Fuel Cells

By Louis P. Solomon with Dick Van Orden

What are fuel cells? They have been talked about for years, and are mentioned whenever you listen to people talk about space flight. Are they a new energy source? What is the science behind them? Are they just a special type of battery?

A battery has chemicals stored inside it. Through chemistry it converts these chemicals to electricity. Once the chemicals are used up, the battery is dead. There are re-chargeable batteries which can have their chemicals restored, but that is a story for another time.

Fuel cells allow chemicals to be constantly fed into the cell, where chemical reactions occur that generates electricity. Similar to a battery, there is an anode and a cathode, an electrolyte, and a very special item: a proton exchange membrane (PEM).

The anode (negative side of the cell) has channels etched in it so that hydrogen can flow throughout the entire anode. The hydrogen is forced into the anode under pressure. The cathode (positive side of the cell) has channels etched in it so that the oxygen (we use air) can interact with the catalyst which covers the cathode. The catalyst is usually very fine platinum that forms a rough surface which is covered with the oxygen. The catalyst faces the PEM. This piece of material allows the movement of Hydrogen atoms through the PEM into the cathode, where they combine with Oxygen atoms. The electrons formed in this chemical reaction flow from the anode to the cathode, outside the cell. This process can generate up to 0.7 volts, per cell. So, if we need 14 volts (direct current) we would need 20 fuel cells stacked together, connected in series.

Chemistry of a fuel cell is quite simple. On the Anode side, $2H2 \Rightarrow 4H+ + 4e-$ and on the Cathode side, $O2 + 4H+ + 4e- \Rightarrow 2H2O$. The Net reaction is $2H2 + O2 \Rightarrow 2H2O$.

In essence, a fuel cell is an electrochemical conversion device. The fuel cells converts hydrogen and oxygen into water, and in the process, produces electricity. What is very interesting is that the fuel cell never dies. As long it is supplied with hydrogen (under pressure) and oxygen (air) it produces electricity and water.

So, in principle, we have solved the entire problem of automobile transportation. We put a fuel cell in every car, replace the internal combustion engine with a direct current motor, and have a bottle of Hydrogen, under pressure. If course, we need the hydrogen, but we have already talked about how that can be obtained in a previous column. So, given this set of facts, why are fuel cells not in use world wide? Are there efficiency issues? Is there a rate problem? What other issues are involved? There are some implementation problems that have to be solved.

If pure hydrogen is used for a fuel cell, the efficiency would be about 80%. This means that 80% of the energy content of hydrogen would available to do work in the form of electrical energy. Hydrogen is difficult to store in pressurized containers. There is a natural leakage.

A reasonable number for the efficiency of an electric dc motor is about 80%. Thus a fuel cell driven by pure hydrogen, using an electric motor would be about 64%. This number will decrease if we use impure hydrogen.

Gasoline powered automobiles are surprisingly inefficient. The overall efficiency is only about 20%.

It is important to understand the feelings of human beings. A driver of a fuel cell powered car would probably want to know:

- Is the car quick and easy to refuel?
- Can it travel a good distance before refueling?
- Is it as fast as the other cars on the road?

It turns out that fuel cell powered cars operate quite well, and can travel good distances between refueling with hydrogen.

But, there are other uses for fuel cells than just cars. For example, as mentioned above, they are used in the space program. They can be used for small and large stationary power plants. All of these fuel cells use different chemistry, but they do not burn fossil fuels. You can have a small fuel cell to power your laptop computer, cellular phones, and even hearing aids. There buses that currently use fuel cells being test in several cities. Finally, you could use fuel cells for your own private home power generation. The heat generated by the fuel cell could be used to make hot water, and also heat your house without using any additional energy.

Fuel cells are here. They work today, and in a variety of different applications. They are still rather expensive, and there always remains more research to make the fuel cells more efficient and cheaper. But, they are available today, and will become ubiquitous in the next few years, or perhaps decades.