AC Transit's Hydrogen Fuel Cell Project

Will Hydrogen Replace Diesel Fuel?

by Larry Plachno

Photos courtesy of AC Transit

AC Transit in California is substantially along in an advanced but locally developed fuel cell project. The next step will be operating full-sized transit buses in regular service using hybrid hydrogen fuel cell power. Here, one of the fuel cell-powered Van Hool buses is being tested.

Will hydrogen replace diesel fuel in powering our next generation of buses? While we do not expect to see major changes in 2005, ongoing research and development is increasingly pointing to hydrogen as the logical fuel of the future. Coming to the forefront in this area is some impressive work already done by AC Transit, a local transit operator in California.

Most research into alternative fuels is funded and sponsored by major corporations involved with engines or fuel. AC Transit's development of fuel cell-powered buses is particularly noteworthy because it is an independent effort by a local transit agency that is turning heads and receiving national recognition. AC Transit is one of the largest transit agencies in California, serving more than 64 million passengers a year throughout a 360-square mile region centered in the East Bay communities across the bay from San Francisco.

Among many in the bus industry, AC Transit has had a reputation for being somewhat of a maverick or independent in seeking solutions to its unique problems. In addition to local transit service in the East Bay communities, AC Transit replaced the former Key System and Southern Pacific Electric commuter service across the Oakland Bay Bridge into San Francisco. At one point, AC Transit operated articulated Eagles on this bridge route and appears to be the only U.S. transit agency to operate intercity articulated buses in regular service. More recently, AC Transit captured the American Public Transit Association's (APTA) "Best of the Best" roadeo award five out of the past six years, instituted a working Bus Rapid Service on crowded San Pablo Avenue, and modernized its fleet with low-floor transit buses from Van Hool in Belgium. AC Transit can also boast having the only in-house state certified apprenticeship program.

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Much of the credit for the fuel cell project goes to Rick Fernandez, who has served as AC Transit's general manager for the past six years and has 29 years experience in transit. Several transit agencies in several cities have been testing fuel cell buses, but the AC Transit program is emerging as the one to watch. Recently, the Environmental and Energy Study Institute (ESSI) of Washington, D.C. named AC Transit as a "National Clean Bus Leader" for its advanced environmental technology initiatives.

Interest in fuel cell technology at AC Transit dates back to 1999 and the APTA show in Orlando. On display was a fuel cell bus from Ballard which caught the attention of the AC Transit staff. Arrangements were made to test a hydrogen fuel cell bus later in 1999. The results were impressive and AC Transit became increasingly active in hydrogen fuel cell research. AC Transit joined the California Fuel Cell Partnership in early 2000 and now sits on the board of the National Hydrogen Association.

Why the interest in hydrogen when engine manufacturers, fuel companies and other transit agencies are experimenting with several alternative fuels including propane, compressed natural gas and liquid natural gas? There are several major reasons for looking at hydrogen as a fuel, but two of them stand out.

The first is that while the popular alternative fuels produce significantly less pollution, pure hydrogen is totally clean. When pure hydrogen is used with fuel cell technology, the only output is heat and water. The second advantage is that the fossil fuels are limited and can be depleted. Hydrogen, on the other hand, can be made from a wide range of fuel sources, including clean, green, renewable wind and solar power. Hence, hydrogen is obviously the ideal power source and the ideal long-term goal.

As any chemistry student can tell you, hydrogen is the lightest element and the most common element in the universe. More than 90 percent of our universe is made up of hydrogen. In addition, hydrogen combines easily with other elements. An excellent example is that water, which covers 70 percent of our planet, is a combination of hydrogen and oxygen.

The radical difference between a conventional combustion engine and a fuel cell is obvious in this photo. That box-like device on the fork lift is a fuel cell which is being put in the engine compartment of one of the Van Hool buses. Not only does the fuel cell have zero emissions, but if engineered properly, it can also be very quiet in operation.

Like the fossil fuels, hydrogen is flammable and will burn. However, unlike the fossil fuels, in the event of a leak or spillage, hydrogen dissipates quickly into the surrounding air without polluting it. Hydrogen fuel cell buses only emit water, no smog producing NOx and no particulate matter, and hence are totally clean and ecologically friendly. Since fuel cell buses operate electrically, they can also be very quiet and reduce noise pollution significantly.

It is also interesting to note that while there are different kinds of fuel cells, most of them can be made and operate efficiently in a wide variety of sizes. You could have fuel cells small enough to power a cell phone or laptop computer and also large enough to provide electricity for a small city. What became obvious is that fuel cells can be used to power automobiles and light vehicles in addition to buses. As a result, AC Transit elected to include some smaller vehicles in their hydrogen fuel cell project.

