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The Lenkurt® DEMODULATOR

Remote Power from FUEL CELLS

Exotic power sources are one of the promising spin-offs from space age technology becoming available for commercial use. The fuel cell—popularized in the Gemini space flights—may become an economical source of power for remote communications sites.

Classically, a fuel is considered the storehouse of the sun's energy. In the "fossil fuels"— coal, petroleum, natural gas — this energy is usually liberated through burning. But conversions involving any intermediate process with high temperatures is not efficient. For example, the conversion of fuel to electricity in a steam turbine involves a number of steps. Fuel is first burned to produce heat. Pressurized steam then does work by turning large turbines. The turbines power an electrical generator. At each step of the conversion, energy is sacrificed.

Electrical energy is the most convenient form of energy to handle, and can be easily converted to mechanical power or heat. For this reason, investigators have been intensely interested in finding ways to produce electricity directly and with high efficiency. The fuel cell, which uses direct conversions for high efficiency, is one answer. In all direct conversion schemes, energy is extracted or transformed from one state to another without mechanical motion. With each step eliminated, greater efficiencies are gained.

The communicator is obviously interested in efficient and practical power sources to run remote relay stations and repeaters. These new devices are also being considered for large scale generation of electric power; to provide motive force for cars, trucks, boats, and even submarines; for use on space ships and satellites; for military communications systems; and almost anyplace where reliable, efficient, and quiet power generation is an advantage.

Energy Sources

Electrical power may be derived by direct conversion from a number of energy sources: thermal, nuclear, radiative, and chemical. Thermal, or heat energy was first used to produce electricity directly in a device discovered in the early 1800's. Known as a thermocouple, the thermoelectric generator consists of two dissimilar metals, such as copper and iron, joined together. When one end of the junction is heated and the other kept cool, a current is caused to flow through the thermocouple. If a number of thermocouples are stacked together forming what is called a thermopile, a usable amount of electricity can be obtained. Remotely located electronic equipment has been powered by such devices.

The heat source of the thermoelectric generator is commonly a gas flame. But a form of nuclear energy can also be tapped. Heat in this case is produced by the decay of radioactive isotopes. Workable units have been produced, but the initial cost is high. The advantage of isotopic power is reliability

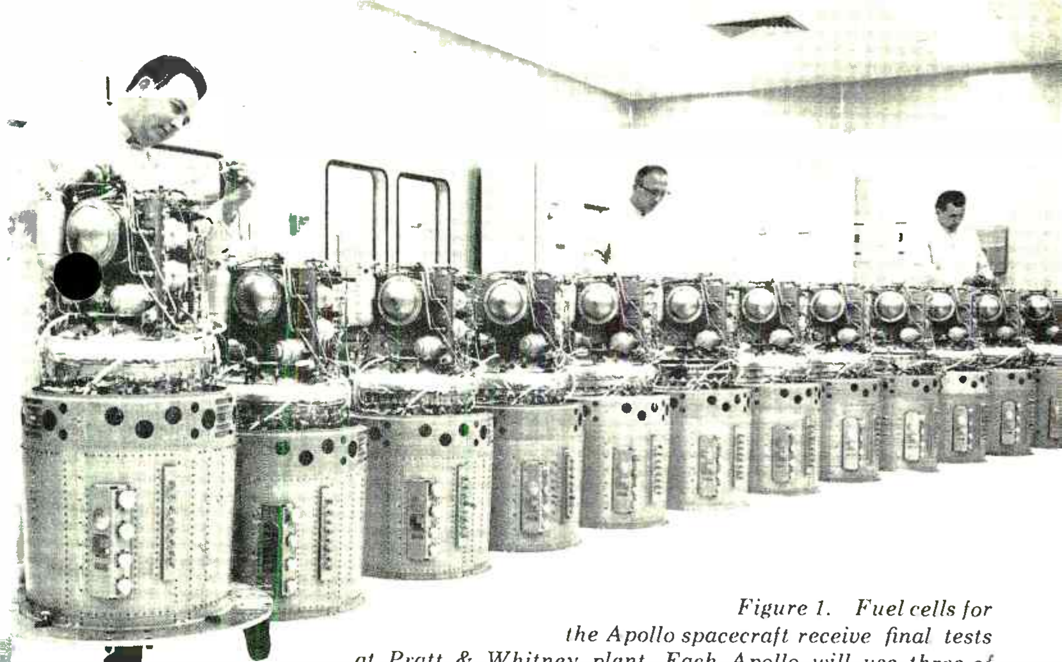

Figure 1. Fuel cells for the Apollo spacecraft receive final tests at Pratt & Whitney plant. Each Apollo will use three of these units, producing up to 2 kW each from pure hydrogen and oxygen.

and long life, even though economics makes the method prohibitive except in the most demanding cases.

