Fuel Cell Package Delivery Vehicle Testing Program

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In Ann Arbor, Michigan on May 19, 2003, senior executives from DaimlerChrysler, UPS, and the U.S. Environmental Protection Agency (EPA) announced the launch of the Fuel Cell Delivery Vehicle Testing Program ("the Partnership"). DaimlerChrysler committed to providing state-of-the-art prototype fuel cell powered vehicles, UPS committed to accumulating mileage on these vehicles in real-world package delivery operation, and EPA committed to installing a hydrogen fueling facility at the National Vehicle and Fuel Emission Laboratory (NVFEL) in Ann Arbor, Michigan.

For more than three years, the three organizations have worked in a close technical and operational partnership to implement the ambitious goals of this unique program and to contribute to the national and international development of this promising transportation technology. This paper reviews the experience of this program, including individual perspectives from each of the three partners.

The Partnership

At the time the Partnership was launched, it represented North America's first commercial application of hydrogen fuel cell vehicle technology. It was the first program to test fuel cell powered vehicles in adverse winter climate along with the first hydrogen fueling station at a U.S. federal facility.

The first fuel cell vehicle UPS operated in the program was a DaimlerChrysler F-Cell. This passenger-car was modified for package delivery operation. The vehicle operated from February to September, 2004. From September to present, UPS operated fuel cell powered Dodge Sprinter package delivery vans. The Sprinter was built to meet UPS specifications for its package delivery vehicles, meeting the same space, weight capacity, and access requirements as a conventional (diesel) delivery vehicle. (DaimlerChrysler has also included the Sprinter as a part of the Technology Demonstration program by the Department of Energy.)

UPS has operated these fuel cell vehicles in their normal daily package delivery routes in the Ann Arbor-Ypsilanti, Michigan area. The vehicles were operated by UPS drivers, who were trained and authorized to access and refuel at the EPA hydrogen fueling facility.

EPA contracted with Air Products and Chemicals, Inc. to install and maintain a hydrogen fueling station at EPA's National Vehicle and Fuel Emissions Laboratory in Ann Arbor. EPA also consulted with the National Aeronautics and Space Administration (NASA) on additional design elements related to safety and security appropriate for a federal facility.

EPA Hydrogen Station Specifications

EPA's hydrogen fueling station is a liquid-hydrogen based design. Hydrogen is delivered in liquid form and stored in the station's super-insulated 1,500 gallon cryogenic tank. Hydrogen is vaporized and is compressed to about 6200 psi (about 425 bar). The high-pressure hydrogen is stored in 3 banks of 12 tanks, totaling 42 kg of compressed hydrogen. The compressed hydrogen is

piped to the dispenser, where computerized controls supply hydrogen at about 5000 psi (about 350 bar) to a fill hose and nozzle. The dispenser uses a fill protocol designed to operate with vehicles equipped for communication with the dispenser, as well as vehicles that do not have this capability.

The station incorporates several design elements recommended by NASA intended to address the potential for accidental or intentional release of hydrogen. These elements include 1) features to quickly vaporize and disperse liquid hydrogen in the very unlikely event of a massive spill (a gravel bed under the liquid hydrogen tank and aluminum strips in the chain link fence), and 2) the location of the station such that the plume of vaporized hydrogen gas in such a situation would not come near the surrounding buildings. Other NASA recommendations that EPA implemented were evaluating site-specific risks in the immediate vicinity of the station and safety training for vehicle operations, first responders, and other local authorities who might enter the fueling area. (See report at epa.gov/fuelcell/420r04016.pdf

Lessons Learned to Date

The goals set by each of the three partners have been exceeded. This section summarizes the key learnings identified by each partner, and how the collective experience has helped advance fuel cell and hydrogen technologies in the U.S. and the world.

DaimlerChrysler

The passenger UPS vehicle is identical to the current DaimlerChrysler F-Cell fuel cell vehicles operating in Germany, Japan, Singapore, and the US. This vehicle is equipped with a 72 kW PEM fuel cell engine, 20 kW peak NiMH battery pack, 65 kW electric drive system, and 1.8 kg of hydrogen on-board. This Mercedes A-Class vehicle can travel slightly over a 100 miles before refueling. The fuel cell Sprinter is a medium-duty delivery vehicle identical on the outside to the conventionally-powered Sprinter. There are two fuel cell Sprinters in the US, one in Ann Arbor, MI and the other in Long Beach, CA. The Sprinter shares the same fuel cell engine and battery as the F-Cell. However, the Sprinter requires a 5 speed transmission and a 80 kW electric drive to accommodate for the larger size and weight of the vehicle. Additionally, the vehicle holds 5.6 kg of hydrogen for a 155 mile range and with a top speed of 82 MPH, it can be driven on any public road.

By achieving significant year-round mileage accumulation, the partnership has provided a major opportunity for UPS to assess state-of-the-art fuel cell vehicle technology. UPS has operated the Sprinter vehicles more than 12,000 miles, including two complete Michigan winter seasons. Although this generation of fuel cell technology cannot be stored outside in the winter, it is very capable of operating in freezing temperatures. The operations of the fuel cell vehicles were successful in this cold climate. The larger hydrogen capacity of the Sprinter brought new challenges for the hydrogen fueling station. The fueling rate recommendation in various guidelines added too much time to vehicle refueling. Thus, DaimlerChrysler collaborated with EPA and Air Products to optimize fueling for vehicles with larger capacity, to minimize fueling time without

compromising capacity and safety. DaimlerChrysler is working with various organizations to advance fueling rate strategies to benefit all OEMs demonstrating fuel cell vehicles.

