

Hydrogen and Fuel Cell Vehicle Evaluation

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Abstract

As the focus sharpens on the next significant advancement in automotive technology, the vision of the hydrogen future starts to emerge. However, the transition to hydrogen as a transportation fuel is a journey with many bumps, holes, and roadblocks that will need to be successfully navigated. The National Renewable Energy Laboratory (NREL) Fleet Test & Evaluation (FT&E) team in Golden, Colorado, is dedicated to evaluating and documenting the performance and operational characteristics of advanced vehicle technologies that use alternative fuels or other concepts that reduce dependency on conventional petroleum fuels. Under the sponsorship of the U.S. Department of Energy (DOE) Hydrogen Program, the NREL FT&E team is investigating the status of fuel cell technology and hydrogen as key elements in a future transportation scenario. Specifically, FT&E is developing plans for evaluating prototype fuel cell buses; near-production light-, medium-, and heavy-duty fuel cell vehicles; and the hydrogen fueling and maintenance infrastructure required to make the vehicles fully operational.

Background

Government and industry-sponsored research regarding hydrogen as a transportation fuel—particularly in mobile fuel cells—is growing rapidly. One of the first fuel cell applications in the transportation arena will be powering transit buses. This is due to their capacity for handling the extra volume currently required for the fuel cell and the associated hydrogen fuel-storage tanks. Preliminary fuel cell bus studies completed by Georgetown University and the Chicago Transit Authority and have been positive. However, additional testing and evaluation is necessary before the buses will be widely accepted by the transit industry.

The California Fuel Cell Partnership (CaFCP) is a focal point for fuel cell development and demonstration activity, and one of its tasks will be to evaluate fuel cells used in transit bus applications. Located in California and associate members of the CaFCP, SunLine Transit

Agency and the Alameda-Contra Costa Transit District (AC Transit) will acquire fuel cell buses for evaluation in normal operation. However, the buses will not be delivered until mid 2004. In the interim, a prototype XCELLSiS fuel cell bus was operated by SunLine's manufacturer to gain experience and knowledge with fuel cell performance and operation characteristics. Unfortunately, the XCELLSiS bus left SunLine in November 2001, and NREL was unable to characterize its performance.

A new prototype fuel cell bus from ISE Research is scheduled to be at SunLine for approximately six months beginning in mid 2002. During that period, NREL will assist SunLine in acquiring data to evaluate the bus performance and prepare the transit agency for its fully commercial fuel cell buses.

The CaFCP is also evaluating fuel cells in light-duty vehicles, looking at a variety of feedstock fuels for the hydrogen normally required for the fuel cells. Individual automobile manufacturers (also CaFCP members) have accomplished preliminary testing of their vehicles in the Sacramento, California, area and are preparing them for commercial release. Market acceptance of these vehicles will be affected by the perceived added value and viability of the technology. Third-party evaluation of the vehicles will be necessary to establish the credibility of manufacturers' claims. Based on past experience of developing and evaluating alternative fuel and hybrid electric vehicles, NREL took the initiative to establish a relationship with the CaFCP to determine how it could assist the partnership with its fuel cell vehicle and hydrogen infrastructure development and evaluation.

Goals and Objectives

The primary goal of the project is to gather performance information on hydrogen light-, medium-, and heavy-duty fuel cell vehicles in an effort to establish their operating characteristics and applicability to fleet service and the transportation marketplace. The secondary goal is to gather and evaluate information on establishing a hydrogen fueling and vehicle maintenance infrastructure.

Project objectives for fiscal year (FY) 2002 include:

- Continuing relationships with SunLine and AC Transit to define the hydrogen fuel cell bus evaluation process and required fueling infrastructure at the AC Transit site;
- Evaluating the performance and operational characteristics of a hydrogen fuel cell bus in revenue service at SunLine; and
- Establishing an effective relationship with the California Fuel Cell Partnership (CaFCP)—of which DOE is a member—and defining the added value tasks NREL can provide to CaFCP's fuel cell vehicle testing and evaluation program.

