydrogen requires pressurization to 5,000 psi. Fill times are reported to NREL as part of quarterly data submissions. All planned permanent station installations with communications are expected to provide additional detailed data to address this milestone.

Milestone 9: Validate FCVs with 250-mile range (complete in 2008), 2,000 hour fuel cell durability, and a hydrogen cost of $3.00/gge, based on volume production (4Q 2009). Progress to date: Ford presented a Technology Demonstrator Vehicle plan on May 3, 2005 that provided a progressive design level approach to demonstrating improved range and performance. This plan has been reviewed and approved by DOE. As new technologies that improve on the potential to meet or exceed these targets are proven feasible, modifications to this plan may be proposed.

Milestone 11: Validate cost of producing hydrogen in quantity of $3.00/gge untaxed (2Q 2008). Progress to date: BP has assessed through meetings with suppliers several technologies to understand their current status and potential of meeting the $3.00 gge target untaxed by 2008. The following is a list of a few of the technologies reviewed to date; H2Gen 2000, Air Products Harvester, Proton Energy High Pressure PEM system with electrochemical compression and GE Autothermal Reformer.

Of these systems, the H2Gen 2000 and the Air Products Harvester units can meet the $3.00/gge untaxed hydrogen production cost target using the H2A model assumptions.

Milestone 12: Five fueling stations and two vehicle maintenance facilities constructed using advanced sensor systems and operating procedures (Year-End 2006).

Service Facilities Progress to date: Ford has completed work on two service facilities (including unique fuel cell vehicle diagnosis and tracking software/hardware) for project vehicles in Dearborn, MI and Sacramento, CA. The third service facility in Orlando, FL was constructed, and is used for vehicle maintenance. However, repair work can not be effectively performed in the open air design and consequently, this type of work is being performed in a nearby, cooperating Ford Dealership. The existing facilities utilize state-of-the-art hydrogen sensors, and have service procedures established for hydrogen fueled vehicles, and operating procedures for personnel working in a hydrogen vehicle service facility.

Fueling Stations Progress to date: In California, the Sacramento Airport station permits have become entangled in internal airport politics. The hope now is that the permits will be issued in the 2Q 2006 which will allow construction to commence by the 3Q 2006. Because of the peak summer travel season the airport is reluctant to allow BP to close the station for 8 weeks to perform a complete station rebuild. Negotiations are underway.

In Florida, planning, zoning, building, water management, and National Environmental Policy Act (NEPA) permits have been submitted. Issuance is expected in July 2006 with construction to commence in late July to early August 2006.

Milestone 14: Validate the ability to produce 5,000 psi hydrogen from natural gas for $2.50/gge, untaxed and with large equipment production volumes (e.g. 500 units/year) in the learning demonstration for 1,000 hours (3Q 2010). Progress to date: We have not found a technology to date that can meet the $2.50/gge cost target.

Accomplishments

Since the last annual report, the principle accomplishments in this technology demonstration are:

- **Deployment of all 18 project vehicles.** By October of 2005, Ford had deployed
  - Eight units in Sacramento, CA (five to the Sacramento Municipal Utility District, and one each to California Department of General Services, Energy Commission and Air Resource Board)
  - Five units in Orlando, FL (two to Progress Energy, two to the Department of Environmental Protection, and one to the State Parks)
  - Five units in Southeast MI: (four to the City of Taylor and one to the City of Ann Arbor)
- **Fleet mileage accumulation** has been reported to NREL
- **Fleet hour accumulation** has been reported to NREL
- **Data submission** of two complete data sets to NREL using automated data collection and report generation techniques
- **Demonstrated fueling fill times** that meet program milestone target of five minutes or less
- **Training programs development and delivery** for emergency responders, service technicians, fleet managers and vehicle operators. Before vehicle

deployment, training has been delivered to many involved personnel as indicated in Table 1.

TABLE 1. Types and Number of People Trained

Training Module	S.E. MI	Sacramento, CA	Orlando, FL	Total
Fleet Manager	5	11	4	20
Operator	22	45	27	94
Service Technician	2	2	2	6
Emergency Responder	28	21	68	117
Totals	57	79	101	237

Since project inception, more operators have been trained in efforts to increase hour and mile accumulation in the fleet.

- **Fueling Station deployment** has begun with the Taylor, MI permanent station in place while stations in Florida and California are scheduled for completion by the end of summer, 2006
- **Fuel data** is being developed on delivered hydrogen and locally produced H_2 from a steam methane reforming (SMR) approach
- **New concept vehicle architecture** has demonstrated the ability to improve vehicle operating characteristics and consumer-focused attributes in designs developed for hydrogen powered drivetrains

Introduction

In order to meet the objectives and deliverables of this technology demonstration project, Ford and BP have developed an approach that permits demonstration of the current state of technology while continuing to develop and prepare demonstrations for newly emerging technologies and techniques.