Another thermal conversion device is the thermionic generator. Much like the vacuum tube, heat is used to "boil off" electrons from a cathode. Collected on an anode (plate), the electron flow becomes a usable force. Different from the electron tube, the generator derives its energy from a direct heat source — even the concentrated energy of the sun has been used.

Man's use of the radiant energy of the sun as a power source is probably better known through the space age use of the solar cell. Used almost exclusively as the power source for unmanned satellites and deep-space probes, the solar cell has proved to be a reliable power generator.

Not clearly associated with direct conversion devices, but worthy of mention as an exotic power source, is the magnetohydrodynamic (MHD) generator. Not unlike the conventional electromechanical generator, the MHD generator relies on the motion of a conductor through a magnetic field to produce electricity. In this case, however, the conductor is a plasma or highly ionized gas. The MHD generator is receiving considerable attention in the field of large scale power generation.

Chemical energy represents that energy stored in a substance and released in the form of heat, light, mechanical energy, or electrical energy during a chemical change. It is with electrical energy that we are at the moment concerned; this is the basis of the fuel cell.

Efficiencies

Most of the power used in the world comes from breaking the chemical bonds in the fossil fuels — coal, petroleum, and natural gas. But conversion efficiencies place definite limitations on the use of the resulting energy.

The internal combustion engine can approach 25 to 30 percent efficiency. However, when the mechanical linkage necessary to power an automobile is added, efficiency falls to about 15 percent for the total system. Steam generation of electricity can approach efficiencies of 25 to 30 percent, and high temperature gas turbines are rated as high as 40 percent. But whenever heat is a part of the energy conversion cycle, there is a definite limit to the efficiencies that may be obtained. And friction in any machine takes its toll.

In the fuel cell there are no moving parts, and the small amount of heat produced is not part of the conversion cycle. Theoretical efficiencies in the fuel cell approach 100 percent. In a practical device, 75 percent is more realistic, although laboratory models have exceeded this in special instances.

The economic desirability of such an efficient system is obvious. But it must be remembered that, as with any new technique, developmental costs are still high and initial investment in the machine still overshadows the advantages of laboratory-gained efficiencies.

Just the same, for applications where other more conventional forms of power are not readily available — in space, under water, and in remote land areas — efficiency may outweigh higher costs.

The Gemini 7 spacecraft, for example, carried a fuel cell system weighing about 575 pounds. To provide the same electrical capability (about 2 kW) for the two-week flight, it would have been necessary to burden the vehicle with 2000 pounds of conventional batteries.

Apollo will carry a fuel cell system rated at 6 kW which, including fuel and auxiliary equipment, weighs 1200 pounds — a tenth the weight of batteries with an equivalent output. In such applications cost is no limitation.

The communicator on earth is likewise interested in power efficiencies. At the installation of a remote microwave site, conventional power sources may represent as much as 30 percent of the total cost. The fuel cell (or other direct conversion device) may in the future reduce this cost and at the same time add convenience.

Fuel Cell Theory

The operation of the fuel cell is actually the reverse of the chemical process called electrolysis, known since the beginning of the 19th century. Electrolysis produces chemical change by passing current through an electrolyte, a solution capable of acting as a conductor. For example, if electrodes are suspended in water (H_2O) and a current passed between them, hydrogen gas (H_2) will form at the cathode (negative terminal) and oxygen gas (O_2) will appear at the anode (positive terminal).

While experimenting with electrolysis in 1839, Sir William Grove discovered that the reverse was also true: he brought hydrogen and oxygen together under controlled conditions and produced water and electric current. While Grove is credited with the discovery of the fuel cell, it was not until after World War II that any concentrated developmental effort was made. And even then it remained for NASA's space need to create the final incentive to develop a usable unit.

The first fuel cells used hydrogen and oxygen. Many other chemical reactions which produce electricity are the subject of much current research. But for a basic understanding of the fuel cell, it is simplest to examine the hydrogen-oxygen unit.