AC Transit's next step in this project was to develop a small hydrogen energy station in conjunction with the California Fuel Cell Partnership and Stuart Energy. This was located at the AC Transit Richmond Division in Richmond, California. It became operational in October of 2002. Now referred to as the Secondary Station, the Richmond Energy

Were it not for the modified roof and the exterior lettering, the average passenger might not be able to tell the difference between a fuel cell-powered bus and a diesel-powered bus. *Left:* From the outside, the 40-foot, three-door Van Hool bus looks much like the diesel-powered units in the AC Transit fleet. There are no special modifications to the rear of the coach or the engine compartment door. *Right:* The interior of the coach is the same as the diesel-powered units in the fleet. With the exception of the power train and its modifications, the parts are interchangeable.

Station produces 24 kilograms (kg) of hydrogen daily from the electrolysis of water. It also can store as much as 47 kg of gaseous hydrogen. The hydrogen is now available to fuel both buses as well as fuel cell-powered automobiles and light-duty vehicles.

Now that hydrogen fuel was available, AC Transit moved ahead with getting an actual fuel cell bus in service. A 30-foot hydrogen-powered fuel cell bus was leased from Thor Industries, ISE Corporation, and UTC Fuel Cells. Thor Industries, originally founded in 1980, is the largest RV manufacturer in North America and is also the largest mid-size bus manufacturer in North America. Based in San Diego, ISE specializes in power control software and systems. They are a leader in developing various hybrid power systems for buses and heavy-duty vehicles. UTC Fuel Cells of Connecticut has been providing fuel cell technology for many years in support of NASA's manned space program and has a long distinguished record of developing state-of-the-art fuel cell systems.

AC Transit put this 30-foot Thor bus in service in 2003 and 2004. It was fueled at the Richmond Energy Station and operated in regular revenue service. In spite of being experimental, the bus averaged the equivalent of 7.5 miles per gallon and 83 percent availability. The results of the test were very encouraging and proved that hydrogen power and fuel cell technology could be viably used in transit service.

AC Transit's fuel cell project got off to a good start in 2003 and 2004 when this bus was put into service. Leased from Thor Industries, ISE Corporation and UTC Fuel Cells, the 30-foot bus was powered by a hydrogen fuel cell and operated in regular service. It averaged the equivalent of 7.5 miles per gallon and 83 percent availability.

At this point it might be appropriate to digress and mention that in spite of the fact that the remainder of the AC Transit fleet was diesel-powered, they had already taken some major steps to reduce pollution. Starting in 1996, AC Transit began repowering its older buses with state-of-the-art low emission engines. Next, they switched to ultra-low sulfur fuel to reduce pollution. More recently, they installed after-treatment traps on hundreds of buses to catch particulates and reduce pollution. As a result, the AC Transit fleet is now not only below current pollution mandates, but their MCI coaches, which are diesel powered, are down to CNG standards in pollution. According to the California Air Resources Board, this combination of improvements resulted in a 76 percent average reduction in hydrocarbon emissions, a 29 percent average reduction in carbon monoxide emissions, and a 29 percent average reduction in particulate matter emissions.

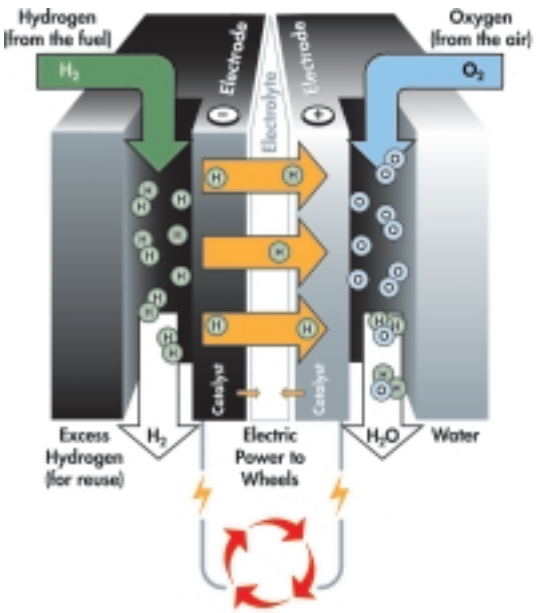
With the success of the 30-foot Thor/ISE/UTC hydrogen fuel cell bus, AC Transit made the decision to escalate their fuel cell project into more and larger buses. As a result, work was started on a larger hydrogen energy station. Located at AC Transit's Seminary Division in Oakland, this came to be known as the Primary Station. Developed in partnership with Chevron Hydrogen, it uses a steam reformer to develop hydrogen from natural gas.