In this approach, Ford will deploy vehicles that contain state-of-the-art fuel cell system designs in customer fleet applications and collect detailed data of the operating parameters using computerized, automated data collection and analysis techniques. At the same time, all new concepts of vehicle and component design will be developed using emerging technologies to demonstrate progress against the DOE's longer term milestones.

At the same time, BP will first deploy delivered hydrogen to permit fleet operations. Once the fleet is deployed, BP will work with local authorities where the cars are operating, to locate, plan and certify permanent hydrogen fueling stations in each of the fleet operating areas.

Approach

Ford Vehicle Demonstration Approach

Two vehicle demonstration phases (see Table 2)

- **Vehicle Phase 1:** developed technology installed in contemporary vehicles for real world use
  - Ford Focus 4 Door
  - Weight: 1600 kg (3520 lbs)
  - Fuel Cell: Ballard Mark 902 fuel cell stack
  - Power: 67kW (87 hp)
  - Power train: Integrated--combines inverter module with AC electric motor transaxle
  - Hybridized – 216 volt battery pack
  - Regenerative braking system
  - Range: 260-320 km (160-200 miles)
  - Max speed: 128+ kph (80+ mph)
  - Fuel: 5,000 psi compressed gaseous hydrogen
  - Emissions: zero
    - Phase 1 Deliverables:
      Real World Data
      Maintenance & Training
      Hydrogen Storage & Interface

- **Vehicle Phase 2:** controlled in-house demonstration of extended range, durability and operating temperature
    - Phase 2 Deliverables:
      Improved Hydrogen Storage & Interface
      Improved Durability
      Improved Economy
      Reduced Weight
      Reduced Cost

  - Fleet vehicles in three differing geographic/ climatic regions
  - Automated data collection methodologies for effective data analysis

TABLE 2. Vehicle Demonstration Phases

Program Elements	*Phase 1*	*Phase 2*
Real World Data	Underway	
Maintenance & Training	Complete	
Hydrogen Storage & Interface	Underway	☑
Durability	Underway	☑
Economy	Underway	☑
Weight		☑
Cost		☑

BP Infrastructure Approach

Employ Two Phase Approach (see Table 3)

- **Infrastructure Phase 1:** Test Infrastructure Deployment
  - Install hydrogen delivered stations
  - Include electronic data collection for select sites
- **Infrastructure Phase 2:** Meet Cost Targets
  - Install onsite hydrogen production and/or 700 bar fueling at select sites

Station Locations

- Orlando, Florida (one)
- Sacramento, California (up to four)
- Taylor, Michigan (up to two)

Results

On the vehicle side, results to date have both met expectations and also provided learning experiences that help formulate future plans.

The cars are operating efficiently (meeting fuel consumption targets) and effectively (charted vehicle "up-time" in excess of 98%). Differences in atmospheric conditions at the fleet locations have provided useful information about the need for control systems that can accommodate a broader range of temperature and humidity. Differences in operating grades and traffic patterns have also identified a need to adjust hybrid battery charging algorithms to maintain the battery and minimize service requirements. The fleet and involved personnel have also demonstrated a 100% safety performance with no incidents or near misses.

Second Phase demonstrators are underway and have demonstrated new concepts for packaging of the various system components for improved performance and noise reductions.

Data from the demonstration fleet, in accordance with the DOE's plan, has been held in the confidential manner developed for this program, and results are being produced and published by NREL as a part of the consolidated data products resulting from multiple participant data submissions.

On the infrastructure side, results have been more difficult to attain. The process of obtaining site leases has been challenging because of concerns of local governments and citizens that have been expressed concern about hydrogen fuel and non-program related issues. Completion of hazard identification exercises and preparation of NEPA documentation, along with DOE interactions and local codes & standards work have all taken longer than originally planned.

However, with the opening of the Taylor, MI permanent fueling station, it has been demonstrated that the myriad of start-up requirements can be met, even at this early technology deployment stage.

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

TABLE 3. Infrastructure Demonstration Summary

Location	Phase 1 Delivered H2	Phase 2 Electrolysis	Phase 2 SMR	Phase 2 700 Bar
Orlando	bp	bp		
Sacramento				
Station S1	bp			
Station S2	bp		bp	
SMUD	bp	bp		
Michigan				
Taylor	bp		bp	bp
Station M2	bp			bp

Conclusions and Future Directions

The project is providing important data on both vehicle performance and infrastructure development. Although vehicle miles and hours are lagging the original plan, efforts are being made to meet the program milestones, and the vehicles are performing at a level that will permit this to happen. Phase 2 vehicles are beginning to demonstrate the performance attributes that were originally envisioned for the program. Ford will continue with the plans as approved for this project, and seek approval for changes that may be beneficial as new technologies are proven feasible.

Infrastructure development has taken longer than planned, but is moving forward. Alternative production techniques and associated cost analysis will be pursued with the completion of the permanent fueling station.