Chemical Reactions

The cell contains two electrodes separated by an electrolyte (Fig. 2). Hydrogen (the fuel) is available at the anode and oxygen (the oxidizer in the chemical reaction) is at the cathode. As the two gases are applied to the electrodes, separate reactions take place. When hydrogen is passed over the anode, electrons are generated and can be made to do electrical work through an external circuit. At the cathode the electrons join with the oxygen to produce what is called an hydroxl ion, with the chemical symbol OH . The ions travel through the electrolyte to complete the electrical circuit.

A closer look at the chemical reactions in the fuel cell will further explain the process. At the anode, hydrogen gas (H_2) is absorbed in the form of hydrogen atoms (H). In the electrolyte are hydroxl ions (OH^-) produced at the cathode. An ion is an atom or group of atoms that has either gained or lost an electron. In this case an extra electron is available and the OH grouping takes on a negative charge. The hydrogen atom and the hydroxl ion join to produce water (H_2O) and at the same time free the extra electron. This electron is now available to flow through the external circuit.

At the cathode, oxygen gas (O_2) is similarly absorbed through the electrode. Here the oxygen atom (O) reacts with both the water (H_2O) in the electrolyte and the incoming electron to form hydroxl ions.

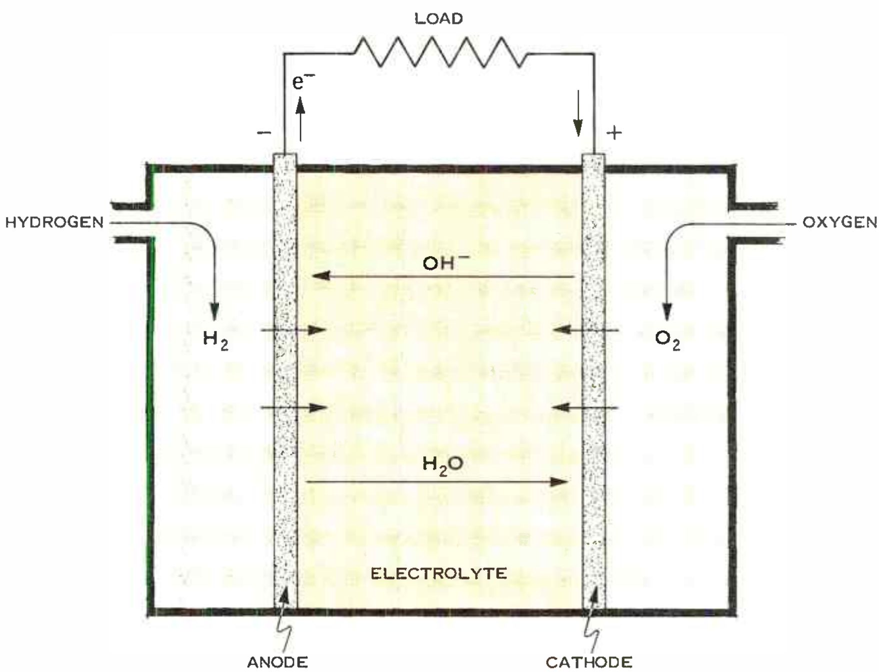

Figure 2. At the anode of the hydrogen-oxygen fuel cell, hydrogen joins with hydroxl ions to produce water, freeing electrons to do work. At the cathode, oxygen reacts with water in the electrolyte and electrons from the external circuit to form hydroxl ions.

These reactions may be summarized using chemical notation. At the cathode

$$1/2\ O_2 + H_2O + 2e^- \longrightarrow 2\ OH^-$$

That is, oxygen plus water plus electrons produce hydroxl ions.

At the anode:

$$H_2 + 2\ OH^- \longrightarrow 2\ H_2O + 2e^-$$

Hydrogen plus hydroxl ions produce water and electrons.

In summary, hydrogen and oxygen can be continually combined in such a way that water and electrical energy result.

The output of a fuel cell is low voltage, high current dc. Individual cells can be stacked in both series and parallel arrangements the same as conventional batteries to increase voltage or current.

Figure 3. Small natural gas fuel cell produces 500 watts of electricity. Smaller units can use gasoline.