Project activity consists of the following three tasks:

- **Data Acquisition and Evaluation Process Definition:** Coordinate with SunLine and AC Transit to further define and document the process for collecting and evaluating performance and operational data on fuel cell buses scheduled for delivery in mid 2004. Characterize the infrastructure modifications that are required to fuel and maintain the vehicles at each site.

- **Fuel Cell Bus Performance Characterization:** Characterize the performance and operation of the ISE Research fuel cell bus to be tested at SunLine starting in late 2001 or early 2002 (initial expected delivery date).
- **NREL Role Definition with the CaFCP:** Define the role that NREL can play in the evaluation of light- and medium-duty fuel cell vehicles associated with the CaFCP.

Data Acquisition and Evaluation Process Definition

AC Transit is a public agency providing transportation services since 1960 to San Francisco's East Bay. AC Transit's mission is similar to all transit agencies and includes providing safe, convenient, courteous, and reliable transit service. AC Transit is the third largest transit agency in California, and 17th largest overall in the United States based on unlinked passenger trips in 2000. (Source: American Public Transportation Association, www.apta.com.) The service area of 360 square miles includes 13 cities and adjacent unincorporated areas in Alameda and Contra Costa counties.

AC Transit's bus fleet includes 815 vehicles (standard and low floor buses, luxury coaches, articulated buses, and paratransit buses) operated from four divisions: Richmond, Emeryville, East Oakland, and Hayward. The AC Transit operation also includes a central maintenance facility and operating and maintenance divisions. The buses service 153 bus lines (including 36 lines transbay to San Francisco), 8,000 bus stops, and 21 million service miles. The annual ridership includes 67.4 million passengers. AC Transit employs 2,521 including bus drivers, maintenance, clerical, support, and management personnel. (Source: www.actransit.org, June 2002.)

The State of California has mandated that by 2003 diesel bus operators with fleets of more than 200 buses must have at least three zero-emission buses. Currently, the only zero-emission buses are considered to be fuel cell powered or all electric buses. All electric buses have limited range capability when using batteries as the energy storage device or require another power source, such as catenary wires, as with trolley bus vehicles. By 2008 in California, 15% of new bus purchases must be zero-emission. AC Transit has expressed its intent to do more than meet the legal requirement by planning a major demonstration of full-size transit buses (40 feet) using fuel cell powered propulsion systems in revenue service. AC Transit intends to show that fuel cell buses can be fueled and maintained efficiently and perform consistently.

In April 2002, AC Transit announced the purchase of four fuel cell buses using compressed hydrogen for \$12.5 million or \$3.1 million per bus. Three of the buses are for AC Transit and one is for SunLine Transit Agency. The AC Transit fuel cell buses will be built on a Van Hool (from Belgium) bus platform (model A330, 40-foot bus) in a hybrid electric configuration using UTC fuel cells. They will be integrated by ISE Research. A potential option to purchase six more fuel cell buses was included in the purchase agreement. The first bus is targeted for delivery to AC Transit in the second quarter of 2004. AC Transit plans to modify its facilities at the Seminary Division in East Oakland to accommodate daily maintenance and repair functions for the fuel cell buses.

Use of liquid hydrogen bulk storage on the AC Transit site is also planned. In January 2001, AC Transit issued a request for proposals (RFP) for the design/build of a hydrogen fueling station and necessary maintenance facility modifications. Although proposals were received, a

satisfactory agreement could not be reached with the fueling station bidder. AC Transit is now considering issuing a new RFP in June or July 2002.

