FUEL CELL ELECTRIC

Electric vehicles use electric motors instead of an internal combustion engine to provide motive force. In development are vehicles that use an electrochemical system, known as a fuel cell, to produce onboard power. Unlike batteries, where electrical energy is converted into stored chemical energy through electrical charging, fuel cells use chemical energy coming from a fuel, which is stored on board, to produce electric energy. Fuel cells continuously convert the chemical energy of hydrogen from the fuel and oxygen from the air to produce electric energy, heat, and water. This electricity is used by motors connected to axles to power the wheels of the vehicle.

HISTORY

William Grove, a British jurist and amateur physicist, first discovered the principle of the fuel cell in 1839. A hundred and twenty years later, NASA developed fuel cells for use during space flight, where they have provided electricity and drinking water for astronauts. Since the space program demonstrated the potential for fuel cell technology, industry has been interested in developing it further. Since 1984, the U.S. Department of Energy has been supporting fuel cell research and development.

Fuel cells are expected to be used widely because they can produce power much more efficiently and cleanly than can fossil or nuclear fuel. Some large office buildings use stationary fuel cells for their own electricity and for hot water and supplemental space heating. Fuel cell technology is being developed to meet similar electrical and heating energy needs on the smaller scale appropriate for individual homes. In March 1998, Chicago became the first city in the world to power buses with hydrogen fuel cells.

CURRENT RESEARCH IN TRANSPORTATION

There are five distinct types of fuel cells, two of which are being seriously considered for land-based vehicles: the phosphoric acid fuel cell (PAFC) and the polymer electrolyte membrane, or proton exchange membrane (PEM).

- PAFC, already used by stationary power generators, may be used in larger vehicles such as transit buses.

- Vehicle manufacturers around the world are investigating the PEM fuel cell because it provides a continuous electrical energy supply at a high level of efficiency and power density.

SOURCES

All fuel cell vehicles (FCVs) currently require some form of hydrogen — either in a pure state or in combination with other elements. Hydrogen is the lightest and most abundant element on earth, making up about 93 percent

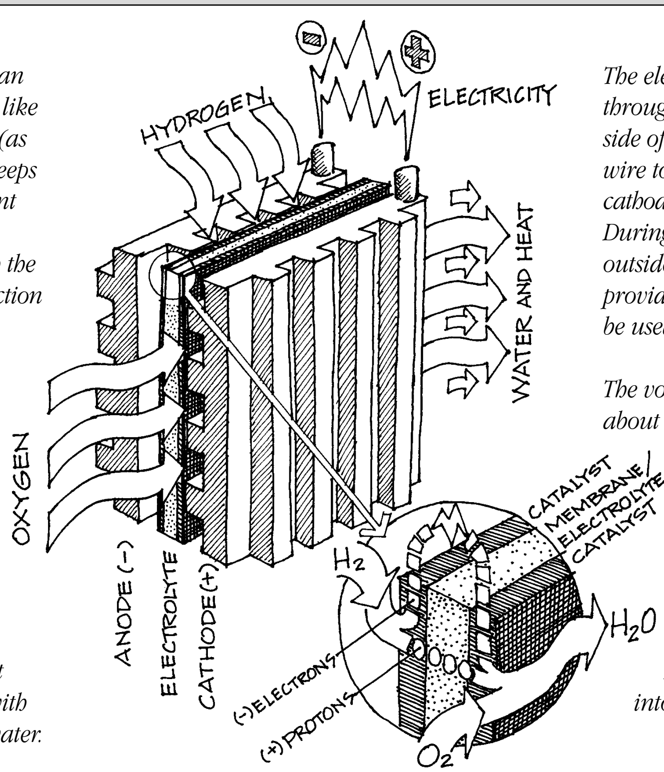
PEM FUEL CELL

At the center of the PEM fuel cell is an electrolyte membrane, which looks like a moist piece of thick plastic wrap (as thick as 2 to 7 pieces of paper). It keeps hydrogen fuel separate from oxidant air. Fuel cell operation depends on movement of hydrogen ions though the membrane (electrolyte) in one direction only (from anode to cathode).

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.

With the help of a platinum catalyst on the cathode side, they combine with oxygen and electrons, producing water.



The electrons (which cannot pass through the membrane) flow from one side of the cell (the anode) through a wire to the other side of the cell (the cathode) in order to complete the circuit. During their route through the circuits outside the fuel cell, the electrons provide electrical power, which can be used to run a car.

The voltage from one single cell is just about enough for a light bulb. When cells are stacked in series, the operating voltage increases. A fuel cell stack can consist of a few cells to a hundred or more cells connected in series, depending on the amount of power needed. Fuel cell stacks are integrated into a fuel cell engine.

of all atoms and 76 percent of the mass of the universe. It is found in water, all plants and animals, and fossil fuels.

