Case Study: Fuel Cells

Fuels cells generate electricity from an electrochemical reaction in which oxygen and a fuel combine to form water. Fuel cells work by converting the chemical energy found in a fuel, such as hydrogen gas, into electricity.

Introduction

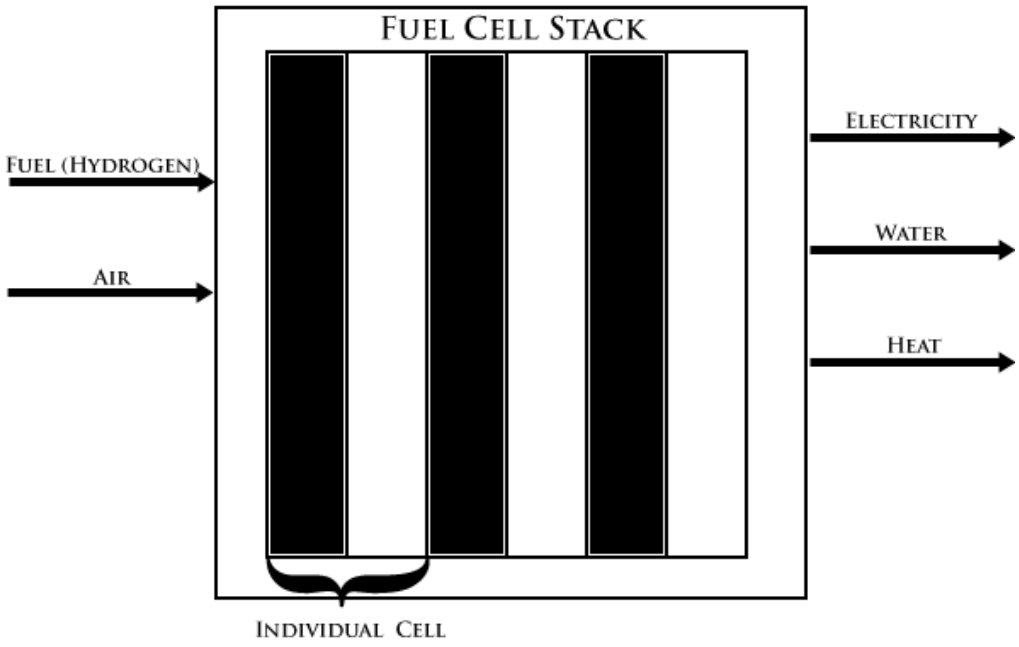
The fuel is oxidized at the anode, flows through a circuit to do electrical work, and is reduced at the cathode.

The resulting electricity can be used in a variety of ways, such as: powering motor vehicles, electrical devices, and airplanes. Fuel cells also produce a by-product of heat which is often used to heat homes. With its multifunctional products and by-products, fuel cells are rapidly becoming the hot ticket alternative source of energy as we move into a more progressive and 'green' era.

What is happening inside a fuel cell?

The fuel cell enables hydrogen to be combined with oxygen to produce electricity, water, and heat. A fuel cell alone only produces a small amount of power. However, grouping the individual fuel cells together creates a fuel cell stack (as modeled below). When delivered to a fuel cell engine, fuel cell stacks create enough energy to power buses and other vehicles, and have even been used to power spaceships.

HYDROGEN FUEL CELL



Each fuel cell contains two electrodes, a positive cathode (where the reduction occurs) and a negative anode (where the oxidation occurs), within the stack. The energy producing reactions take place at the electrodes. Each individual cell is separated by a electrolyte (either in solid or liquid form). This electrolyte carries electrically charged particles between the cathode and anode. The rate of the given reaction can be sped up with the help of a catalyst like platinum.

The power being output by a fuel cell is equal to the voltage multiplied by the current, and is measured in watts.

Factors That Reduce Efficiency in Fuel Cells

- The activation barrier can cause a loss of 200 mV to be generated because the reactions may take more energy to catalyze, especially in the case of the reduction of oxygen at the anode.
- Many times, the flow of waste water and fuel occurs at a rate that exceeds the capabilities of the fuel cell's physical capabilities.
- The efficiency of a fuel cell is dependent on the amount of power that is drawn from it. As a result, the efficiency of a fuel cell is almost proportional to its voltage.

