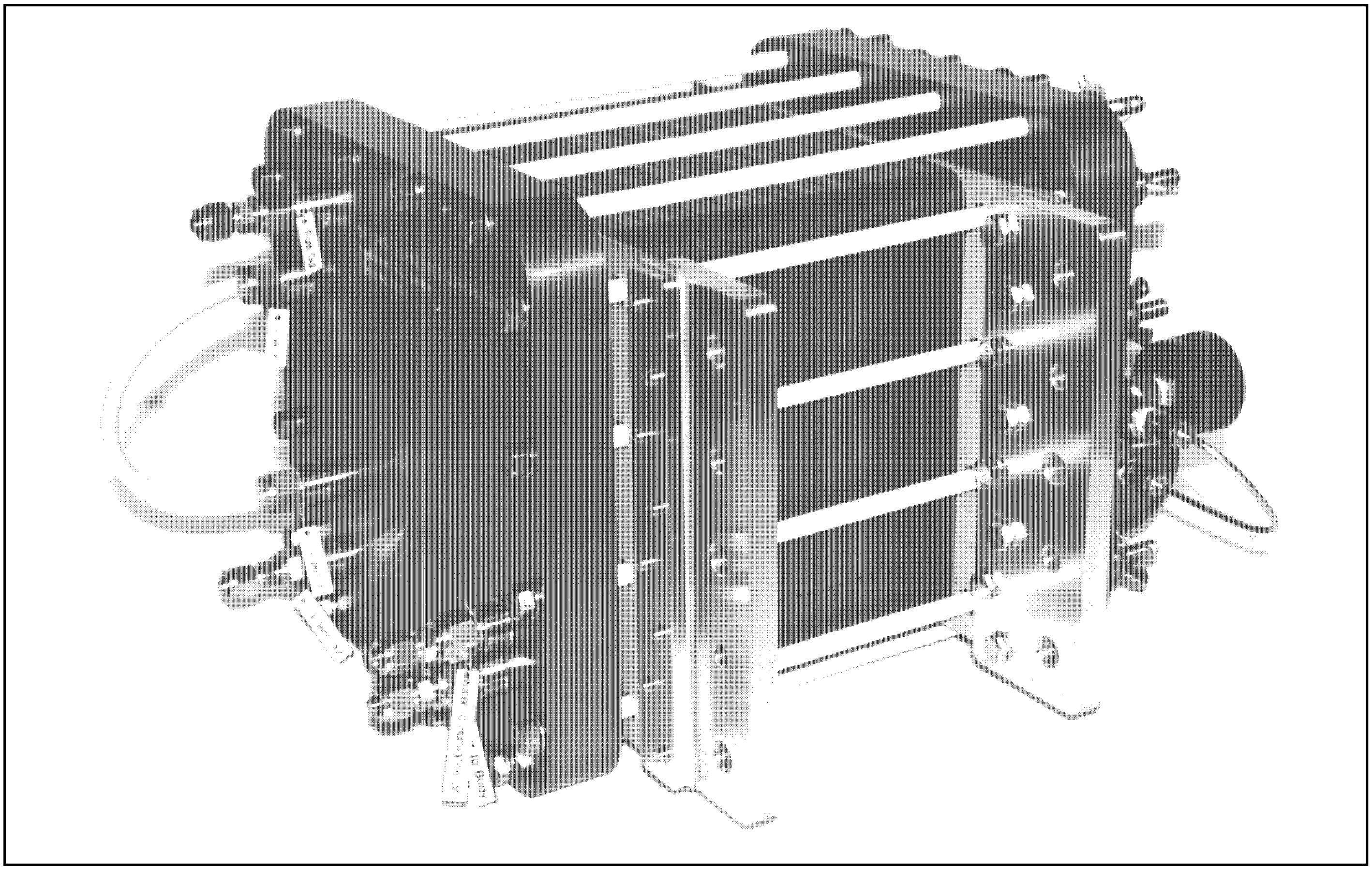

Above: This 1.7 kW prototype PEM fuel stack made by Ballard Power Systems is 20 inches long and weighs 81 pounds.

Hydrogen Fuel Cells - the power source of the '90s

Dr. Robert Wills

Imagine a car that can travel 300 miles without refueling, that performs as well as the gasoline cars of today, that uses one-half as much energy per mile, eliminates our dependence on fossil fuel and produces only water as a byproduct. Hydrogen fuel cells may make such vehicles a reality before the end of the decade. They could even cost less to run than gasoline cars.

What is a fuel cell

Practical fuel cells were first developed in the 1960s for the U.S. space program. A fuel cell is a device that converts a chemical fuel (generally pure hydrogen) directly into electricity. A fuel cell is like a battery that never runs down. The chemicals that are consumed (hydrogen & oxygen) are continually fed into the cell, rather than being a component that is used up.

Fuel cells may also be thought of as "reverse electrolysers". When two electrodes are put into a salty water solution and a current is passed, water is broken down into hydrogen and oxygen. This process is called electrolysis. Fuel cells perform the reverse action - they combine hydrogen & oxygen to form electricity and water.

Fuel Cell Vehicles

Battery electric vehicles can solve some of our transportation problems, but they have three major flaws, all related to energy storage: batteries are expensive, heavy, and even the best offer only limited vehicle range.

In the short term, hybrid battery electric vehicles with small internal combustion engine "range extenders" will be used to provide the vehicle range and performance that we are used to. By the year 2000, developments in fuel cell technology promise a cleaner, more efficient alternative to the internal combustion engine, & a new age of pollution-free driving.