This Primary Station in Oakland will dispense up to 150 kg of hydrogen daily. Two dispensers will allow two buses to be fueled simultaneously. The station will also provide fuel for AC Transit's fleet of Hyundai fuel cell light-duty vehicles. AC Transit will be operating up to nine light-duty Hyundai Tuscon fuel cell light-duty vehicles as a participant in the U.S. Department of Energy's Validation Project.

In addition to its primary purposes, this Chevron Hydrogen station has the capability to add a stationary fuel cell to use excess hydrogen to generate electricity for the facility. It also will include the "Hyroad Learning Center" which will introduce visitors to how hydrogen is produced, stored and used for power in fuel cells. In addition, the center will educate visitors on the challenges in developing a clean and sustainable energy and transportation system. It is expected to be open and operational in late 2005.

By this time AC Transit was developing its new San Pablo Bus Rapid Service to provide better transportation on San Pablo

If you open the engine compartment door on one of the fuel cell buses, the modern power source immediately becomes obvious. The fuel cell "box" is a striking change from the conventional diesel engine. Passengers may appreciate the smooth and quiet operation. Mechanics may appreciate the cleaner, high-tech working environment.



Hydrogen Powering A Fuel Cell To Generate Electricity

Source: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy

A fuel cell bus has considerably fewer moving parts than a conventional diesel bus. This diagram shows how hydrogen is fed into one side of the fuel cell while oxygen from the air is fed into the other side of the fuel cell. The hydrogen and oxygen combine to form water while producing electricity to move the bus.

The fuel cell buses are fueled with hydrogen at an energy station. Shown here is one of the hydrogen dispensers which is remarkably similar to gas and diesel pumps used at gas stations and truck stops.

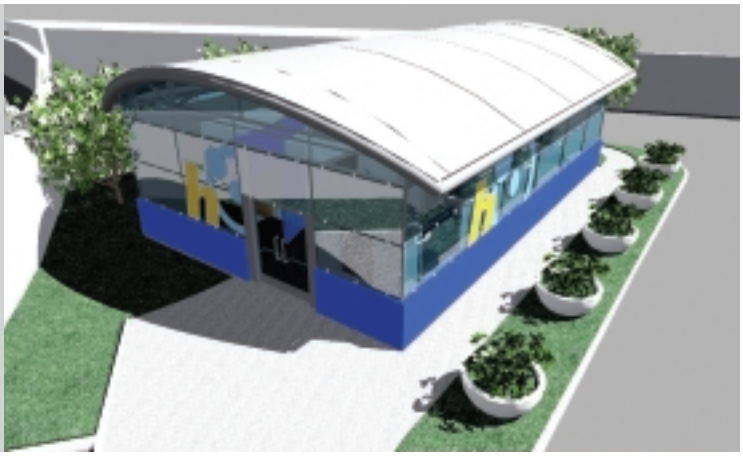
Avenue, a major artery in the East Bay communities. After looking at several alternatives, AC Transit decided to purchase 131 diesel-powered, Belgian-built Van Hool A330 40-foot low-floor transit buses plus 57 diesel-powered Van Hool AG300 60-foot articulated, low-floor transit buses. [see the October, 2004 issue of NATIONAL BUS TRADER].

Looking for a way to expand their hydrogen fuel cell project to full-size transit buses, AC Transit made the decision to order three additional new 40-foot Van Hool A330 buses

and equip them with hydrogen fuel cell power. Since this request was so revolutionary, it prompted some questions in the hallowed halls of the Van Hool plant in Belgium. As a result, a small group of Van Hool staff, including resident mechanical wizards Luc Wouters, Paul Jenne, Hugo deRoo, and Francis Stevens, made their way to AC Transit in California to look into the hydrogen fuel cell project. The Van Hool group was satisfied with what they saw. As a result, Van Hool built three specially modified A330 low-floor transit buses without drive trains for the AC Transit's fuel cell project. The three as-yet-unpowered buses came to be called "gliders."

The building of these three hydrogen fuel cell buses has caused a great deal of interest in the bus industry. First, because they are full size transit buses to be placed in true high capacity transit service. Second, this is not a stock "off-the-shelf" package but a unique set of components designed specifically for hybrid bus applications.