Different Types of Fuel Cells

- **Alkaline Fuel Cells (AFC):** AFC's use alkaline electrolytes like potassium hydride. Generally, a solution of potassium hydroxide in water is used as the electrolyte. The cell operates at 150-200 degrees Celsius, and can generate anywhere from 300 Watts to 5 MegaWatts. AFC's were first used in the Apollo Space Mission by NASA.
- **Molten Carbonate Fuel Cells (MCFC):** MCFC's use molten carbonate salt as the electrode. This fuel cell has a high efficiency rate of 60%. These cells operate at about 600 degrees Celsius. The generated power varies, and some units have been built with outputs as high as 100 megawatts. Because of the high temperatures, these cells are not generally used in the home.
- **Zinc Air Fuel Cells (ZAFC):** In this type of fuel cell, there is a gas diffusion electrode, a zinc anode separated by electrolyte and a mechanical separator. Oxygen reacts with the zinc and produces zinc oxide, which gives off electricity.
- **Phosphoric Acid Fuel Cells (PAFC):** This fuel cell's anode and cathode are made with specks of platinum on a carbon and silicon carbide form that supports the phosphoric acid electrolyte. PAFC's are commonly used in large commercial vehicles i.e. buses.
- **Proton Exchange Membrane Fuel Cells (PEMFC):** This fuel cell uses a polymeric membrane as the electrolyte along with platinum electrodes. PEMFC's can function at pretty low temperatures and are therefore commonly used for cars and buildings.
- **Direct Methanol Fuel Cells (DMFC):** This fuel cell is similar to the Proton Exchange Membrane Fuel Cell; however, instead of using gaseous hydrogen as the fuel, liquid methanol is used.
- **Solid Oxide Fuel Cells (SOFC):** SOFC's can operate at 800°C to 1000°C. SOFC'S are able to do so, because they use a solid ceramic electrolyte. Like MCFC's, SOFC's can also preform at an efficiency around 60%. These fuel cells are often used for generating heat and electricity in industry and auxiliary power in motor vehicles.

	AFC	MCFC	PAFC	PEMFC	SOFC
Electrolyte	Potassium Hydroxide	Immobolized Liquid Molten Carbonate	Immobolized Liquid Phosphoric Acid	Ion Exchange Membrane	Ceramic
Operating Temperature	60°C-90°C	650°C	200°C	80°C	1000°C
Efficiency	45-60%	45-60%	35-40%	40-60%	50-65%
Electrical Power	Up to 20 kW	>1 MW	>50 kW	Up to 250 kW	>200 kW
Possible Applications	Submarines, Spaceships	Power Stations	Power Stations	Vehicles	Power Stations

The Benefits of Fuel Cell Power

Fuel cells create little to no environmentally damaging emissions: generally, the only byproduct in a hydrogen fuel cell, typically found in automobiles, is water.

- As long as fuel is always available, the fuel cell can run for an infinite amount of time.
- Fuel cells offer cleaner, quieter, and more efficient power production than conventional internal combustion engines.
- Fuel cells can use a variety of gases, such as: natural gas, methanol, gasoline, and hydrogen. Fuel cells are extremely reliable; in just six years, most fuel cells can achieve 99.9999% reliability.

Where are Fuel Cells Being Used Now?

Fuel cells are being used all over the globe. Here are some examples:

- NASA was the first to use fuel cells commercially in the 60's. In fact alkaline fuel cells have flown over 100 missions and been used for over 80,000 hours for NASA.
- The US Navy has used fuel cells in submarines since the 80's.
- Backed by the European Union, *Clean Urban Transportation for Europe*, "CUTE" fuel cell buses have been successfully implemented in various European cities.
- As part of its national project to create a fossil fuel free economy, Iceland, has begun to convert its fishing fleet from diesel engines to hydrogen fuel cells.
- Fuel cells are also being designed to be able to power smaller electronics such as cellular phones, laptop computers, and also for use as an auxiliary power source.
- Many major car manufacturers all over the world have already created various prototypes of fuel cell powered automobiles.

Outside links

- Online Encyclopedia Article: http://en.wikipedia.org/wiki/Fuel_cell
- Video Of How It Works: http://www.youtube.com/watch?v=esuAlB4NVi0
- The Chemistry: http://www.princeton.edu/~chm333/200...hemistry.shtml
- The History: http://www.princeton.edu/~chm333/200...-history.shtml

References

1. Petrucci, Ralph H. General Chemistry: Principles and Modern Applications 9th Ed. New Jersey: Pearson Education Inc. 2007.

2. Koppel, Tom. Powering the Future : The Ballard Fuel Cell and the Race to Change the World. New York: John Wiley & Sons, Incorporated, 1999.

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