The Key: Efficiency

Internal combustion engines are limited by the laws of thermodynamics to a maximum efficiency (the mechanical work output divided by the chemical energy in) of about 30%. Practical engines are closer to 20% efficient, and when stop-start driving is considered, efficiency drops to about 15%. Fuel cells are not limited by the thermodynamic Carnot cycle, and can convert fuel to electricity at up to 80% efficiency. Efficiencies of more than 50% have been demonstrated to date. This means that you can go three times as far in a fuel cell car as in a gasoline car, on the same amount of fuel.

Fuel Options

There are two ways of storing the hydrogen needed to run a fuel cell car. Either pure hydrogen can be stored in gas, liquid, or "metal hydride" form, or hydrogen can be generated onboard from hydrocarbon fuels such as compressed natural gas or methanol.

The "reforming" of methanol or other hydrocarbons to produce hydrogen and carbon dioxide has the advantage of easy fuel storage but the disadvantages of needing a small, onboard chemical processing plant, and still polluting the atmosphere with carbon dioxide.

Storage of pure hydrogen in cryogenic liquid or high pressure gaseous forms poses safety hazards that are unacceptable for general transportation. Storage in metal hydrides, where hydrogen atoms lodge in the atomic lattice of metals such as magnesium and titanium, offers safety and ease of use, but carries the penalty of high costs and much added weight (only 2-5% of the weight of the storage system is actually hydrogen).

When the system is looked at as a whole, however, this extra weight is compensated by the reduced weight of the drive system (the fuel cell, electric motor and motor controller) when compared to a gasoline engine and transmission, and reduced fuel requirements. Fuel cells capable of 10 kW continuous output and electric motors rated at up to 100 HP should be available at weights of less than 50 lbs apiece.

The safety of hydrogen as a fuel is often questioned. In fact, hydrogen is in many ways far safer than gasoline - it is non-toxic and disperses quickly. So little gaseous hydrogen is available in a hydride storage system (and heat is needed to liberate gas from the metal matrix) that such systems are inherently far safer than gasoline storage in today's cars.

A Hydrogen Economy

A hydrogen powered car needs a means to refuel. This could take the form of hydrogen refilling stations where hydrogen is piped or trucked from central generating sites. These "gas" stations will be worthy of their name. Hydrogen is produced in large quantities today from natural gas via a reforming process. This is the cheapest source at present. In future, we can look forward to large scale photovoltaic/electrolysis power stations in the southern U.S.A. producing hydrogen for the whole country. Pipelines, including the existing natural gas network, could be used for distribution.

Hydrogen can also be produced from water and electricity via electrolysis. This could be done actually at the "gas" stations, or alternately, small electrolysers could be installed in cars, or in home garages, to provide a means of refueling from grid electric power. In the short term, home or onboard electrolysers are the only alternative, despite higher fuel costs, as a network of hydrogen gas stations will take some time to evolve.

Economics

Dr John Appleby of Texas A&M University's Center for Electrochemical Systems & Hydrogen Research has calculated that a fuel cell car powered by hydrogen made from natural gas could cost as little as 1.5¢ per mile in fuel cost, compared to 4.4¢ per mile for gasoline. A fuel cell car could cost one third as much to run as the car of

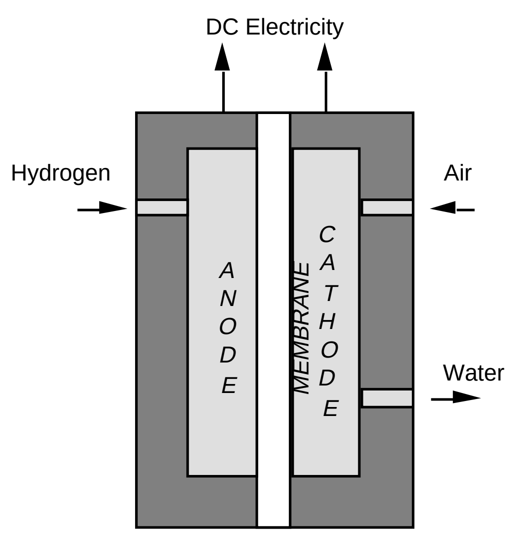

Diagram of PEM cell: The Proton Exchange Membrane Fuel Cell has platinum impregnated electrodes either side of a plastic film electrolyte.

today! Maintenance costs would be minimal with no engine oil changes, no spark plugs, no exhaust system, and with the regenerative braking reducing the mechanical brake wear. The fuel cell life could be as long as 100,000 hours. Appleby puts the cost of electrolytic hydrogen fueling at 5.6¢ per mile, and straight battery electric vehicles at 3.5¢ per mile plus 2 - 5¢ per mile in battery replacement costs.

The benefits of zero-pollution vehicles, such as the fuel cell car, should also be included in economic comparisons. Estimates of the social and health costs of burning gasoline in our cities range from $1.15 up to $4.50 per gallon of fuel.

Another researcher at Texas A&M, Dr. David Swan, has predicted that fuel cell system costs can drop to $272 per kW with mass production. He estimates a complete 75 kW peak, 25 kW continuous fuel cell/battery hybrid drive system would cost $8,550, about $1000 more than a conventional gasoline drive. Other estimates are as low as $4,450 for a complete drive system.

How long to Market?

While government and car manufacturers' predictions of fuel cell cars range from 2005 to 2050, recent advances have made practical cars possible within a few years. Many small companies are working on fuel cells for vehicles. Ballard Power Systems in Vancouver, B.C. plan to have a fuel cell powered bus on the road by 1992 and are also working with General Motors on automobile applications. Dr. Roger Billings of the American Academy of Science, Independence, MO, has developed fuel cells that are not only small, light and efficient, but can operate in reverse as electrolysers. He plans to deliver a demonstration fuel cell vehicle to the Penn. Energy Office in mid-1991.

We are about to leave oil behind, and enter the age of the fuel cell.

Access

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