Fuel Cells:
Power of the Future

With the great increase in gas prices in the last few years, along with the threats of global warming and pollution, more money is now being pumped into alternate ways to power automobiles. One of the leading possible technologies for the future is the fuel cell. Fuel cells promise to power our cars and trucks, but they may also be the future power source for portable electronics and homes and businesses. Fuel cells create electricity by combining hydrogen and oxygen to form water and electricity. The various applications of fuel cells, the types of fuel cells, and the future of the fuel cell industry are the noteworthy topics one must be informed on to be familiar with fuel cells.

Probably one of the most anticipated results of the further development of fuel cells, fuel cell powered cars may take the place of conventional gasoline powered cars in the near future. The FCX, a fuel cell powered car, has been developed by Honda (see figure 1). The fuel cell is powered directly from hydrogen. The four-seater, while having good acceleration, has the whining noise associated with most electronics. Two tanks hold 3.75 kilograms of compressed hydrogen and allow the car to get 190 miles when full. This is lower than most internal combustion engine cars today. Because of the fuel cell, Honda admits it cannot guarantee the FCX will start at temperatures below 4 degrees Fahrenheit. California seems like a promising state for the first fuel cell cars to be sold. The state's warmer weather and planned "Hydrogen Highway" are more suited for that state than the environments of more northern states. As fuel cells advance, they should be able to start at lower temperatures (MacGillis).

Figure 1: The Honda FCX (Glowicki).

Today, if one's cell phone is low on batteries, one can plug it into a car's outlet to charge it. In the future, along with fuel cell powered cars, fuel cell powered portable electronics may also be available. Many Japanese electronic companies are looking toward a future of products which run off the electricity produced by fuel cells instead of batteries. Companies like Toshiba are developing fuel cells to run off methanol, a type of alcohol (see figure 2).The fuel cells in development allow cell phones users to talk for five hours, or about twice as long as a standard cell phone (Dvorak). Recent advances in fuel cells for portable electronics are pushing the industry forward. PolyFuel Inc has furthered its development on its portable electronics fuel cells. PolyFuel has developed a new hydrocarbon direct methanol fuel cell (DMFC) membrane that gives allows fuel cells to have 5,000 hour lives in durability testing. Previous fluorocarbon membranes are not as advanced as recent developments. Many believe fuel cells must have between a 2,000 and 3,000 hour lifespan in order to be viable for commercial use. The 5,000 hour milestone should help propel fuel cells as a viable energy alternative in portable electronics (LaPedus).

Figure 2 is an example of one of Toshiba's smallest fuel cells. (Smith)

Other companies are also betting their futures on fuel cell technology. H2Volt, based in Berkley, California, has developed four-inch high fuel cells that could replace the battery in today's power hungry cell phones. New portable electronics devices have created greater power needs. Batteries, while improving over the years, have not advanced nearly as far as the devices which they need to power. While some companies are simply trying to advance their batteries with different combinations of chemicals, Siemens-backed H2Volt, like many other companies, is attempting to create fuel cells that will eventually replace batteries (Baker). According to Farshid Arman, a Siemens director and member of the H2Volt board, “We’re going from hours on a laptop battery to days. Or from days on a cell phone battery to weeks.” (qtd. in Baker) The fuel cells for portable electronics are essentially the same as larger, more complex fuel cells. They combine hydrogen with oxygen to form water and electricity (Baker). While fuel cells use in portable electronics may seem like a far way off, other uses of fuel cells are currently in use today.

Fuel cells are currently being used to generate the base load energy for buildings. FuelCell Energy, Inc, a company which builds ultra-clean power plants for commercial and industrial use, sold a 500 kilowatt Direct FuelCell ® (DFC ®) to LOGANEnergy. LOGANEnergy will oversee installation and operation while Direct FuelCell will take care of maintenance. The fuel cell is for the U.S. Navy's Marine Corps Base, Camp Pendleton, in California. The 500 kilowatts will be produced by two 250 kilowatt DFC300MA ™ units. They will provide base load energy and heat for a Bachelor Enlisted Quarters which is home to more than 200 people and a Mess Hall serving over 400 people daily (FuelCell Energy, Inc). The unit should be running by the end of 2006. Two more units could be added to bring total energy production to one megawatt. Also, up to $1.25 million could be available from the State of California Self Generation Incentive Program (FuelCell Energy, Inc). Camp Pendleton's training programs occur on land used by more than 400 species of mammals and birds on 17 miles of coastline. The addition of the fuel cells should help keep the environment safe. It is not just the environment that will benefit. Some expect money will actually be saved and of course, there is great security in knowing the power can still be on even if the power grid goes down. Fuel cells have certain advantages over other clean energy sources. Unlike wind turbines and solar panels, fuel cells offer greater practical use because they can be installed in so many more places. FuelCell Energy has over 40 power plants under its operation which have produced about 80 million kilowatt hours. The Direct FuelCell ® that will be installed was actually developed in collaboration with MTU CFC Solutions, Gmvh, a subsidiary of Daimler Chrysler (FuelCell Energy, Inc).

