Additional Fuel Cell Information

A REEL Power [tm] (Renewable Energy Education Lab) Experiment
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Additional Fuel Cell Information

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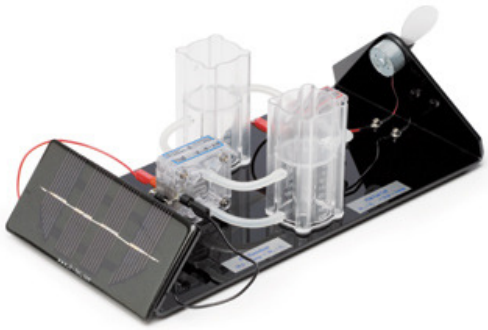
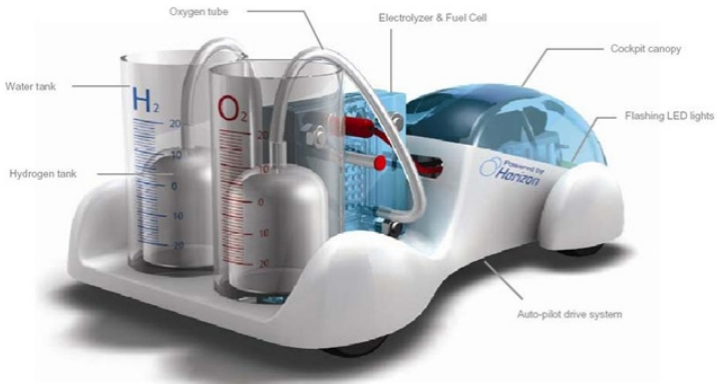
Suggested Fuel Cells

For best results a reversible PEM fuel cell that has graduated cylinders for measuring hydrogen and oxygen is recommended. Two general types are illustrated below. Visit www.fuelcellstore.com for more choices.

Fuel Cell image courtesy h-tec (www.h-tec.com)



Hydrocar image courtesy Horizon Fuel Cell Technologies (*www.horizonfuelcell.com*)



Maximum of 3 volts DC

Limit the voltage placed across a PEM fuel cell to 3 volts DC maximum; otherwise, you may damage it with a higher voltage. Choose your solar panel, battery or variable DC power supply carefully.

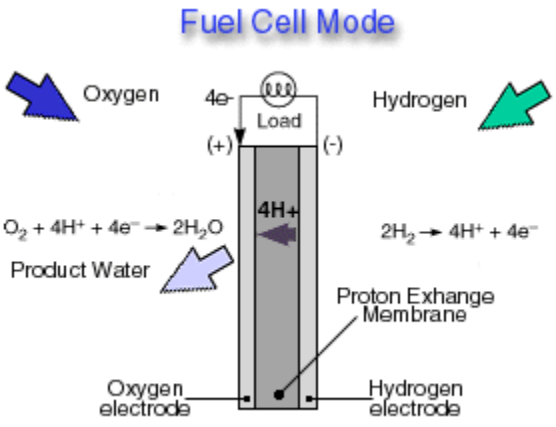
Hydrating and Purging the Fuel Cell

Hydrating is a process by which distilled water (make sure it's distilled) is applied to both sides of the MEA or Membrane Electrode Assembly. Before performing each experiment, make sure that the fuel cell is completely hydrated and purged of all hydrogen. Fuel cells that are not used for prolonged lengths of time need to be hydrated by cycling through the electrolysis and fuel cell modes several times.

Purging is a process by which all hydrogen in the fuel cell storage container, transport tubing and internal MEA is exhausted. Besides allowing the hydrogen to vent to the air, if at all possible, the next best thing is to apply a low value resistor across the electrical terminals in order to consume any residual hydrogen.

How Reversible PEM Fuel Cells Work

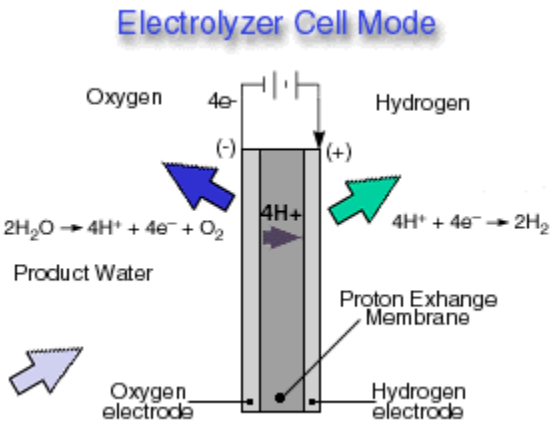
In principle, a fuel cell operates like a battery. It produces electricity by using chemicals. The chemicals are usually very simple, often just hydrogen and oxygen. In this case, the hydrogen is the "fuel" that the fuel cell uses to make electricity. The oxygen needed by a fuel cell is usually obtained from air. Although the majority of fuel cells use hydrogen as the fuel, some fuel cells use methane, and a few use liquid fuels such as methanol. However, unlike a battery a fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied.