Due to the delay in the contract placement of the hydrogen fueling facility at AC Transit, documentation of the fueling infrastructure at the facility will not be accomplished by NREL during fiscal year (FY) 2002. The FT&E team continues to develop a working relationship with AC Transit and has produced a preliminary vehicle evaluation plan. NREL will conduct the evaluation with AC Transit and University of California, Davis (UC Davis), both of which have already reviewed and approved the plan. Finalization of the evaluation plan will occur as the delivery date of the fuel cell buses approaches. NREL, AC Transit, and UC Davis (Levin, Miller, Eudy 2002) collaborated on a paper describing the project and presented at the 2002 World Hydrogen Energy Conference.

Fuel Cell Bus Performance Characterization

The delivery of the prototype 30-foot fuel cell bus from ISE to SunLine Transit Agency is delayed, increasing the possibility that the second project objective to evaluate the performance of the bus may not be met this fiscal year. The prototype bus was originally scheduled for delivery to SunLine in January 2002. However, there has been an indefinite delay due to technical problems with the fuel cell propulsion system. If the bus is delivered before the end of FY 2002, some data will be gathered as preliminary information toward meeting the objective. Evaluation of the ISE prototype fuel cell bus performance is expected to occur during FY 2003.

NREL Role Definition with the CaFCP

The CaFCP was established on April 19, 1999, with the following goals:

- To demonstrate vehicle technology by operating and testing the vehicles under real-world conditions in California;
- To demonstrate the viability of alternative fuel infrastructure technology, including hydrogen and methanol stations;
- To explore the path to commercialization from identifying potential problems to developing solutions; and
- To increase public awareness and enhance opinion about fuel cell electric vehicles, preparing the market for commercialization.

The partners include companies and organizations from around the world:

- **Vehicle Manufacturers:** DaimlerChrysler, Ford, General Motors, Honda, Hyundai, Nissan, Toyota, Volkswagen
- **Fuel Cell Developers:** Ballard Power Systems, UTC Fuel Cells
- **Fuel Providers:** BP, ExxonMobil, Shell Hydrogen, ChevronTexaco
- **State Government Agencies:** California Air Resources Board, California Energy Commission, South Coast Air Quality Management District
- **Federal Government Agencies:** DOE, U.S. Department of Transportation, U.S. Environmental Protection Agency (new partner)

There are also nine associate partners who assist with specific areas of expertise to help meet the CaFCP's goals:

- **Hydrogen Gas Suppliers:** Air Products and Chemicals, Inc. and Praxair
- **Hydrogen Fueling Stations:** Pacific Gas & Electric; Proton Energy Systems, Inc.; and Stuart Energy Systems
- **Methanol Fuel Supplier:** Methanex
- **Bus Transit Agencies:** AC Transit (East San Francisco Bay), SunLine Transit Agency (Palm Springs), and Santa Clara Valley Transportation Authority (San Jose)

According to DOE, the partnership is not forthcoming regarding the status of the original equipment manufacturer fuel cell vehicles or the technical issues that are being addressed. NREL consequently took the initiative to set up meetings with the CaFCP Light-Duty Vehicle and Fuels Teams to define activities that DOE/NREL could become involved in to increase the amount of information available.

Light-Duty Vehicle Team

An initial meeting with the Light-Duty Vehicle Team (Vehicle Operations or VeOps Team) was held on February 26, 2002. NREL made a short presentation to begin the discussion of a data acquisition proposal. The presentation was well received by the team, sparking suggestions for NREL to participate in subsequent partnership meetings, including VeOps and Fuels team meetings and those of the Working Group. Although receptivity to NREL acquiring vehicle data was reserved (primarily due to the prototypic and proprietary nature of the fuel cell vehicle technology), the suggestion of a Web-based "suggestion box" was accepted by those in attendance. Partnership participants would use the suggestion box to identify problems, issues, and development needs they might be reluctant to identify in a meeting with other manufacturers or fuel providers. This information would help to characterize the status of system integration and vehicle development for CaFCP members who do not have intimate knowledge of the vehicles but support their development and integration into the transportation arena.