Of all the complexities of fuel cells, one of the best known features of fuel cells is their ability to create electricity from hydrogen. Fuel cells are supplied with hydrogen, or a compound containing hydrogen, and combine it with oxygen to create an electrical current (See Figure 1 for this process). When pure hydrogen is used, only heat and water, along with electricity, are produced. (U.S. Department of Energy) Because fuel cells run a hydrogen, a compound containing hydrogen must first pass through a fuel reformer which allows the hydrogen contained in the fuel to be used. (Fuel Cells 2000) The most basic parts

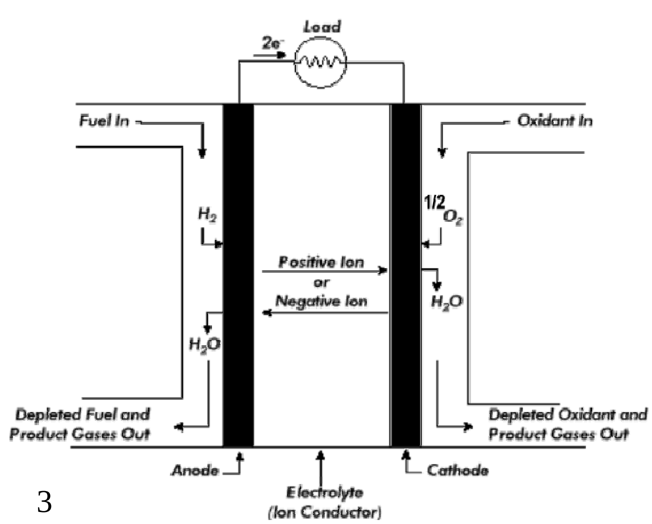

Figure 3: the basic parts of a fuel cell (Schematic of…).

of a fuel cell are an electrolyte and two electrodes with a catalyst. The fuel, hydrogen or a compound containing it, is presented to the anode which separates the negatively charged electrons from the rest of the now positively charged portion. Oxygen gains electrons at the cathode and possibly positively charged protons or water. Oxygen combining with the protons forms water while the latter produces hydroxide ions. While certain fuel cells differ in the next step, one of the products formed at either the anode or cathode moves through the electrolyte the meet the other product. Because of this process and the fact electrons will not pass from the anode through the electrolyte, an electrical circuit is formed for them to follow to get to the other side. This electrical circuit is the electricity produced by fuel cells (See figure 3 for this process) (U.S. Department of Energy).

Although fuel cells have the same general characteristics, they can vary greatly in the materials they are made of and use. Fuel cells are name according to the type of electrolyte they use.

One of the first and oldest fuel cells, the Alkaline fuel cell, was developed by the National Aeronautics and Space Administration (NASA) for use on the Apollo missions. For the electrolyte, these fuel cells use “an aqueous solution of alkaline potassium hydroxide soaked in a matrix” according to Fuel Cell 2000. The alkalinity of the electrolyte creates a faster reaction in the cathode to allow great amounts of energy to be produced. Alkaline fuel cells operate from between 150 and 200 degrees Celsius and output between 300 watts to 5 kW per cell. Alkaline fuel cells have been far too expensive for practical use in commercial applications. This problem is currently being tackled by certain companies hoping to reduce the cost of these fuel cells (Fuel Cells 2000).

Direct Methanol Fuel Cells (DMFC’s), like those being developed by Polyfuel, use “a polymer membrane as the electrolyte,” according to Fuel Cells 2000. They can operate at 40 percent efficiency at temperatures between 50 and 100 degrees Celsius. Because of this low temperature in comparison to other fuel cells, DMFC’s are one of the most practical alternatives to batteries in portable electronics. Direct Methanol Fuel Cells also have an advantage over other fuel cells technologies because a reformer is not needed. The catalyst actually takes hydrogen straight from the methanol fuel. Until recently, the fuel cells would sometimes not produce power as the process took place, but recent developments have fixed this (Fuel Cells 2000).