Through a single electrochemical process, a fuel cell produces electricity, water, and heat using fuel and oxygen in the air. This process is called the "Fuel Cell Mode". Water is the only emission when hydrogen is the fuel. As hydrogen flows into the fuel cell on the anode side (a platinum catalyst facilitates the separation of the

hydrogen gas into electrons and protons (hydrogen ions) in a proton exchange membrane or PEM fuel cell like the one in our experiments).

The hydrogen ions pass through the membrane (the center part of a PEM fuel cell) and, again with the help of a platinum catalyst, combine with oxygen and electrons on the cathode side producing water. The electrons, which cannot pass through the membrane, flow from the anode to the cathode through an external circuit containing an electric load, which consumes the power generated by the cell. The overall electrochemical process of a fuel cell is called "reverse hydrolysis," or the opposite of hydrolyzing water to form hydrogen and oxygen.



A reversible fuel cell can accomplish "hydrolysis" through the supply of electricity to the cell and a supply of water to the cathode. This process is called the “Electrolyzer Cell Mode”. Only certain fuel cell types are reversible, that is, can also accomplish the electrochemistry associated with both the production of electricity from fuel and oxidant and the production of fuel and oxidant from water when supplied with electricity.

The Reversible fuel cell concept is one that incorporates a reversible fuel cell that can accomplish both hydrolysis and reverse hydrolysis in the same cell. This allows one to consider the completely renewable production of electricity by using a renewable energy supply (e.g., solar, wind) to produce hydrogen and oxygen from water which can subsequently be used to produce electricity through the same fuel cell from the fuel and oxidant produced previously.

A Little History

The fuel cell can trace its roots back to the 1800's. A Welsh born, Oxford educated barrister, who practiced patent law and also studied chemistry or "natural science" as it was known at the time, named Sir William Robert Grove realized that if electrolysis, using electricity, could split water into hydrogen and oxygen then the opposite would also be true. Combining hydrogen and oxygen, with the correct method, would produce electricity. To test his reasoning, Sir William Robert Grove built a device that would

combine hydrogen and oxygen to produce electricity, the world's first gas battery, later renamed the fuel cell. His invention was a success, and Grove's work advanced the understanding of the idea of conservation of energy and reversibility. Interest in Grove's "gas battery" diminished as the dawn of cheap fossil fuels approached and the soon to be discovered steam engine captivated the present day society.

Fast-forwarding to the 1960's, a new government agency was about to undertake the first step in maturing fuel cell technology. The National Aeronautics and Space Administration (NASA) was developing the mission critical systems for the first prolonged manned flight into space. Once in space, the orbiter needed a source of electricity. Batteries were ruled out due to the size, weight and toxicity necessary to support a mission of eight days in space. Photovoltaics were not practical, at the time, due to the size and weight of the solar panels necessary. The once obscure fuel cell became the technological solution to NASA's dilemma of how to provide power for extended missions to space. The earlier problems of cost and fuel supplies that plagued fuel cells became irrelevant as the spacecraft was already carrying liquid hydrogen and oxygen. An additional benefit of fuel cells over other technology was that the astronauts could consume the fuel cell's water by-product. On the early missions powered by fuel cells, there were problems with the systems that required attention. On each subsequent mission the fuel cells became increasingly reliable and today NASA's space shuttle relies on fuel cells for electricity and drinking water once in orbit.

NASA and the space program provided fuel cells with the initial research and development the technology required. Since their adoption by the space program, fuel cell technology has achieved widespread recognition by industry and government as a clean energy source for the future. With this in mind, the amount of interest in fuel cells has expanded exponentially to where 8 of the 10 largest companies in the world are involved with fuel cells in some respect. Today, billions of dollars have been spent on research and the commercialization of fuel cell products. Over the next couple of years, the products that have been in the commercialization process will begin to be available to consumers.

Fuel Cell Environmental Benefits

- **High Fuel Efficiencies**

  By converting fuel directly into energy through an electrochemical reaction, fuel cells extract more power out of the same quantity of fuel when compared to traditional combustion. This direct process results in a reduced amount of fuel being consumed and greater efficiencies, 30% to

90%, depending on the fuel cell system and if the surplus heat is utilized. Combustion-based energy generation first converts the fuel into heat, limited by Carnot's Law of Thermodynamics, and then into mechanical energy, which provides motion or drives a turbine to produce energy. The additional steps involved in combustion generation allow energy to escape as heat, friction and conversion losses, resulting in lower overall efficiencies.

- **Low Emissions**

  When hydrogen is the fuel - water, heat and electricity are the by-products of the electrochemical reaction in a fuel cell generating electricity, instead of carbon dioxide, nitrogen oxides, sulfur oxides and particulate matter inherent to fossil fuel combustion. When fossil fuels are reformed into hydrogen, emissions of carbon dioxide, nitrous oxides, sulfur oxides and other pollutants are a fraction of those produced through the combustion of the same amount of fuel.

- **Reduction in Environmental Damage Inherent to Extractive Industries**

  Fuel cells avoid the environmental damage associated with the extraction of fossil fuels from the Earth when the hydrogen is produced from renewable sources. If a hydrogen spill occurred, it would evaporate instantly because hydrogen is lighter than air, leaving only water behind. This is a dramatic departure from the legacy that oil drilling, transportation, refining and waste products have left on the Earth.

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