V.C.3 Technology Validation: Fuel Cell Bus Evaluations

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Objectives

- Evaluate the performance of fuel cell buses in real-world service to determine the status of the technology.
- Coordinate with the Federal Transit Administration (FTA) and international fuel cell bus demonstration programs to harmonize data collection methods and enable comparison of a wider set of vehicles.

Technical Barriers

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

- A. Vehicles
- B. Storage
- C. Hydrogen Fueling Infrastructure
- D. Maintenance and Training Facilities
- E. Codes and Standards

Approach

- Design data collection evaluation plan for fuel cell bus demonstration based on existing and proven data collection and evaluation protocol developed and used for DOE heavy vehicle evaluations.
- Collect and analyze performance data on ThunderPower fuel cell bus and associated infrastructure at SunLine Transit Agency.
- Coordinate with other fuel cell bus project representatives to begin sharing data.

Accomplishments

- Verified that the ThunderPower fuel cell bus could be operated in revenue service and fulfill service demands from a performance and reliability standpoint.
- Presented plans for evaluating fuel cell buses in California and led session on harmonizing data collection at first International Fuel Cell Bus Workshop held in November 2003. (Supports DOE's International Partnership for a Hydrogen Economy by working with other evaluators to develop an internationally acceptable standard for comparison of programs/projects worldwide.)

Future Directions

- Collect, analyze, and report on performance data of fuel cell bus in service at Hickam Air Force Base.
- Collect performance data on three 40-foot fuel cell buses at Santa Clara Valley Transportation Authority in San Jose, California as a part of the California Fuel Cell Partnership (CaFCP) Bus Team.
- Investigate reliability, durability, and life cycle of fuel cell buses as part of on-going evaluations.
- Coordinate with FTA to plan second International Fuel Cell Bus Workshop in conjunction with next Clean Urban Transport for Europe (CUTE) meeting to be held in Europe in fall 2004.

Introduction

Manufacturers have been working with fuel cells in transportation applications since the early 1990s. Heavy-duty vehicles offer the advantage of allowing for larger propulsion systems though this sometimes comes to the detriment of passenger or cargo space. Fuel cell systems for buses have experienced significant progress during the last several years but more work is needed to prove reliability and durability.

Thor Industries and ISE Research developed and manufactured the 30-foot ThunderPower bus. It uses a compressed hydrogen proton exchange membrane (PEM) fuel cell power plant developed by UTC Fuel Cells in a hybrid configuration. The ThunderPower bus is one of a few fuel cell buses in the United States, and its use is a prelude to an upcoming demonstration program in California that will include seven more full-sized fuel cell buses. (Figure 1)

Figure 1. ThunderPower Fuel Cell Bus

Demonstration projects, such as that of the ThunderPower fuel cell bus, are necessary to validate the performance of the current generation of fuel cell systems. Lessons learned in evaluating the buses in revenue service will help assess the status of fuel cell bus technology and determine issues that need further development. Evaluating the ThunderPower prototype bus showed that a fuel cell bus can provide service in transit applications comparable to that of a conventional bus, and can operate in a hot desert climate. There are still barriers to the use of fuel cells in transportation applications that need to be addressed before commercialization can occur. Future evaluations should help address these barriers including: extended life of the fuel cell, reliability and durability of the fuel cell systems, and costs of vehicles and infrastructure.

Coordinating with other demonstrations projects world-wide will also be important to provide the opportunity to gather and compare data from a larger statistical set of vehicles and leverage resources without duplicating efforts.

Approach

NREL and Battelle researchers have developed an evaluation protocol to provide:

- comprehensive, unbiased evaluation results for advanced technology vehicle development and operations,
- evaluation of hydrogen infrastructure development and operation, and
- descriptions of the facility modifications required for safe operation of the fuel cell vehicles.

The evaluations include economic, technical, emissions, and safety factors. The evaluation is a collaborative effort conducted in participation with the transit fleet and the vehicle and fuel cell

