Alternate Fuel Technology – Fuel Cell Vehicles

This is another is a series of articles on alternate fuel vehicles, and part one of two discussing Fuel Cells, Fuel Cell Vehicles, and hydrogen motorfuel. For comments or questions, contact ASE's Bob Rodriguez at 703-713-3086 or brodriguez@asecert.org.

While running a vehicle on water may have seemed the stuff of folklore a few years ago (remember rumors of the elusive "water carburetor?"), it's now a reality thanks to the *hydrogen fuel cell electric engine*. If you want to know more about how hydrogen fuel and fuel cell powered vehicles will change our transportation landscape, read on.

Ford's Focus FC-5 sedan is fueled with methanol. It's a 2000 model prototype FCV.

The fuel cell "engine" runs on pure hydrogen, perhaps the most abundant element on earth, and oxygen. What's more, hydrogen has "three times the energy content per pound as either gasoline or diesel fuel", and has "71% less greenhouse gas emissions per unity energy over the whole fuel cycle relative to gasoline"[1]. The fuel cell itself emits no pollutants.

What Is A Fuel Cell?

Simply put, a fuel cell (abbrev. FC) is a chemical reactor that generates electricity. Some call it a fuel cell "engine" (see "Nuts and Bolts" sidebar). Fuel cells did not gain popularity until NASA's space program began using them for electrical power (and water) during space flight. But the comparatively high costs involved prevented commercial acceptance. Today, with renewed concern over energy prices, energy conservation, and the environment, fuel cells are gaining popularity for commercial applications. We're told that three major fuel cell "growth markets" will emerge in the not-too-distant future: portable power for electronic devices, stationary power for homes and industry, and transportation (motive) power.

How'd you like to work under this hood? You're looking at a Chevy Suburban converted to an FCV by Virginia Tech engineering students.

According to the Society of Automotive Engineers (SAE), "Most major auto manufacturers have… announced plans to commercialize [fuel cell powered] cars in 2003 or 2004." Research is focused on developing practical and reliable FCs that can operate under a variety of automotive load and temperature conditions. Lowering fuel cell production and materials costs is a prime goal as well.

The polymer electrolyte membrane (PEM) type fuel cell (see sidebar) seems to be one of the best suited for automotive applications because of its relatively low operating temperature and quick response to load changes. Many think 50 KW of output is a minimum for acceptable automobile performance. Market demand for fuel cells and FCVs (fuel cell vehicles) has resulted in an increasing number of companies striking innovative deals to bring fuel cell technology to the marketplace. FC powered transit buses, vans, automobiles, auxiliary power units (for trucks), even wheelchairs, are undergoing tests in various locations and climates in the U.S. and abroad.

Why Use Fuel Cells?

No noise, no pollution, energy independence, abundant sustainable fuel…take your pick! Fuel cells are relatively efficient, currently around 40% and potentially much higher than the internal combustion engine; the FCV is *at least* 1.75 times more efficient than present ICE (internal combustion engine) vehicles. The only "pollutants" from direct hydrogen fuel cells are water and some heat…a major plus for the environment. What's more, unlike petroleum, hydrogen is virtually unlimited in supply. And unlike "pure" battery-electric vehicles (BEVs), fuel-cell vehicles can be refueled quickly and offer greater range. Some are working on developing a "closed loop," capturing the fuel cell's water emission and then reusing the water by-product for more fuel.

GM's HydroGen I is a good example of a fuel cell hybrid electric vehicle. It runs on liquefied (cryogenic) hydrogen and the emits only water and oxygen.

If you haven't guessed by now, this is an exciting time—we are on the leading edge of the "hydrogen age" and all its implications. We're shifting from fossils fuels and heat engines to clean hydrogen power. According to Dr. Doug Nelson at Virginia Tech, "These fuel cell systems…are [a] new technology, not yet off-the-shelf…but one of the few ways to get a true zero emissions vehicle." In his view, the systems are maturing relatively rapidly. GM's Vice Chairman Harry Pearce sees great potential too. "The fuel cell will revolutionize power generation, not just for automobiles, but for homes, businesses, and virtually every power need."

The Fuel Cell Electric Vehicle, or FCV

If you've read previous EV and HEV articles in the *ASE TechNews*, you have a basic idea of how hybrid vehicles (HEVs) work using an internal combustion engine. The ICE powered hybrids are leading the way to market acceptance of FCVs. The fuel-cell vehicle is likewise a hybrid, but uses the "electric engine" instead of a heat engine. The FC supplies primary power for the electric traction motor(s) and for charging the vehicle's battery modules. As in other hybrids, battery modules serve as backup secondary power—a kind of "electric supercharger."

Competition for developing economical and practical fuels cell vehicles is intense. Virginia Tech engineering students won honors in the 1999 Partnership for a New Generation of Vehicles (PNGV) Student FutureCar Challenge with their 20 KW series hybrid fuel cell '97 Chevrolet Lumina sedan. They demonstrated that a pure hydrogen vehicle could carry 5 passengers and still provide acceptable performance, trunk space, range and good mileage. (They named it "ANIMUL H_2"—for *Lumina*, spelled backwards!)

The PNGV goal of seeing manufacturers build mid-sized vehicles achieving 80 miles per gasoline-equivalent-gallon is becoming a reality by using fuel cell engines. U.S., European, and Asian vehicle manufacturers are building and testing both direct and reformed[2] hydrogen FC vehicle models for release to the market as early as 2003–2004. (A fuel cell bicycle will be available soon in 2002.)

