Hydrogen Learning Demonstration Project: Fuel Cell Efficiency and Initial Durability*

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Abstract

The U.S. Department of Energy (DOE) initiated the "Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project" to conduct an integrated field validation that simultaneously examines the performance of fuel cell vehicles and the supporting hydrogen infrastructure. Detailed technical insights from the vehicles and infrastructure study are being fed back into DOE's research and development program to guide and refocus future research, making this project a "learning demonstration." Four cooperative agreements between DOE and industry partners have been awarded and commenced. These four teams will ultimately support up to 130 fuel cell vehicles, which will be validated on-road, as well as up to 20 hydrogen refueling stations. Approximately 65 first-generation vehicles have already entered into service with customers, and many new hydrogen refueling stations have opened, with more vehicles and stations planned. Lessons learned from this project on the interrelationship between the vehicles and the infrastructure will influence ongoing development of codes and standards. The auto industry and the energy companies are strongly committed to this project, and the government's investment in this project is matched by each industry team.

This DOE/industry collaborative project will continue from 2004-2009, during which multiple generations of technology will be tested. At time of publication the project had collected 5 calendar quarters of vehicle and infrastructure data, and technical performance of vehicles and infrastructure has been compared against DOE targets. Examples of 2009 DOE validation targets include a 250-mile vehicle range, 2,000-hour durability of vehicle fuel cell stacks, and a hydrogen production cost of $3/gge untaxed, when produced in quantity. This paper provides a status update covering the progress of the demonstration and validation project since inception. This includes a new set of public composite data products being released from the project, the second to be published. The composite data products aggregate individual performance into a range that protects the intellectual property and the identity of each company, while maintaining the ability to publicize the progress made by the hydrogen and fuel cell industry relative to program objectives and timeline. New results from this project include data on the current status of fuel cell durability and efficiency. Some of the results that were published in March, 2006 [1] are updated with six months of additional data. Comparison of progress toward DOE technical targets are made through these composite data products, and future project activities and analysis are discussed.

Introduction

Hydrogen fuel cell vehicles are being developed and tested for their potential as commercially viable and highly efficient zero-tailpipe-emission vehicles. Using hydrogen fuel and high-efficiency fuel cell vehicles provides environmental and fuel feedstock diversity benefits to the United States. Hydrogen can be derived from a mixture of renewable sources, natural gas, biomass, coal, and nuclear energy. Many of the potential feedstocks would enable the United States to reduce emissions and decrease its dependence on foreign oil. Numerous technical barriers remain before hydrogen fuel cell vehicles are commercially viable. Significant resources from private industry and government are being devoted to overcoming these barriers.

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The U.S. Department of Energy (DOE) is working with industry to further develop these technologies through its Hydrogen, Fuel Cells & Infrastructure Technologies (HFCIT) Program. This multi-faceted program simultaneously addresses hydrogen production, storage, delivery, conversion (fuel cells), technology validation, deployment (education), safety, and codes and standards. Many key technical barriers, such as hydrogen storage and fuel cell durability, have been identified and are being addressed. Additional challenges may become apparent through integrated, real-world application of hydrogen technologies. Prior to this project, the number of fuel cell vehicles in service has been small, and vehicle operation has been focused primarily in California, limiting the quantity and geographic diversity of data collected. To address vehicle and refueling infrastructure issues simultaneously, DOE is conducting a large-scale "learning demonstration" involving automotive manufacturers and fuel providers that is called the "Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project."

Project Objectives and Targets

One of the HFCIT Program's key objectives is to conduct parallel learning demonstrations of hydrogen infrastructure and fuel cell vehicles to evaluate the status of the technology and identify remaining technical barriers. We will accomplish this objective through validating the vehicle and infrastructure as a complete system solution. The quantity and breadth of data collected and analyzed will allow us to evaluate technology status versus DOE program targets and give recommendations to DOE on refocusing research and development as appropriate. The ability to refocus research and development as an integrated part of DOE's program makes this project unique.

This project has specific performance targets for 2009, which will be used to evaluate progress toward the 2015 targets. The targets listed in Table 1 address key barriers to successful market entry. Fuel cell stack durability is critical to customer acceptance of fuel cell vehicles. Although 2,000-hour durability in 2009 is considered acceptable to validate progress, a 5,000-hour lifetime (equivalent to approximately 100,000 miles) is estimated as a requirement for commercialization. Vehicle range is also an important consumer expectation. Although many factors contributed to the failure of all-electric vehicles to gain market acceptance despite California government mandates, limited vehicle range is widely accepted as being a significant contributor. Finally, hydrogen production cost is a key metric because consumers are much less likely to purchase an alternative fuel vehicle if the fuel is significantly more expensive than gasoline.

