Fuel Cells

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PDH: 3

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Lamps, burning coal oil and coal gas, lit the living rooms of most homes of the early 1900's. But when electric light bulbs replaced those smoky, smelly sources of illumination, homes became brighter, cleaner, and safer. At first only the wealthy could afford electric lights. But as the demand went up and the cost went down, more and more of the population were able to afford electric lighting even though there was plenty of coal to continue lighting buildings in the usual way. The better technology won.
D.S. Scott and W. Hafele. "The Coming Hydrogen Age: Preventing World Climate Disruption." International Journal of Hydrogen Energy. Vol. 15, No. 10, 1990.

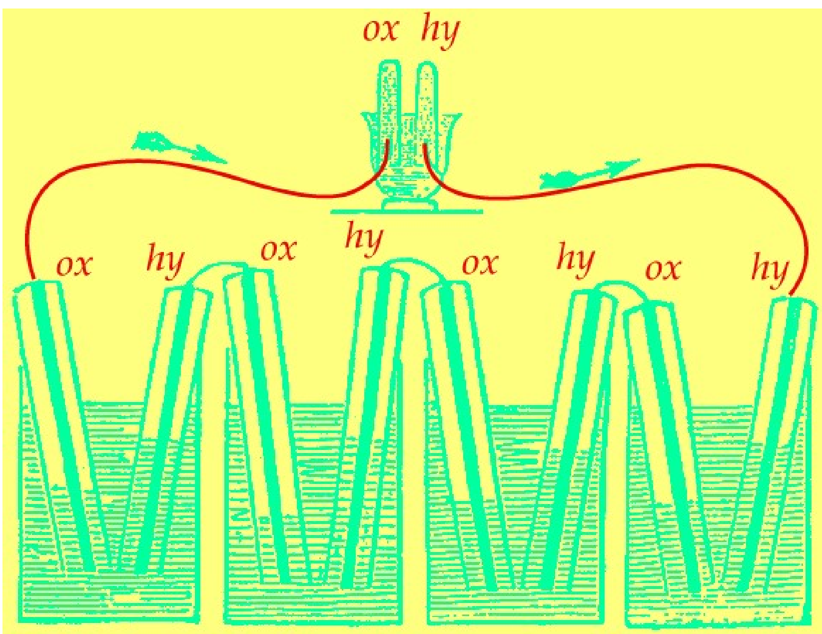
"I cannot but regard the experiment as an important one..."

William Grove writing to Michael Faraday,
October 22, 1842

A Brief History

Although fuel cells have been around since 1839, it took 120 years until NASA demonstrated some of their potential applications in providing power during space flight. As a result of these successes, in the 1960s, industry began to recognize the commercial potential of fuel cells, but encountered technical barriers and high investment costs

— fuel cells were not economically competitive with existing energy technologies. Since 1984, the Office of Transportation Technologies at the U.S. Department of Energy has been supporting research and development of fuel cell technology, and as a result, hundreds of companies around the world are now working towards making fuel cell technology pay off. Just as in the commercialization of the electric light bulb nearly one hundred years ago, today's companies are being driven by technical, economic, and social forces such as high performance characteristics, reliability, durability, low cost, and environmental benefits.



In 1839, William Grove, a British jurist and amateur physicist, first discovered the principle of the fuel cell. Grove utilized four large cells, each containing hydrogen and oxygen, to produce electric power which was then used to split the water in the smaller upper cell into hydrogen and oxygen.

The automobile, it is fair to say, changed the industrial and social fabric of the United States and most countries around the globe. Henry Ford epitomized “Yankee ingenuity” and the Model T helped create the open road, new horizons, abundant and inexpensive gasoline...and tailpipe exhaust. More people are driving more cars today than ever before — more than 200 million vehicles are on the road in the U.S. alone. But the car has contributed to our air and water pollution and forced us to rely on imported oil from the Middle East, helping to create a significant trade imbalance. Today many people think fuel cell technology will play a pivotal role in a new technological renaissance — just as the internal combustion engine vehicle revolutionized life at the beginning of the 20th century. Such innovation would have a global environmental and economic impact.

“In today’s world,
solving environmental problems
is an investment, not an expense.”