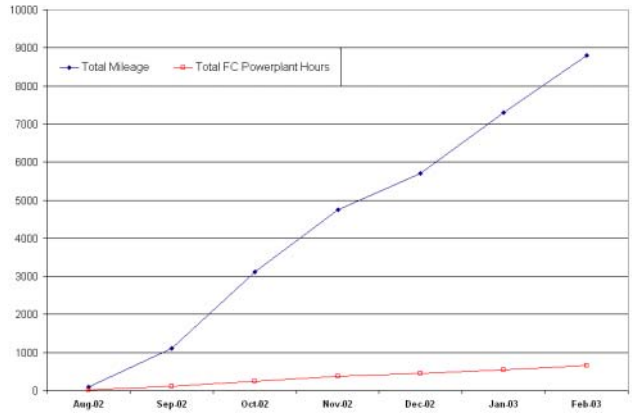

Figure 2. Total Accumulated Mileage and Fuel Cell Stack Hours

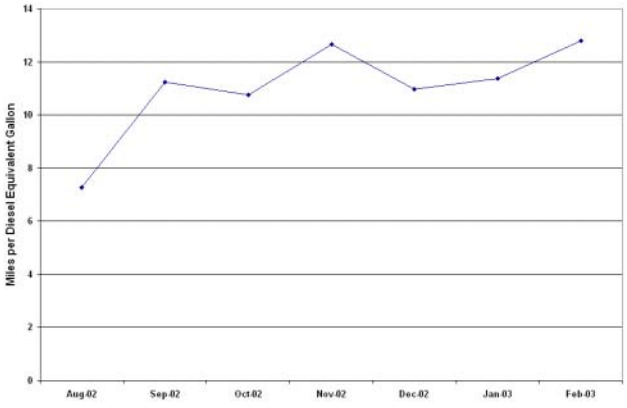

Figure 3. ThunderPower Bus Fuel Economy by Month

manufacturers, as well as other government partners involved in evaluating fuel cell technology in transit applications.

This evaluation project has two key objectives:

- to generate credible data results and evaluations that go beyond the "proof of concept" of fuel cell buses and infrastructure for provision to the transit bus and fuel cell industries.
- to establish a record of in-use performance including progress over time and experience from integration of vehicle systems, operations, and facilities for the fuel cell buses and supporting infrastructure.

Results

NREL evaluated the ThunderPower fuel cell bus for six months in service at SunLine Transit Agency in Thousand Palms, California. NREL collected data on the operation, maintenance, and performance of the ThunderPower bus while in operation at SunLine. These data include fuel (hydrogen) fills, vehicle use (availability for service, route assigned, miles per day), and maintenance activities, such as warranty repairs. The demonstration lasted six months—not enough time to study reliability and durability in-depth. The bus was built to meet the objectives defined for this demonstration and not necessarily as a commercial product. The intent of this demonstration is to assess how close this technology is to commercialization.

Figure 2 shows the ThunderPower bus accumulated 8,800 miles and 640 fuel cell stack hours of operation at SunLine. These numbers take into consideration the service time lost when the bus was down because of problems with the fuel cell cooling system in December 2002. The availability of the bus averaged 71% while at SunLine.

The diesel gallon equivalent (DGE) fuel economy for the ThunderPower bus was 10.7 miles per DGE during the nonrevenue period and 12 miles per DGE during the revenue period. SunLine reports that its CNG ElDorado buses average around five miles per DGE on the same route. The fuel economy for the hybrid fuel cell bus is nearly 2.4 times higher than that of the CNG buses currently used on the route. Figure 3 shows the average fuel economy of the ThunderPower bus at SunLine. The chart shows that the fuel economy slowly rose.

The first International Fuel Cell Bus Workshop was held in an effort to harmonize data collection and analysis across world-wide fuel cell bus demonstration programs. NREL presented the DOE plans to evaluate fuel cell buses in the U.S., followed by a discussion of specific data that should be collected and shared between programs. Plans are underway to hold a second workshop in Europe to enable participation of more international program representatives.

Conclusions

Based on the results of this analysis and the response from the project partners, the SunLine demonstration was deemed to be a success. Although it was a prototype (or pre-commercial) vehicle, the ThunderPower bus operated in revenue service at a reliable level for most of the evaluation period. To summarize:

- The bus met or exceeded all goals set for the demonstration at SunLine.
- Availability for service was 71% for the six-month demonstration period. This availability level may have been higher with quicker response to some of the problems experienced.
- The bus ran for six months at SunLine with interruptions for some public relations activities, accumulating 8,800 miles and 655 fuel cell fuel power plant hours.
- The hybrid fuel cell bus operated in revenue service with an energy equivalent fuel economy 2.4 times higher than a similar CNG bus operating in the same service at SunLine.
- SunLine was pleased with the commitment and support provided by ISE Research and the project team which was and will continue to be essential for the successful demonstration of the fuel cell bus
- There is a need to learn more about the reliability and durability of this type of propulsion system in transit buses. Longer-term demonstration is needed to understand how close the technology is to commercialization.

FY 2004 Publications/Presentations

1. K. Chandler, L. Eudy, Fuel Cell Bus Demonstration Projects, "SunLine Test Drives Hydrogen Bus", NREL, Golden, CO, DOE/GO-102003-1768. (August 2003)

2. K. Chandler, L. Eudy, "Fuel Cell Transit Bus Coordination and Evaluation Plan", NREL, Golden, CO. (October 2003)

3. K. Chandler, L. Eudy, "ThunderPower Bus Evaluation at SunLine Transit Agency", NREL, Golden, CO, DOE/GO-102003-1786.2. (November 2003)

4. L. Eudy, "DOE/NREL Data Collection and Evaluation of Fuel Cell Transit Buses", International Fuel Cell Bus Working Group, Long Beach, CA. (November 2003)

5. L. Eudy, "Testing & Analysis of Advanced Propulsion Systems", 2004 American Public Transportation Association Bus & Paratransit Conference, Denver, CO (May 2004)