Although hydrogen is abundant in many compounds, obtaining enough pure hydrogen for popular use and developing the infrastructure for fueling private cars with pure hydrogen pose a challenge. Dispensing hydrogen fuel for fleets of large trucks or buses is easier to envision. In that case, liquid hydrogen would be trucked from central production facilities to fuel dispensing facilities, where cryogenic pumps would be used to load gaseous hydrogen fuel onto vehicles.

Fuel cells can also operate on hydrogen that is stripped on board the vehicle from hydrocarbons found in gasoline, methanol, or other fuels.

- Methanol, a simple fuel made of four hydrogen molecules, one carbon molecule, and one oxygen molecule, is an excellent source of hydrogen and can be easily distributed through the existing fuel infrastructure with minor modifications.

- Natural gas (methane) is also an excellent hydrogen carrier, although a widespread natural gas distribution system for cars does not yet exist.

- Gasoline, formulated without sulfur, could also be used. It could be distributed through the same distribution system as other gasoline products. Although reliance on gasoline would prolong U.S. dependence on foreign oil, fuel cells would reduce the amount of gasoline used because they are two to three times more efficient than internal combustion engines in converting fuel to power.

- Sodium borohydride, a derivative of borax, has also shown promise in powering fuel cells. Borax is found throughout the world in substantial natural reserves. In a chemical process that releases pure hydrogen for fuel cells, the only by-products are water and naturally occurring minerals called borates, which can be reclaimed as a source of fuel. It could be distributed, with minor modifications, through the existing fuel infrastructure.

VEHICLE ALTERATIONS

Vehicle alterations depend on the type of fuel that is used by the fuel cell to produce power. A direct hydrogen fuel cell would involve no combustion and would not need any pollution- or noise-control devices. Hydrogen may be stored on board in compressed high-pressure gas cylinders, as a liquid in insulated storage tanks at low temperature and pressure, as a metal hydride, or as some other hydrogen-rich solid or liquid fuel, such as sodium borohydride. A fuel cell–based propulsion system relying on gasoline, methanol, or methane for hydrogen includes a fuel cell stack, a reformer and catalytic burner, a cooling device, and an air compressor/expander. (The onboard reformer is a device that uses heat and catalysts to break the strong hydrocarbon bonds in the gasoline, methanol, or methane used as a source of hydrogen.) A high-pressure cylinder is needed if methane is used. A fuel tank or gas cylinder is needed to carry hydrogen or hydrogen-rich liquid fuel. Cars using sodium borohydride as a source of hydrogen would need a waste tank to hold the spent fuel until it could be recycled into new fuel.

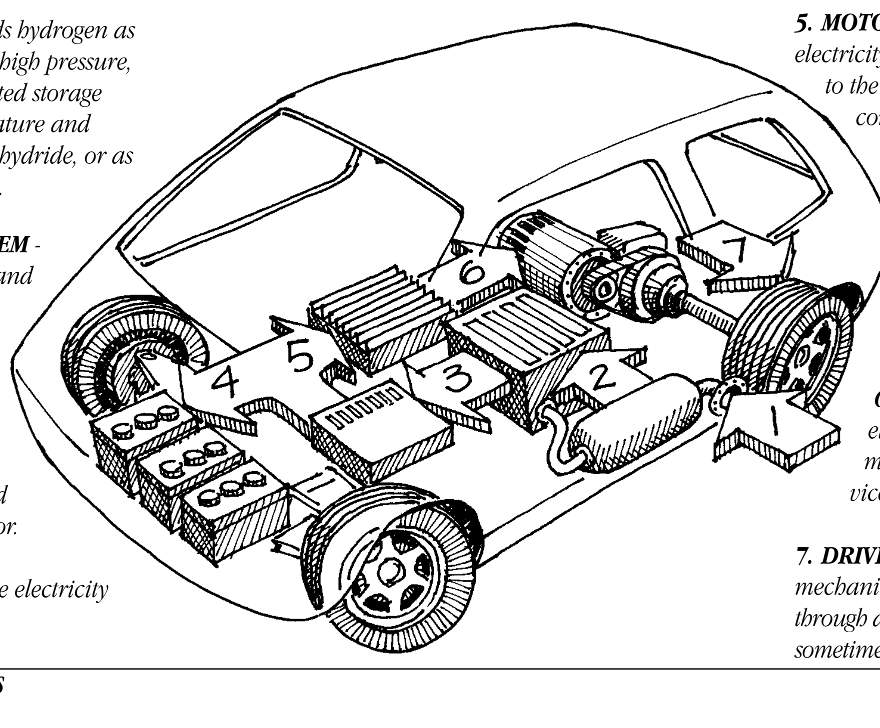
HOW A HYDROGEN FUEL CELL ELECTRIC CAR WORKS

1. FUEL TANK *- holds hydrogen as a compressed gas at high pressure, as a liquid in insulated storage tanks at low temperature and pressure, as a metal hydride, or as some other solid fuel.*