Related issues…

When and where will we be able to purchase hydrogen to fuel FCVs? Where do the oil companies stand on sustainable hydrogen and alternative feedstocks for H_2? Will hydrogen be stored off-board or on-board, and by what means? What about hydrogen safety issues? These issues are still being debated. We'll cover these topics, and more, in a future edition of *ASE TechNews*. For now, you can do your own research on fuel cells, FCV developments, and the H2 infrastructure on the Internet by referring to our "More Info" sidebar.

More Info

Studies show that U.S. fuel cell markets will more than quadruple between now and 2004. To learn more about fuel cell developments, visit these selected Internet sites.

American Hydrogen Assn	www.clean-air.org
American Methanol Institute	www.methanol.org
Apollo Energy Systems	www.electricauto.com
Ballard Power Systems	www.ballard.com
Ceramic Fuel Cells Limited	www.cfcl.com.au/content.htm
Electric Transit Vehicle Institute	www.etvi.org
Energy Partners	www.energypartners.org
Fuel Cells 2000	www.fuelcells.org
	www.fuelcells.org/fct/galtrans.html
Breakthrough Technologies Institute	www.yournextcar.orgPageOne.html
H-Power Corp	www.hpower.com
International Fuel Cells	www.internationalfuelcells.com
International Assn for Hydrogen Energy	www.iahe.org
National Hydrogen Assn	www.HydrogenUS.com
Plug Power	www.plugpower.com
Rocky Mountain Research Institute	www.rmi.org/sitepages/pid304.asp
U.S. Dept. of Energy – H_2 Info Network	www.eren.doe.gov/hydrogen/basics.html
	www.afdc.doe.gov/altfuel/hyd_general.html
U.S. Fuel Cell Council	www.usfcc.com

1. *"Design and Development of the 2000 Virginia Tech Fuel Cell Hybrid Electric Future Truck", SAE 2000.*
2. *If liquid or gaseous fuels like gasoline, natural gas, propane, methanol, etc. are stored on-board the FCV, a fuel reformer is normally required to extract the hydrogen for use by the fuel cell. By contrast, the direct hydrogen FCV stores gaseous or liquid (cryogenic) hydrogen on-board. Several companies make fuel cells which accept hydrogen rich feedstocks directly.*

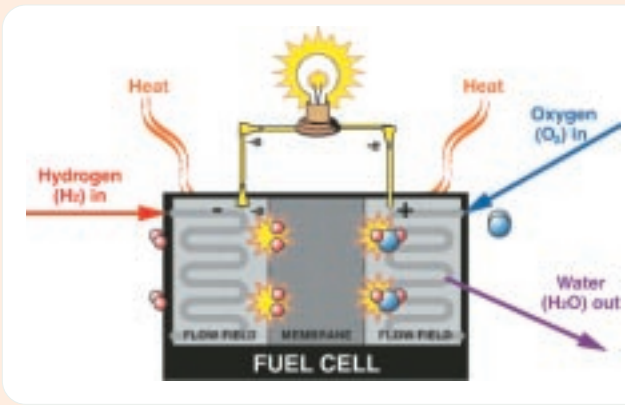
Nuts and Bolts:
How a Fuel Cell Electric Engine Works

A hybrid-electric vehicle runs on batteries, plus another (primary) power source. The fuel cell electric engine can serve as the primary power source. Just as a single internal combustion engine cylinder lies at the heart of an ICE package, the single fuel cell lies at the heart a fuel cell electric engine.

Each individual cell (see illustration) generates electrical power by converting the chemical energy of a fuel continuously into electrical energy by way of an electrochemical reaction, silently, and without combustion. Fuel cells typically utilize hydrogen for fuel, and oxygen (usually from air) as the oxidant in the electrochemical reaction. Hydrogen and oxygen are combined to generate electricity. The hydrogen used comes from processed (reformed) hydrogen-rich feedstocks such as natural gas, methanol, gasoline, propane, or other products including water. Reforming may occur off-board, or on-board the vehicle.

Different types of fuel cells exist, but the PEM type is regarded as the most practical for vehicle applications. It consists principally of two electrodes—the anode and the cathode—separated by a polymer electrolyte membrane (PEM). Each of the electrodes is coated on one side with a platinum-based catalyst. Hydrogen fuel is fed into the anode and air enters through the cathode. In the presence of the platinum catalyst, the hydrogen molecule splits into two protons and two electrons. The electrons (current) flow from the hydrogen molecule through an electrical circuit with a potential of about 0.7 volts (or more) per cell. Protons from the hydrogen molecule are transported through the polymer electrolyte membrane and combine at the cathode with the returning electrons and oxygen from the air to form water and generate heat.

Many individual cells are "stacked" in series to generate useful power—50KW is considered desirable for automotive applications. The complete fuel cell engine package may include a fuel reformer, a compressor, a heat exchanger and other ancillary devices to make it work under varying automotive temperature and load conditions.



Many applications could utilize the heat generated by the fuel cell for water and space heating and for industrial uses. Fuel cell systems are attractive power generation devices because of their inherently high efficiency, zero or very low noxious emissions, low noise, ability to utilize by-product heat (co-generation) and "modularity of construction." Such features allow fuel cells to be manufactured in virtually any size and even clustered to suit application requirements.

(Courtesy of H-Power Corporation)