FUEL CELLS
PAST, PRESENT AND FUTURE

BY

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Fuel cells have been receiving a lot of attention recently. President George W. Bush, in his 2003 State of the Union Address, announced a $1.2 billion hydrogen fuel incentive to assist with the technology development of hydrogen powered fuel cells for vehicles, homes and businesses. On February 10, 2004, General Motors and Dow Chemical started the first of 400 hydrogen powered fuel cells that will convert hydrogen produced at the Dow plants to electricity. The electricity will be used to help power the plants. Several automobile manufacturers have introduced fuel cell cars, including General Motors, Ford, Toyota and Honda (**Figure 1**).

Figure 1 - Honda Fuel Cell Powered Vehicle
(Courtesy of Honda Motor Company)

Fuel cell powered vehicles are not new. The first fuel cell vehicle was built in 1959. The alkaline fuel cell powered tractor was built by Allis Chalmers, used to plow an alfalfa field in West Allis, Wisconsin, then donated to the Smithsonian Institute where it is on permanent display (**Figure 2**).

Figure 2 - Allis Chalmers Alkaline Fuel Cell Powered Tractor (Courtesy of the Smithsonian Institute)

Fuel cells have been used to power different kinds of vehicles such as submarines, airplanes, buses, fork lifts, lawn mowers, and scooters (**Figure 3**).

Figure 3 - Fuel Cell Powered Scooter (Courtesy of Honda Motor Company)

Fuel cells are classified by their electrolyte and operational characteristics. The most promising types include Polymer Electrolyte Membrane, Alkaline, Direct Methanol, Phosphoric Acid, Molten Carbonate, Solid Oxide and Unitized Regenerative, also known as Reversible.

The Polymer Electrolyte Membrane (PEM) fuel cell (**Figure 4**), with its light weight and low operating temperature of less than 200°F, is favored for vehicular applications. PEM fuel cells operate on hydrogen and oxygen (from air). The pure hydrogen is typically stored at high pressure in onboard tanks. Hydrogen's low density prohibits the storage of enough fuel to travel distances comparable to gasoline powered vehicles.

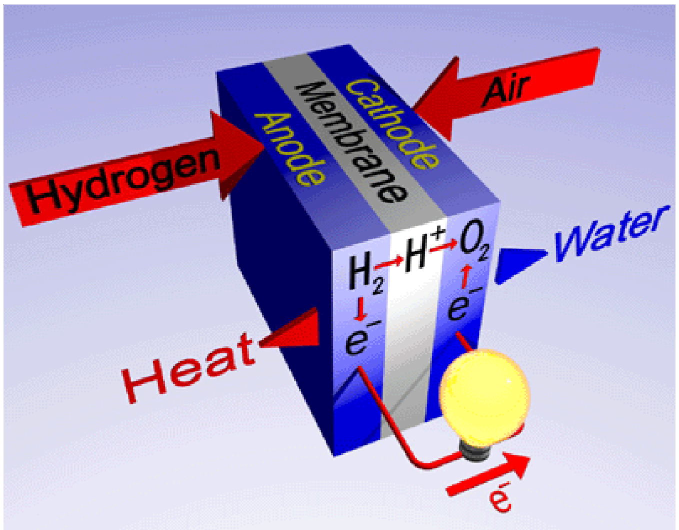

Figure 4 - Polymer Electrolyte Membrane Fuel Cell (Courtesy of Fuel Cell Today)

Hydrogen vehicles will need a network of refueling stations similar to gasoline stations that are utilized today. Other fuels can be used, but must be reformed onboard, which drives up the purchase price and maintenance costs. The reformer also releases carbon dioxide, a greenhouse gas.

Alkaline fuel cells (AFCs) are one of the oldest fuel cell technologies. The electrolyte used is a potassium hydroxide and water solution. AFCs are 60% efficient and have been used for the production of electrical power and water on the Gemini and Apollo spacecrafts, but their short operating time renders them less than cost effective in commercial applications. Their susceptibility to poisoning by even a small amount of carbon dioxide in the air requires purification of the hydrogen and oxygen. This problem adds to the cost of the fuel cell and shortens its operating cycle.

A newer cell technology is the Direct Methanol fuel cell (DMFC). The DMFC uses pure methanol mixed with steam. Liquid methanol has a higher energy density than hydrogen, and the existing infrastructure for transport and supply can be utilized. Research and development on DMFCs are 3 - 4 years behind other fuel cell technologies.

Over 200 Phosphoric Acid fuel cells (PAFCs) are being used today, primarily for stationary power generation. Since PAFCs are less efficient, they tend to be large, heavy and expensive. The efficiency is increased from approximately 40% - 85% when used for cogeneration.

Molten carbonate fuel cells (MCFCs) have several advantages. Their efficiency can approach 85% if waste heat is used. MCFCs are not prone to poisoning from carbon monoxide or carbon dioxide, and the fuel cell can actually use these oxides as fuel. The 1200°F operating temperature reforms the fuel to hydrogen within the fuel cell. The high temperature also allows the use of non-precious metals as catalysts. All of these features help reduce the cost of this type of fuel cell. The major disadvantage is component breakdown caused by the high operating temperature and corrosive electrolyte, which reduces the life of the cell.

Another high temperature unit is the Solid Oxide fuel cell (SOFC) which operates at 1830°F using a hard, non-porous ceramic compound as the electrolyte. Most of the attributes of MCFCs also apply to SOFCs. Additionally, a SOFC can be fueled by gases made from coal, since it is the most sulfur resistant of all fuel cell types. Efficiency of this fuel cell is normally 50 - 60%, but improves to 80 - 85% with waste heat recovery.

The newest technology is the Unitized Regenerative fuel cell (URFC). Similar to other types, the URFC can produce electricity from hydrogen and oxygen while generating heat and water. They can also use electricity to divide the excess water into oxygen and hydrogen, which are stored for subsequent fuel cell consumption. The electricity for this electrolysis process can even come from solar power. The URFC is lighter than a separate electrolyzer and generator making it a good choice for weight conscious projects such as fuel cell powered vehicles.

A recent project at the University of Louisiana at Lafayette provided hands-on experience with the design, procurement, installation and operation of a fuel cell. The project, which was funded by the Louisiana Department of Natural Resources and the U. S. Department of Energy, involved the utilization of a 5 kilowatt (kw) PEM fuel cell (**Figure 5**) to provide power for a small campus building. Detailed engineering analysis and economic assessments were performed on the potential integration of the fuel cell and the installed desiccant dehumidification system in a combined heat and power mode. Although the project proved that the installation and operation of such a system is feasible, it cannot show economic savings until operating efficiency, manufacturing cost and fuel cell life are significantly improved. Another major aspect of this project was the connection of the fuel cell to the electric grid of the Lafayette Utilities System.

Figure 5 - 5 kw Polymer Electrolyte Membrane

Although fuel cells have been around for many years, and are receiving more attention than ever before, they are still not economically feasible in many applications. As designs improve and manufacturing matures, fuel cells could become the power source of the future.