Microbial Fuel Cells (MFC's) have seen recent developments that may push for more research on their development in coming years. MFC technology has only been tested in the laboratory so a production model may be years away. The technology uses bacteria like Rhodoferax ferrireducens and Beobacter metallireducens to produce electricity or hydrogen. It was discovered that certain bacteria actually have enzymes that help to transfer electrons. Hydrogen can be produced from Microbial Fuel Cells, but it requires another power source. This hydrogen could be used as fuel for another fuel cell, perhaps for an automobile. While scientific breakthroughs have allowed the technology to advance in the last few years, a breakthrough would be needed to allow the fuel cells to be commercially viable. Today, MFC's produce much less power than conventional Fuel Cells. If this can be overcome, Microbial Fuel Cells could find a market in the United States, where $25 billion is used to treat wastewater (Holzman). The electricity used for this, 1.5 percent in the nation, should not be wasted. Microbial Fuel Cells would break down the waste to produce even more power (Holzman).

Molten Carbonate Fuel Cells (MCFC's) are some of the most versatile fuel cells being developed. They operate at a high 60 percent efficiency with an 85 percent cogeneration rate. Operating at 650 degrees Celsius to allow for greater conductivity of the electrolyte, these fuel cells can run on a variety of fuels including "hydrogen, carbon monoxide, natural gas, propane, landfill gas, marine diesel, and simulated coal gasification products," according to Fuel Cells 2000. Even though the high operating temperature of MCFC's means a variety of fuels can be used, corrosion and other breakdowns occur more readily at the higher temperatures (Fuel Cells 2000).

Phosphoric Acid Fuel Cells (PAFC's), are actually available for purchase today for large structures. Over 200 of these fuel cells have been installed "in hospitals, nursing homes, hotels, office buildings, schools, utility power plants, an airport terminal, [and] landfills and waster water treatment plants" internationally according to Fuel Cell 2000. Current models can produce 200 kilowatts of electricity. PAFC's are 40 % efficient at producing electricity, compared to 35 % for the United States utility power grid. Because of the need to keep the phosphoric acid at a high temperature among other reasons, these fuel cells operate between 150-200 degrees Celsius. For the electrolyte, these fuel cells use "liquid phosphoric acid soaked in a matrix," according to Fuel Cells 2000. Some of the major advantages of Phosphoric Acid Fuel Cells is their 85 percent cogeneration efficiency, meaning a great proportion of the waste produced can be used for more power. PAFC's are also able to tolerate impure hydrogen and can operate with a 1.5 percent carbon monoxide concentration in the fuel (Fuel Cells 2000).

Solid Oxide Fuel Cells (SOFC's) are also being developed for large scale industrial use, but they are also being developed for automotive use. Instead of a more common liquid electrolyte, these fuel cells use "a hard ceramic material of solid zirconium oxide and small amounts of yttria," according to Fuel Cells 2000. At 60 percent efficiency and an 85 percent cogeneration rate, these fuel cells have a maximum cell output of 100 kilowatts. SOFC's operate at about 1000 degrees Celsius (Fuel Cells 2000).

With the great variety of fuel cells and the applications to which they can perform for, fuel cells may one day power all cars, portable electronics, and some buildings, but that day may be a long way off. Market researcher NanoMarkets LLC predicts 2006 will be an important year for fuel cells and 2009 will yield a market worth $1.1 billion (LaPedus), reaching $1.6 billion by 2010 (Baker). Even though the future looks bright for fuel cells, they still "need political push" according to Jo Twist. "Dramatic changes," according to Sir David King, the chief scientific advisor of the United Kingdom's government will occur in the next 10 to 20 years (qtd. in Twist). There are currently two basic views on why fuel cells are needed: energy independence and cleaner emissions (Twist). The latter reason may not be true for all fuel cell applications. While hydrogen is an abundant element, it must first be separated from oxygen, in the case of water, or from a hydrocarbon. Natural gas can be used in this process, but it in itself creates the emissions fuel cells are trying to eliminate. For a fully emissions free process, hydrogen would need to be produced through the electricity produced by photovoltaic, hydroelectric, wind, or nuclear means (Hydrogen Horizons). If these alternative energy sources are put into effect, the dependence on foreign energy sources and almost no harmful waste from energy production can be achieved. Only with these two outcomes will almost everyone accept fuel cell technology as the power source of the future.

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