



Date: September 7, 2006
Committee Meeting Date: September 13, 2006
Board Meeting Date: NA
ACTION DISCUSSION INFO X

BOARD MEMORANDUM

TO: 2000 Measure A Watchdog Committee (Citizens Advisory Committee)
Santa Clara Valley Transportation Authority
Board of Directors

THROUGH: Michael T. Burns
General Manager

Michael T. Burns signature

FROM: Donald A. Smith, Jr.
Chief Operating Officer

Donald A. Smith, Jr. signature

SUBJECT: Zero Emission Bus Demonstration Program Status Report

FOR INFORMATION ONLY

BACKGROUND:

In accordance with California Air Resources Board (CARB) requirements Title 13, section 1956.4, the Santa Clara Valley Transportation Authority (VTA) and the San Mateo County Transit District (SamTrans) are currently conducting a two-year Zero Emission Bus (ZEB) Demonstration Program. The ZEB Demonstration Program is intended to test the viability of emerging clean-fuels technology. The program will help move zero-emission hydrogen fuel cell technology closer to becoming commercialized and available to public transit operators across the country.

In addition to procuring and operating three ZEBs, the demonstration program consists of training VTA and SamTrans personnel on this new technology, and facility modifications that include the installation of a hydrogen fueling station and a stand-alone, two-bay maintenance facility.

The goals of the ZEB Demonstration Program are to:

- Determine the status of fuel cell technology in transit applications,
Identify issues and challenges, and
Provide community outreach and educate the public on fuel cell and hydrogen technology.

In June 2002, a contract was awarded to the Gillig Corporation for three 40-foot, low-floor, hydrogen fuel-cell buses, with VTA as the lead agency in demonstrating the operation of these buses and SamTrans sharing in the capital and operating costs. Since the start of revenue service on February 28, 2005, the ZEBs have operated on several VTA Bus Lines including 22, 32, 33, 45, 46, 47, 53, 59, 62, 63, 71, 102 and 104 as extra revenue service. Extra revenue service means these buses are placed on routes between two regularly scheduled buses. This was done to minimize any inconvenience to passengers should a fuel-cell bus break down in service.

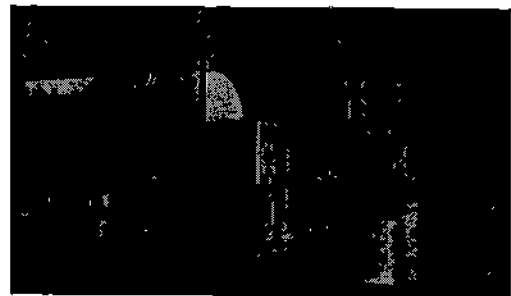
The Federal Transit Administration (FTA) and the U.S. Department of Energy, through the National Renewable Energy Laboratory (NREL), continue to actively participate in the ZEB demonstration program and are in the process of preparing an evaluation report utilizing data provided by VTA. The NREL issued a preliminary report covering the program through October 2005.

## **DISCUSSION:**

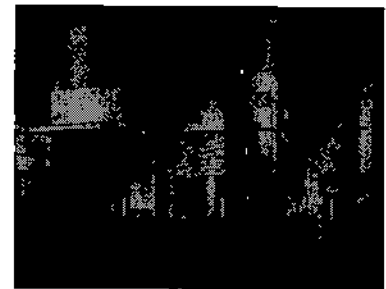
### **Infrastructure**

A hydrogen fueling facility and a new hydrogen fuel-cell bus maintenance facility were constructed at the Cerone Division. The bus wash and guard stations were also designed to accommodate the fuel cell buses. Construction of this infrastructure has provided VTA with a tremendous amount of experience in the design and operation of hydrogen fuel-cell bus infrastructure.

The hydrogen fueling facility, designed and constructed by Air Products and Chemicals, Inc. (Air Products) under a lease agreement, was completed in May 2004 and commissioned in November 2004. Significant progress and improvements have been made to the hydrogen dispensing station during the program, including safety and incident reporting and improved fill time. More than 300 successful fuel cell vehicle refills have been performed to date. The high cost of hydrogen and vent losses at the facility continue to be operational challenges.