Rick Fernandez, AC Transit's general manager, put in a lot of effort searching out and bringing together just the right combination of components which would best suit AC Transit's application. The three non-powered, 40-foot A330 gliders arrived from Van Hool in the fall of 2004. They are compatible with the other A330 buses in the fleet except for the power system. Modifications at AC Transit's Seminary Division in Oakland will permit the staff to work indoors on as many as four 40-foot fuel cell buses at the same time.



This artist's rendering depicts the new "Hyroad Learning Center" which will be part of the soon-to-be-completed Primary Station in Oakland. Visitors will learn how hydrogen is produced, stored and used.

The fuel cell selected is the 102 KW Pure Motion™ power system manufactured by UTC Fuel Cells of Connecticut. What makes this fuel cell special is that it operates at near ambient pressure, which should reduce maintenance problems while also running quieter because it does not require a compressor. Rick wanted a hybrid system with a battery which would store power from regenerative braking. Hence, three zebra nickel sodium chloride batteries are included. These store energy from regenerative braking and can provide an additional 95 KW of booster power. Electric motors to actually move the bus come from Siemens and have their ELFA drive. ISE in San Diego is responsible for integrating the various components around their own power control software and systems.

Sunline Transit in Thousand Oaks, California was so impressed by the system that they asked AC Transit to build an extra bus for them. Hence, ISE in San Diego is producing a fourth bus for Sunline Transit at the same time that it puts the hydrogen fuel cell system into the three Van Hool buses for AC Transit.

In actual operation, the buses will fuel up with hydrogen at the energy station. Each of the Van Hool buses have eight hydrogen tanks which will provide an operating range of 250-300 miles. The UTC fuel cell has a polymer electrolyte membrane and, unlike an internal combustion engine, virtually no moving parts. The hydrogen is fed into the anode where a catalyst separates hydrogen's negatively charged electrons from the positively charged protons. Meanwhile, oxygen from the air enters into the cathode. Hydrogen protons move through the electrolyte membrane between the anode and cathode, producing electricity. When they get to the cathode, they combine with the oxygen to produce water and heat. All of this can be accomplished with very few moving parts and, if done right, with very little noise.

Electricity from the fuel cell is then controlled by the ISE system. It can be used to move the bus by powering the electric motors connected to the wheels or for power steering, air conditioning and other accessories. When braking, the electric motors can be used as generators to produce electricity which is stored in the zebra nickel sodium chloride batteries for future use. The buses are expected to have a fuel economy of approximately six miles per gallon, a maximum speed of 65 miles per hour, climb a sustained grade of 18 percent, have zero emissions, operate with a quiet all-electric drive, and have a life span of approximately 12 years. They are expected to go into service in late 2005.

In June of 2005, AC Transit became the first transit agency in California to join the California Climate Action Registry. Created by California statute in 2001, this non-profit organization enables companies and other organizations to create a baseline for moni-

A look inside the fuel door on one of the Van Hool fuel cell buses gives us a view which is somewhat different than gasoline and diesel-powered buses. The fuel cell buses are expected to have a fuel economy of approximately six miles per gallon, climb a grade as high as 18 percent and operate as fast as 65 miles per hour.

toring greenhouse gas emissions. As a member, AC Transit will publicly report its greenhouse emissions, which will be verified by independent monitoring organizations. Improvements in reducing greenhouse emissions can then be easily documented.

In June of 2005, ISE was still installing and testing the hydrogen fuel cell components in San Diego when they set up one of the Van Hool buses so that AC Transit could show it. Early June found mayors from the world's largest and most environmentally significant cities convene in San Francisco for the United Nation's World Environment Day. A meeting of 70 mayors at San Francisco City Hall was held to negotiate Urban Environmental Accords. As part of an exhibition of cutting-edge "green" technology, the mayors were treated to a ride on one of the new AC Transit fuel cell buses. It was brought up from ISE in San Diego just for this event. Passengers were surprised because the bus was so quiet, they did not know whether it was on or not.

The three 40-foot Van Hool hydrogen fuel cell buses are expected to enter regular service at AC Transit on or about October of 2005. In 2006 and 2007, operation of the buses will be evaluated by the Department of Energy. Numerous people in the bus, fuel, engine and other industries will be watching this operation and evaluation very carefully. If these full-size, hydrogen fuel cell buses do well, we can expect to see considerably more hydrogen fuel cell buses in the future. ❑

What makes the AC Transit hydrogen fuel cell project noteworthy is that uses full-size transit buses and a power system developed by AC Transit specifically for a bus application. The three fuel cell buses are built by Van Hool and, with the exception of the power train modifications, are fully compatible with 131 similar diesel-powered buses in the AC Transit fleet. The hybrid hydrogen and battery power system takes advantage of regenerative braking for greater economy in bus operations.