2. FUEL CELL SYSTEM *- combines hydrogen and oxygen to generate electricity.*

3. COMPUTER *- decides whether to store electricity in the battery or send it directly to the motor.*

4. BATTERIES *- store electricity until it is needed.*



5. MOTOR CONTROLLER *- sends electricity smoothly and efficiently to the motor as needed. It is controlled by an accelerator pedal. If regenerative braking is installed, the controller will allow the motor to act as a generator and return braking energy to the energy-storage system.*

6. MOTOR *- converts electrical energy to mechanical energy and vice versa.*

7. DRIVETRAIN *- transfers mechanical energy to wheels through a differential and sometimes a transmission.*

As with other EVs, a typical fuel cell vehicle has an electric motor instead of an internal combustion engine, electronic controls instead of an ignition system, and the addition of a high-voltage electrical system. Fuel cell systems for automobiles also include a small battery pack as a buffer between the fuel cell stack and the electric motor.

An EV is propelled when the electric motor receives sufficient electricity from the battery pack to provide the torque needed to turn the wheels at the rate desired. The accelerator pedal is connected to an electronic control module that regulates the amount of current or voltage drawn from the battery system. Most EVs use regenerative braking — slowing the vehicle by capturing kinetic energy, converting it back into electrical energy, and then channeling it to the battery pack for later use.

MAINTENANCE

Because a PEM fuel cell stack has no moving parts, maintenance is minimal. An FCV's reformer and catalytic burner, cooling device, and air compressor/expander need regular maintenance, however.

STORAGE AND SAFETY

Care needs to be taken in transporting and refueling whatever gaseous, liquid, or solid fuel is used to power the fuel cell. Hydrogen storage and transportation systems will need to be engineered to be as safe as the fuel systems in current automobiles. Storage and transportation of methanol are similar to those of gasoline. Yet, because methanol is corrosive to some metals and damaging to rubber and some plastics, fuel storage tanks and dispensing equipment must be corrosion and damage resistant. California requires that underground storage tanks for methanol be double walled. Unlike other hydrogen carriers, sodium borohydride is not flammable. Storage and transportation are similar to those of gasoline.

With high-voltage circuits, vehicle manufacturers are using a number of disconnect systems to isolate the rest of the vehicle from the fuel cell's voltage. Lethal levels of electricity may be present, however, so the fuel cell's electrical system should be treated with the same caution and respect as a full fuel tank in an internal combustion engine.

PERFORMANCE

Acceleration, speed, and handling for well-designed EVs are equivalent to, or better than, those of comparable internal-combustion-powered vehicles. As with other electric-drive vehicles, fuel cell cars are quiet.

RANGE AND REFUELING

PEM fuel cells, which rely on liquid fuel, provide an acceptable driving range. Compared with conventional vehicles, FCVs will use fuel more efficiently, traveling as far as 80 miles per gallon. This longer range is due in part to the efficiency of the fuel cell power system and in part to the lighter weight of an FCV. (It has a smaller fuel tank and lacks a large internal combustion engine. For larger scale applications, fuel cells are smaller and lighter than batteries.)

Refueling a private automobile will likely involve replacing the hydrogen-rich fuel, such as liquid gasoline, methanol, or sodium borohydride, at existing fueling stations. This refueling takes much less time than recharging a battery.

If using compressed natural gas (CNG), refueling can be “slow” (generally taking six to eight hours and commonly done overnight) or “quick” (about five minutes, which is comparable to a gasoline fill-up). Overnight refueling is possible in individual homes with small compressors, which may be located in a home's garage and connected to the natural gas supply of the house.

EMISSIONS

In order to make a clear comparison with other fuels and fuel systems, the entire life cycle of a fuel cell must be analyzed. That includes the process of manufacturing and of safely disposing of fuel cells that have limited use. The fuel cell itself is potentially a pollution-free energy technology, even when idling in stop-and-go traffic. In contrast, conventional vehicles produce most of their emissions under such conditions. There are no evaporative emissions from the fuel cell stack. Only water vapors are produced.

When run on pure hydrogen, fuel cells are true zero-emission vehicles. In these systems, hydrogen chemically combines with oxygen, producing only electricity, water, and waste heat. Since no carbon is involved, emissions of carbon monoxide, carbon dioxide, and ozone-forming compounds are eliminated. There are no nitrogen oxides.

Fuel cells that rely on gasoline, methanol, or other carbon-based fuels as a source of hydrogen produce small amounts of tailpipe emissions (e.g., sulfur dioxide and nitrogen oxides), with water and carbon dioxide being the major by-products. Compared with traditional combustion engines, methanol fuel cells cut smog-forming pollution more than 90 percent. Because of their efficiency, fuel cell vehicles can cut greenhouse-gas emissions by more than half.

As fuel cell vehicle technology develops, emissions levels are expected to be further reduced. As fuel reformers become smaller and more optimized for low emissions, FCVs operating on methanol are expected to have nearly zero emissions.