A separate maintenance facility was designed and built for the fuel cell bus demonstration. This two-bay building houses the equipment and some of the spare parts needed to maintain and repair fuel cell buses. This facility was designed to meet the requirements for handling hydrogen, and, like the fueling station, the maintenance building is equipped with the necessary devices to enable safe operation and maintenance on hydrogen buses and other vehicles. Safety devices include hydrogen- monitoring systems, flame sensors and anti static coated doors. This facility opened for operation in November 2005.

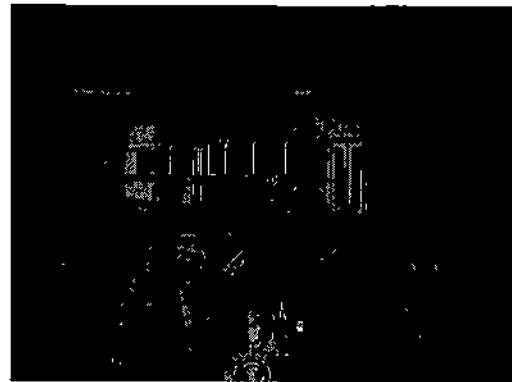


Other facilities, including a new guard station and bus wash, were also designed and constructed to accommodate the hydrogen buses.

The total cost for these facilities to meet the requirements of operating the hydrogen fuel cell buses at VTA is \$4.4 million. This cost includes the three-year lease for the Air Products fueling facility.

**Training**

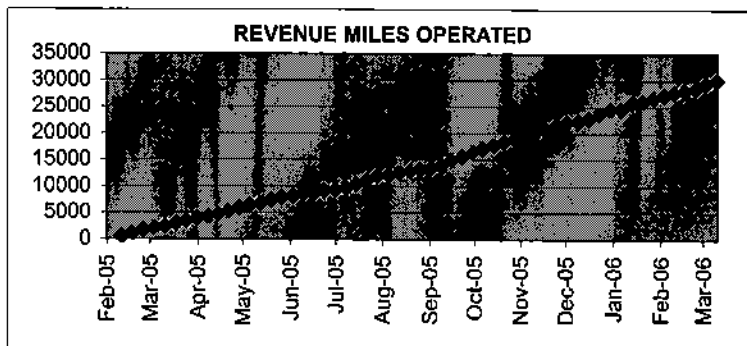
Familiarization training on hydrogen fuel cell buses and safety working with and around hydrogen is a high priority for VTA. General training was provided to all staff at the Cerone Division, as well as local emergency responders (fire and police). More than 150 emergency responders were trained. The two VTA mechanics assigned to the fuel cell buses also received training at Ballard for the fuel cell propulsion system, as well as customized training from Air Products on the operation of the hydrogen dispensing station. The bus drivers were trained on the fuel cell bus and fuel cell system. VTA continues to provide familiarization training for emergency responders. VTA has and continues to accommodate requests for tours and brings the buses to events as time and resources allow. These include participation at Earth Day events, schools such as San Jose State University and West Valley College, and as part of President Bush’s recent visit to the California Fuel Cell Partnership.



**Operation**

Fuel cell buses are considered prototype technology. The NREL preliminary report evaluates the operational experience of the three ZEBs in extra revenue service for an eight-month evaluation period (March 2005 to October 2005). For this report, five of VTA’s latest standard 40’ buses were used as a reference sample. These buses operated out of the same division as the ZEBs. During this period, two ZEBs were operated peak weekday hours with one available as a spare. VTA limits the use of the buses to times when a trained ZEB mechanic and bus driver are available. It should also be noted that VTA, Ballard Power Systems and Air Products and Chemicals Inc. continue to make changes and modifications to the bus and fueling facility to improve operation of the ZEB program. ZEBs are taller, heavier, have range limitations, and operate on hydrogen – all of which limit where they can operate.