Batteries vs. Fuel Cells

Conventional batteries, it should be noted, are closely related to the fuel cell. However, the battery is self contained and must either be discarded or recharged when its stored energy has been used up. The fuel cell will continue to produce electrical energy as long as fuel is supplied.

The storage battery has advantages where high power is needed over a short period of time. The fuel cell is more applicable for needs of moderate power over longer times. A combination of the two, with the fuel cell charging the storage battery between uses, could capitalize on the strong points of both. It is also characteristic of the fuel cell that when no current is being drawn, it does not expend fuel.

The hydrogen-oxygen fuel cell was the first to be produced and received most of the early research effort. In its basic form as described, it is not too difficult to follow the progress of chemical events. However, even the first successful cells were more sophisticated than our example.

For instance, the gases hydrogen and oxygen do not readily interact at room temperatures. Some cells operate at much higher temperatures (250°F to 500°F) and use chemical catalysts in the electrodes to help the reactions along.

Hydrocarbon Fuels

There are many practical reasons for development to shift now to systems that operate on fuels other than hydrogen. The hydrocarbon fuels seem ideal because of their availability. A cell using fuel oil or natural gas, for example, could be operated almost anyplace in the world without serious problems of transporting of fuel. Methane, gasoline, kerosene and alcohol are among the hydrocarbons being investigated, along with the noncarbons ammonia and hydrazine.

The engineering problems associated with fuels other than hydrogen have placed many barriers in the way of a practical system. The direct conversion of hydrocarbons is particularly difficult. But a compromise is being used — a system now under field test with the Army breaks down hydrocarbon molecules and extracts hydrogen, which can be accepted by the fuel cell. However, the indirect process is not as efficient as direct conversions.

While the complication of manufacture and transportation of pure hydrogen makes other fuels desirable, the availability of pure oxygen also presents problems. Although a ready source of oxygen, air contains some undesirable elements. Current models of hydrocarbon-air fuel cells must process the air before it is used, removing carbon dioxide and stabilizing temperature and humidity.

Hydrocarbon-air systems now being tested include a package of two 35-pound man-carried units producing 500 watts at 32 volts. Another unit with an output of 3 kW can be carried by jeep or small truck.

Applications

The possible applications of the fuel cell are about as varied as the uses of electricity — but can be extended beyond that. The use of a practical and efficient direct energy conversion device as a substitute for heat engines in the generation of electrical power immediately leads to the application of power for electronic equipment. Large scale power generators are also considered. But it is not out of the question to consider this new technique as a substitute for other motive forces. Allis-Chalmers has put fuel cells to work powering a farm tractor, and the Army is now testing a ¾-ton truck powered by a fuel cell package developed by Monsanto Research Corporation. Boats, submarines and many other vehicles will also be the subject of increased research.

Generation of electrical power at home is also being looked at. The development of a power plant operating on natural gas has been launched, with Pratt & Whitney Aircraft carrying out the program. The company also developed the fuel cells to be used on the Apollo spacecraft.

The only moving parts in the fuel cell are found in the gas flow mechanism. As a result, the fuel cell is a very quiet machine—both mechanically and electrically — an ideal advantage to the military. They are capable of resisting a good deal of shock and acceleration, and are affected very little by radiation, all points in favor of space applications. And the water byproduct is actually a plus in manned space travel where astronauts must take with them all food and supplies.

The telecommunications industry is primarily interested in fuel cells to provide power to remote locations. Brown, Boveri and Company, of Switzerland, has been operating a television relay station on fuel cell power for nearly two years.

Operators in this country have yet to put a commercial device to work in such application, but interest in the fuel cell and other direct conversion devices is high. As repeater equipment uses more solid state circuitry, thereby reducing power requirements, this type of power will become more realistic. In the meantime, engineering progress will account for increases in efficiency, reduction in size and weight, and the practicality of using common fuels.

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Lenkurt Hosts International Conference

Representatives of 25 countries participated in the plenary session of the International Telecommunications Union's (ITU) Groupe Autonome Speciale-3 (GAS-3), hosted by Lenkurt in San Francisco. Opening the session, from left, are Jean Rouviere, ITU director, from Geneva; Ben Abdellah, GAS-3 chairman, from Morocco; Gerd Wallenstein, Lenkurt vice president of planning, chairman of GAS-3 economics sub-group, and session coordinator; Charlton W. Hunter, Lenkurt president; and R. Parker Sullivan, president of General Telephone Company of California.

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