NREL completed the initial version of the suggestion box in May 2002 and had it posted on the CaFCP Web site. Further discussion with the VeOps Team is necessary to familiarize the members and motivate its use. The usefulness of the site will be better defined and refined over the coming months.

Subsequently, the VeOps Team requested that NREL develop a method to gather information on California fleets to identify good candidates for evaluation and testing of light-duty fuel cell vehicles. Using selection criteria developed in conjunction with the VeOps Team, NREL is developing a Web-based fleet information database that would allow interested fleet managers to provide information about their fleets. The database will be available to CaFCP members for their use in defining fleet partners and planning their future demonstration activities.

Fuels Team

On March 7, 2002, a teleconference was held with the CaFCP Fuels Team. During the meeting, NREL gave a presentation that focused on fueling infrastructure and the need for information acquisition and dissemination. Like the VeOps Team, the Fuels Team was receptive to NREL's participation and suggested subsequent discussions be held to better define a prospective role.

NREL has continued to participate in Fuels Team meetings and has defined an initial task to be accomplished for the team. The task is to develop fact sheets on existing hydrogen fueling stations that could be used by partnership auto manufacturers. The fact sheets will identify critical specifics of the station, such as fueling pressure, flow rate, and fueling interface, as well as provide information on the type of fuel generation and storage system in place at the site. NREL will also be developing information on the process of hydrogen fueling station siting and implementation.

Proposed Future Work

The late arrival of the ISE/UTC fuel cell bus at SunLine Transit Agency has delayed NREL's evaluation of the vehicle. As of early June, the vehicle had not arrived at the site, so the evaluation of the performance and operation of the prototype bus will most likely occur in FY 2003. As with all advanced vehicle technologies, adjustments and tuning will be necessary to prepare the vehicle for in-service demonstration. This may take a month or more after delivery. NREL will work with SunLine to characterize the bus vehicle systems and operational performance when appropriate.

Finalization of the AC Transit fuel cell bus evaluation plan will occur during the coming year using lessons learned from the preliminary ISE bus evaluation at SunLine. NREL will also work with the other members and associate members of the CaFCP to better define the required products from the fuel cell bus evaluations. This will include becoming more aware of similar fuel cell bus demonstrations occurring in Europe and Asia.

The solicitation for the hydrogen fueling station and maintenance facility modifications at the AC Transit facility is scheduled to occur in mid 2002. Assuming this procurement is successful, NREL will participate with AC Transit in documenting the station design and the facility modifications. This will provide needed information for other transit agencies looking to move towards this technology.

Under continued sponsorship from DOE, NREL will further its participation with the CaFCP VeOps and Fuels Teams. The candidate fleet database Web site will be finalized and implemented and NREL will work with the VeOps team to refine the database as appropriate. NREL will also take information from the suggestion box and assemble it in a meaningful way for partnership members so they can respond and react to the information gathered. Information derived from the suggestion box is expected to lead to additional project directions useful to the partners.

As a derivation of the suggestion box and fleet database activities, NREL will continue to work with the VeOps team to determine the appropriate data to collect from vehicle operation for dissemination to a wider audience. Currently, the only information that is shared among the automotive partners is number of fueling events, vehicle riders, and fuel cell vehicles on site. Information on fuel efficiency, operation and maintenance characteristics, and systems durability is desirable from the perspective of the nonautomotive partners to better understand the status and progress of technology development.

Characterization of existing hydrogen fueling stations will continue in cooperation with the CaFCP Fuels Team and will be used to define the critical elements in getting a station designed,

sited, approved, and implemented. This information will also be useful in defining fueling station cost drivers and related technology areas requiring further development.

References

Levin, J.; Miller, M; and Eudy, L.; 2002. "Fuel Cells for the Transportation Industry: Developing a Credible Demonstration Program on the Path to Commercialization" from *Proceedings of the 14th World Hydrogen Energy Conference, 2002*. Montreal, Canada.