**Bus Operation** — During the testing and service period through the end of March 2006, the



three fuel cell buses accumulated more than 39,700 miles of which over 30,000 miles were in revenue service. The demonstration program got off to a relatively slow start in late 2004 due to facility and refilling issues at the site. However, the fleet usage has improved significantly throughout 2005 and early 2006.

**Bus Availability** — During the evaluation period, the fuel cell buses had an availability rate of 52% for each weekday, with a goal of 67% of the time. (No differentiation was made between standard bus maintenance issues and those attributed specifically to the fuel cell and system.) During this same evaluation period, the five reference diesel buses had an availability of 84%. Bus availability has improved tremendously since the evaluation period. For the first three months of 2006, ZEB bus availability averaged 85%. This availability improvement is due to the modifications implemented as failure modes are discovered as well as greater familiarity of the maintenance staff with the operation and maintenance of hydrogen fuel cell buses.

**Fuel Economy and Costs**—During the evaluation period, the fuel cell buses averaged 3.05 miles per kg of hydrogen, which translates into 3.45 miles per diesel equivalent gallons. This fuel economy includes all hydrogen fuel added to the buses even if there was some venting for maintenance or testing during the evaluation period. With the diesel buses as the baseline (4.0 mpg), the fuel cell buses had a fuel economy 13% lower on an energy equivalent basis. Considering the cost, the fuel cost for the ZEBs averaged \$2.802 per mile as compared to \$0.512 per mile for the reference diesel buses (see table below). Ongoing bus fleet operations are an important mechanism for evaluating and improving fuel economy and reducing hydrogen losses.

**Maintenance Costs**— During the evaluation period, the total maintenance cost of the three fuel cell buses was \$4.26 per mile, compared with \$0.59 per mile for the diesel buses. These costs include parts and labor to maintain and repair the buses. The total maintenance costs (including fuel) are much lower for the diesel buses compared to the fuel cell buses (see table below). This reflects the fact that the fuel cell buses are in the prototype development stage for transit bus service, which creates a need for significant mechanic/technician labor for troubleshooting. Additionally, parts costs are greater as these are prototype vehicles and use specialized parts. As an example, the cost to replace a fuel cell module is approximately \$248,000 per module and each bus is equipped with two fuel cell modules. The total cost to replace two fuel cell modules is \$496,000. The estimated useful life of a fuel cell is approximately 2 years/2000 hours/30,000 miles. Ongoing bus fleet operations provide significant opportunities to assess preventive maintenance cycles of fuel cell bus systems and how they can be matured and optimized for commercial release.

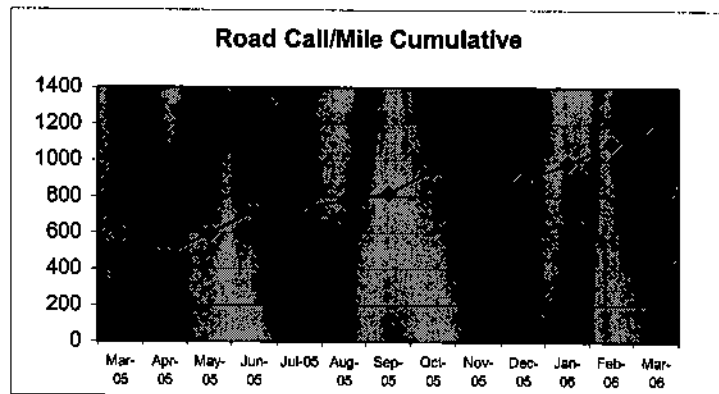
	<b>Standard Bus Evaluation</b>	<b>ZEB Evaluation</b>
Number of Vehicles	5	3
Fuel Cost Per Mile	\$0.512	\$2.802
Maintenance Cost per Mile	\$0.589	\$4.260
Total Maintenance Cost per Mile*	\$1.010	\$7.062

\*Does not include the cost of fueling station vent loss  
 Labor cost is based on a \$50 per hour labor rate

**Reliability**— During the evaluation period, the fuel cell buses had 983 miles between road calls (MBRC) for all road calls and 1,044 MBRC for propulsion-related road calls (those road calls related only to the fuel cell and fuel cell systems.) The diesel buses had 9,019 MBRC for all road

calls and 11,424 MBRC for propulsion-related road calls. Ongoing fuel cell bus fleet operations will continue to drive the road call incidents down, as further improvements are implemented and the availability goes up. The MBRC has significantly improved since the evaluation period. For the first three months of 2006 the buses averaged 3,900 MBRC.