Table 1: Project Performance Targets

Performance Measure	2009*	2015**
Fuel Cell Stack Durability	2000 hours	5000 hours
Vehicle Range	250+ miles	300+ miles
Hydrogen Cost at Station (untaxed)	$3/gge	$2-3/gge

* To verify progress toward 2015 targets
** Subsequent projects to validate 2015 target

Industry Partners

DOE has awarded cooperative agreements to four teams to participate in this project. Each team includes both an automotive original equipment manufacturer (OEM) and an energy provider, with automotive OEMs leading three of the teams, and an energy provider leading the fourth. Figure 1

shows the teaming arrangement of the four teams along with their fuel cell vehicles. The major companies making up the four teams are as follows:

- Chevron and Hyundia-Kia
- DaimlerChrysler and BP
- Ford Motor Company and BP
- General Motors and Shell

Figure 1: OEM & Fuel Supplier Teams, Along with Representative Vehicles

Key Results to Be Presented

At time of publication, the final composite data product results were being reviewed by our industry partners to ensure accuracy. This section includes two of the key representative composite data products (without including actual data) that we anticipate will be approved for presentation in November, 2006. In addition to the type of results shown here, other new and updated composite data product results will be presented. Specifically, improved representations of the hydrogen quality sampled at all of the H2 refueling stations will be presented which include scatter plots of actual data (without company attribution). This allows the hydrogen community to see where data are clustered, and whether data points at the edges of the ranges are outliers or represent a cluster of many data points. H2 station maintenance data will also be presented, including a comparison of the ratio of scheduled to unscheduled maintenance. Driving and refueling data were also analyzed to determine what fraction of the theoretical and actual on-road driving range (based on fuel economy and usable on-board H2 storage) was actually being seen with the vehicles in operation.

Fuel Cell Durability: One of the key technical barriers listed in Table 1 is a technical target of 2000-hour fuel cell stack durability by 2009. DOE has set an intermediate target in 2006 for stack durability of 1000 hours, using a 10% voltage degradation (under full load) methodology as an indicator of significant degradation. Actual end-of-life (failure) of each stack may be shorter or longer than the projection at 10%, but the slope obtained from voltage degradation is a metric that can be applied uniformly across all four teams, including stacks that fail prematurely or do not fail during the duration of the project due to a long life. While Figure 2 shows what this composite data product might look like at the end of the 5-year project (using artificial data), the version that will

be presented in November will have one bar/range that covers just the first time period of 2005-2006.

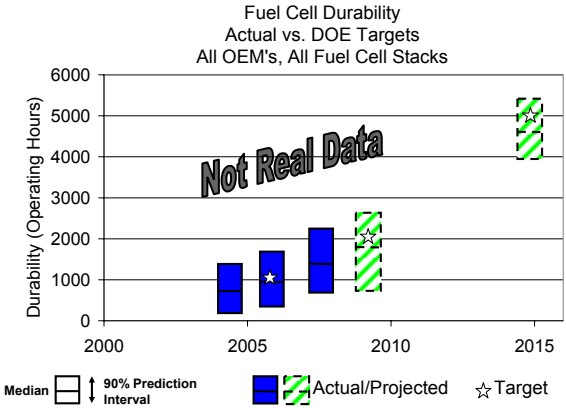

Figure 2: Fuel Cell Durability Compared to DOE Target of 1000 Hours in 2006 (not real data)

Fuel Cell System Efficiency: In addition to fuel feedstock diversity, high efficiency is one of the compelling reasons to introduce hydrogen powered fuel cell vehicles. Figure 3 shows that a range of actual fuel system efficiencies will be presented at the 25% load point and compared to the DOE 2010 target of 60%.

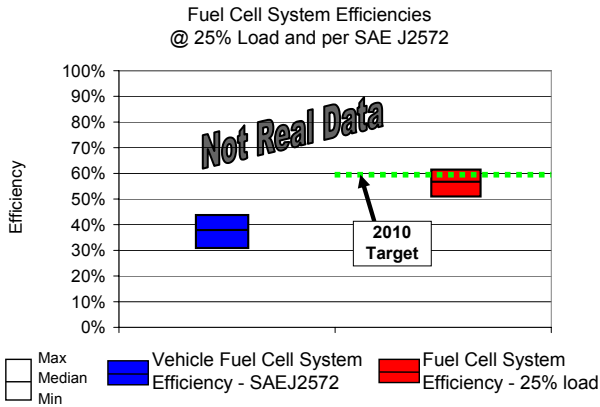

Figure 3: Fuel Cell Efficiency Obtained Through Controlled Dynamometer Testing (not real data)

References

[1] Wipke, K., C. Welch, H. Thomas, S. Sprik, S. Gronich, J. Garbak, D. Hooker, "Hydrogen Fleet & Infrastructure Demonstration and Validation Project: Progress Update," NHA Annual Hydrogen Meeting and Exposition, Long Beach, CA, March 2006.