William Clay Ford, Jr.
Chairman and CEO, Ford Motor Company,
September 1998

1998, Chicago became the first city in the world to put pollution-free, hydrogen fuel cell powered buses in their public transit system.
(Courtesy: Ballard Power Systems)

The first fuel cell powered bicycle to compete in the American Tour-de-Sol.
(Courtesy: H-Power)

Fuel cells are not just laboratory curiosities. While there is much work that needs to be done to optimize the fuel cell system (remember, the gasoline internal combustion engine is nearly 120 years old and still being improved), hydrogen fuel cell vehicles are on the road — now. Commuters living in Chicago and Vancouver ride on fuel cell buses. You can take a ride around London in a fuel cell taxi and even compete in the American Tour de Solon a fuel cell bicycle. Every major automobile manufacturer in the world is developing fuel cell vehicles. To understand why fuel cells have received such attention, we need to compare them to existing energy conversion technologies.

“The mission of our global fuel cell project
center is nothing less than to make us the leader in
commercially viable fuel cell powered vehicles.”

Harry J. Pearce, Vice Chairman,
Board of Directors, General Motors.
May 1998

The Future Car Challenge, sponsored by the U.S. Department of Energy, presents a unique assignment to students from North America's top engineering schools: convert a conventional midsize sedan into a super efficient vehicle without sacrificing performance, utility, and safety. In 1999, the Virginia Tech team entered the competition with a fuel cell vehicle.

Where the Action in Fuel Cells is Today

Allied Signal
Volvo
Ballard
DaimlerChrysler
Detroit Edison
DuPont
Shell
Ford
General Motors
Honda
Mazda
Georgetown University
Case Western Reserve University
Los Alamos National Laboratory
Motorola
Penn State University
Princeton University
Rolls-Royce
Argonne National Laboratory
Sanyo
DAIS
Siemens
British Gas
Plug Power
University of Michigan
Texas A&M University
ARCO
Epyx
International Fuel Cells
H-Power
Energy Partners
Hydrogen Burner
W.L. Gore
A.D. Little
Institute of Gas Technology
Vairex
Electrochem
Giner
Jet Propulsion Laboratory
Toyota
University of California
Exxon
Westinghouse Renault
3M
Nissan BMW

Carnot Cycle vs. Fuel Cells

The theoretical thermodynamic derivation of Carnot Cycle shows that even under ideal conditions, a heat engine cannot convert all the heat energy supplied to it into mechanical energy; some of the heat energy is rejected. In an internal combustion engine, the engine accepts heat from a source at a high temperature (T_1), converts part of the energy into mechanical work and rejects the remainder to a heat sink at a low temperature (T_2). The greater the temperature difference between source and sink, the greater the efficiency,

$$\textbf{Maximum Efficiency} = (T_1 - T_2) / T_1$$

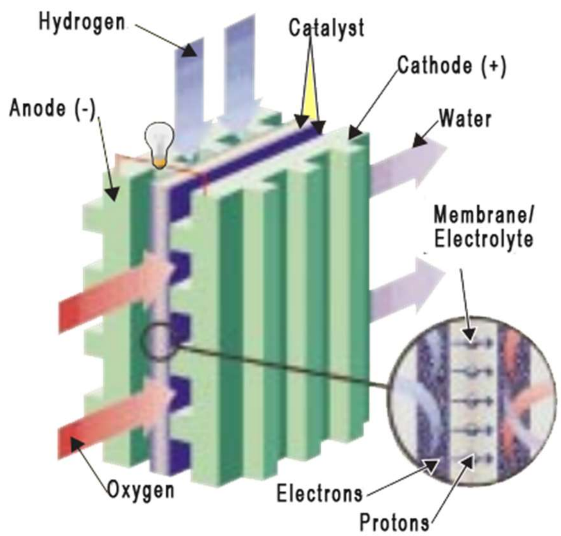
where the temperatures T_1 and T_2 are given in degrees Kelvin. Because fuel cells convert chemical energy directly to electrical energy, this process does not involve conversion of heat to mechanical energy. Therefore, fuel cell efficiencies can exceed the Carnot limit even when operating at relatively low temperatures, for example, 80°C.

The Very Basics

- A fuel cell is an electrochemical energy conversion device. It is two to three times more efficient than an internal combustion engine in converting fuel to power.
- A fuel cell produces electricity, water, and heat using fuel and oxygen in the air.
- 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). The hydrogen ions pass through the membrane (the center of the 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 a motor or other electric load, which consumes the power generated by the cell.

The voltage from one single cell is about 0.7 volts – just about enough for a light bulb – much less a car. When the cells are stacked in series, the operating voltage increases to 0.7 volts multiplied by the number of cells stacked.



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