In the course of the test program, DaimlerChrysler was able to identify and address several technical issues. One interesting observation was the overcooling of the thermal system in temperatures below zero degrees Celsius. Based on earlier experience, DaimlerChrysler has expected under-cooling to be a potential problem with fuel cell technology, but over-cooling was not anticipated. The large amount of data gathered enabled the implementation of two software revisions to improve the performance and fuel economy of these vehicles. Working together with our partners, DaimlerChrysler was also able to eliminate some redundant requirements during refueling to move the technology closer to conventional fueling operations. For example, testing showed that the electrically conductive concrete pad in front of the dispenser provided more than sufficient conduction between the vehicle and the station. The requirement for direct vehicle grounding was no longer necessary.

The Partnership also provided DaimlerChrysler with important experience in moving fuel cell vehicles into customers' hands, a key step on the way to commercialization. DaimlerChrysler was able to hand over full control of the vehicles and day-to-day decisions to UPS. Service and maintenance on the vehicles were provided by DaimlerChrysler.

DaimlerChrysler also actively worked with local officials and UPS officials to provide training on hydrogen safety and emergency response as they apply to the test vehicles. These proactive efforts, in conjunction with training provided by EPA and Air Products relating to the hydrogen fueling station, generated a high level of hydrogen understanding and support from local officials.

UPS

UPS has for many years played a leadership role in the demonstration of innovative alternative vehicle technologies and fuels. UPS believes that the experience of the Partnership has added a very successful chapter to company history. The company has strived to use the vehicles in a manner as close as possible to other vehicles in the fleet, and this effort has been a significant success.

As UPS gained experience with the capabilities of the Sprinter, it has been possible to expand its operation and thus accumulate more miles more quickly. Early in the program, UPS operated the vehicle on a single route of 70 miles in the Ann Arbor area. More recently, UPS has been able to assign two daily routes to the vehicle, which nearly doubles the daily operation. The Sprinter frequently refuels twice per day at the EPA station and delivers well over 200 packages per week.

The customers' response to having their packages delivered by an innovative zero-emission vehicle has been positive. The operators have been trained to answer basic questions about the vehicle and the Partnership. UPS, in coordination with DaimlerChrysler, has displayed and demonstrated the vehicles in numerous public venues.

UPS has been very active with DaimlerChrysler in establishing procedures for the proper storage and

operation of the vehicle inside the company's Ypsilanti, Michigan package center.

EPA

EPA's Office of Transportation and Air Quality has responsibility for developing and implementing national motor vehicle air pollution control programs. Part of this role is to participate with industry and academia in identifying and developing emerging transportation technologies that show potential for significant environmental benefits. EPA's involvement in the Partnership significantly contributed to the understanding of how hydrogen fueling infrastructure and fuel cell vehicle technologies may best move toward commercialization.

With the design, installation, prove out, and daily operation of a hydrogen fueling station, EPA has been in a position to contribute to the national development of hydrogen infrastructure. The station's use averages 30 fills per month, supplying the UPS Sprinter vehicle and other fuel cell vehicles. The overall availability of the station to its customers has exceeded 98 percent. The station also has provided fueling to fuel cell and hydrogen vehicles from other auto manufacturers for public events or testing programs scheduled in southeast Michigan.

Although a positive experience, operating the station has clearly demonstrated that hydrogen infrastructure is still in the development stage, and that technological improvements will continue to be necessary before widespread commercialization of hydrogen fueling becomes a reality. Although the station maintained a high level of availability, failures in each of the systems of the station were more frequent than expected. Fortunately, only a few of these failures resulted in the need to briefly suspend fueling services. All failures were carefully evaluated by EPA and Air Products. Corrective actions were taken to reduce or eliminate the possibility of recurrences. In several cases, the lessons learned from this station carried over to fueling stations elsewhere in the U.S. These improvements include dispenser hose leak guards, enhanced software controls, alarms, and improved preventive maintenance procedures.

The Partnership has also facilitated the development and improvement of vehicle testing procedures for hydrogen and fuel cell vehicles. EPA completed an innovative upgrade of an existing dynamometer test cell to safely test hydrogen-fueled vehicles and incorporated hydrogen capability into a newly-constructed test cell. This capability has allowed the testing of six hydrogen vehicles from several manufacturers with different technologies. A direct result of this testing has been EPA's leadership role in establishing test procedures for hydrogen vehicles, especially when determining the most accurate methods to measure hydrogen fuel consumption.

EPA has shared the technical and operational experiences of the Partnership in many settings, including a federal interagency task force on hydrogen, the DOE "Learning Demonstration" Program, the California Fuel Cell Partnership, and SAE International.

Conclusions

DaimlerChrysler, UPS, and EPA believe that the Partnership represents a major success in government/industry collaboration on emerging transportation technologies. Each member organization has been able to achieve the individual goals it set forth at the launching of the Partnership. The staffs of the three organizations have worked extensively together to successfully coordinate organizational needs and address technical issues. The Partnership has led to improvements in fuel cell technology and hydrogen infrastructure, the knowledge of which has been widely disseminated. Overall, the organizations believe that the Partnership represents a major step in moving hydrogen and fuel cell technologies forward toward commercialization.