The improved reliability is in part due to modifications to the bus to address specific problems in the following areas:



- **Engines Shutting Down in Service**

VTA experienced ZEB engines shutting down while the bus is in operation without experiencing a serious problem. The intent is for an engine shutdown to occur when there is a major system problem such as a fire or an accident. The causes of engine shutdowns vary and include sensor malfunctions and adjustments. Several modifications have been made to correct this situation without affecting the safety of the systems.

- **Pressure Relief Device (PRD) Failures**

The PRD is a device that releases pressure from the hydrogen fuel tanks under excessive pressure or temperature conditions. The fuel tanks' nominal operating pressure is 5000 psi. Each of the eleven hydrogen fuel tanks is equipped with two PRDs (one on each side for redundancy). VTA has seen an excessive number of PRD failures. The problem was investigated and new PRDs were installed where necessary.

- **Inverter Failures**

The two fuel cells modules produce up to 450 VDC (volts direct current). The current from the fuel cells is converted to AC to drive the three-phase inductive Reuland Electric motor. This conversion is done through the inverter and controls systems. In the early stages, VTA experienced a number of inverter failures. Modifications to the inverter, as well as the inverter cooling system have been made.

### **Incidents**

- **Fueling Station Fire**

During the initial commissioning of the fueling station in the summer of 2004, a thermocouple failed on the pressure side of the liquid pump. This failure caused the hydrogen to escape and a fire started. The Emergency Stop button was activated to close the main hydrogen valves at the tank. The fire stopped after the hydrogen in the lines burned out. The fire caused VTA to install additional flame detectors as well as modify emergency procedures and increased the training for both VTA personnel as well as emergency responders. There have been no fires since.

- **Hydrogen Leaks**

There have been a number of hydrogen leaks at the facility. Other than the fire indicated above, the leaks did not result in a fire. However, several leaks caused major disruption of service for VTA. In several instances the leaks caused the Fire Department to respond and close down the facility until they determined the condition to be safe.

- **Fueling Station False Alarms**

VTA has gained tremendous experience related to the fueling system and facility. A number of false alarms at the fueling station have occurred. These false alarms were caused by issues varying from telephone connections, flame sensors picking up welding sparks approximately 400 foot away, jack hammering, power failure, faulty flame sensors etc. In several instances, VTA experienced responses from the local Fire Department. Emergency responders closed down the facility causing major service disruptions until it was determined to be a false alarm and it was safe to continue transit operations.

## **WHAT IS NEXT?**

VTA currently plans to operate the fuel cell buses through the end of their useful life and in accordance with FTA requirements, assuming the availability of parts, vendor support and ability to maintain and repair the ZEBs. Continued operation in future years may require significant additional funding. This could be due to the fuel cell system overhaul cycles, the continued high cost for maintenance and fuel, fueling facility lease and unforeseen issues. VTA, Ballard, and Air Products have expressed interest in continuing this demonstration program if the costs appear reasonable and funding can be made available. Significant investment and effort have been committed to test and operate this equipment. There is still significant work to be done (and lessons to be learned) before fuel cell buses and infrastructure equipment are truly commercial.

The two-year fuel cell transit bus program with VTA has accomplished a great deal and contributed significant knowledge of the potential application of fuel cell vehicles in public transportation. Continuing the program would build on the achievements to date, providing the following benefits:

- The current prototype fleet of fuel cell transit buses have been field tested, issues found and improved upon to the point where they provide a mature demonstration. The usage and availability of this fleet has improved during the program to the point where another year of fleet trials will generate strong gains from the investment made to this point.
- The VTA Cerone Division now has a hydrogen refueling station that can be of great benefit to further learning, including improvements for future fueling facility infrastructure supporting the growth of hydrogen fuel cell vehicles in the Bay Area and throughout California. Continuing the fuel cell bus demonstration will contribute to further improvements and efficiencies in the refueling system and ensure Cerone's importance for ZEB refueling efforts in the area.
- The VTA Cerone Division now has a qualified and approved hydrogen-safe building for bus maintenance. This facility represents an investment that can be further recaptured by

extending the fleet demonstration. Furthermore, maintaining this facility and center of capability may be of great interest and advantage for future development programs.

- Evaluation of the prototype bus fleet will be improved as a result of extended fleet trials. Metrics such as usage, availability and road calls have continued to improve as the design matures, and an additional year to demonstrate these prototypes will provide more meaningful evaluation data for the fleet.
- Evaluating the potential for upgrades of the fuel cell system with new fuel cell technology can be considered for further improvements. Such upgrades may include a hybrid design as well as more efficient and compact fuel cell system designs.
- On-going public relations is an important element to extending this fuel cell bus demonstration fleet at VTA. The visibility and public awareness that transit demonstration fleets provide is a strong stimulus to the commercialization of fuel cells for automotive and bus applications.
- On-going education is also an important element to this program's proposed extension. Education of operators, certification bodies and emergency responders is necessary to promote fuel cell adoption.

The incremental investment required to extend this fleet demonstration through the useful life of the ZEBs will leverage the substantial investment, learning and capabilities to-date, and provide a return of benefits to stakeholders and supporters.

## **REGULATORY ISSUES**

The California Air Resources Board (CARB) is proposing to modify the existing regulations. The proposal includes an advanced zero emissions bus demonstration program utilizing a larger fleet of ZEBs. The requirements pertain to transit agencies that operate more than 200 buses. The requirements include:

- Participating transit agencies would be required to operate a minimum of 10 advanced ZEBs starting in 2009.
- Multiple agencies in a joint effort would be required to operate a minimum of 12 advanced ZEBs starting in 2009.
- Implementation of the 15% ZEB requirement would be delayed from 2008 to 2010.
- CARB would review the feasibility of implementing ZEB technology in July 2010.

The Metropolitan Transportation Commission (MTC) is proposing to establish a joint effort in the Bay Area that would include AC Transit, Golden Gate Transit, MUNI, SamTrans and VTA. These transit agencies and MTC are presently meeting as a "Zero Emission Bus Working Group". The intent is to minimize cost and maximize potential funding sources. Additionally, MTC is proposing to recommend implementation of the 15% ZEB requirement to 2014 as a more realistic timeline.

**FISCAL IMPACTS:**

The budget for the ZEB Program remains unchanged at \$18,450,000. The budget consists of \$6 million from 2000 Measure A Local Sales Tax, \$6 million from SamTrans, \$5.1 million from the Federal Transit Administration, \$0.3 million from the California Energy Commission, and \$1 million from the Bay Area Air Quality Management District.

Project commitments to date are \$15,880,229 or 86% of the total budget, with total expenditures to date of \$15,347,677.

**Cash Flow**

Category	Expenditures to Date
Facility Construction	\$ 1,306,341
Facility Major Procurement, Leasing, and Fuel	\$ 737,488
VTA Labor (Construction)	\$ 772,184
Professional Services	\$ 531,339
Bus Procurement and Related Expenses	\$ 10,339,374
VTA Labor (Bus)	\$ 1,440,948
Overhead Costs	\$ 220,003
<b>Total Expenditures Through January 2006</b>	<b>\$ 15,347,677</b>

Extension of the program will require additional funding for maintenance, fuel, manufacturer's support and operational costs. Staff is preparing costs estimates based on the information to date. Additionally, implementation of the new CARB regulations with the advanced ZEB demonstration program will add costs that include the purchase and operation of additional ZEBs. Staff is preparing cost estimates for the possible options.

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