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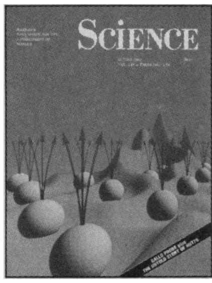

COVER Pictorial representation of the many-particle state underlying the fractional quantum Hall effect, occurring in two-dimensional electron gases at high magnetic field. The height of the green landscape gives the probability of finding any single electron in relation to its companions (red balls) and to the flux lines (arrows) of the magnetic field. See page 1510. [Illustration courtesy of T. S. Duff and T. Kovacs, AT&T Bell Laboratories]

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Applications of Fuel Cells

When the Apollo astronauts traveled to the moon, electricity for their spacecraft was furnished by electrochemical cells fueled by hydrogen and oxygen. These gases combined in the cells to generate water and dc power. No pollutants were produced. About 70% of the chemical energy available in the reaction of hydrogen and oxygen was transformed into electrical energy. In contrast, when coal is oxidized in boiler plants, only about 33% of the chemical energy becomes available as electricity and large amounts of pollutants are released.

Since the 1960s, substantial efforts have been made to adapt fuel-cell technology to large-scale earthly applications. A major impediment has been the cost of equipment. Each cell generates 0.6 to 0.8 V at power densities of 1 to 2 kW/m^2. Many cells with large areas must be connected in series to obtain substantial amounts of power. Through sustained effort capital costs have been lowered by one to two orders of magnitude and further improvements are in sight. Prospects are that in the coming decades fuel-cell technology will have a large role in global energy production.

A number of different types of fuel cells are under development. Two are closest to becoming practically important. One, based on use of phosphoric acid as an electrolyte (PAFC), operates at 200°C. A second, in which a molten mixture of alkaline carbonates (MCFC) is used, runs at 650°C. Fuel for the PAFC is hydrogen and air furnishes the oxygen. Methane, other small hydrocarbons, and biogas can serve as sources of hydrogen, but they must separately undergo reforming to yield hydrogen by reaction with hot water. The MCFC is more tolerant and can convert many fuels to hydrogen internally. The conversion efficiency of PAFC for electricity is slightly greater than 40% and that of MCFC is about 55%. In both cases by-product heat is available for other uses. In some circumstances constructive utilization of fuel energy is greater than 80%.

Most operating experience has been accumulated using PAFC systems, which in turn has led to a recent first announcement of commercialization. A subsidiary of United Technologies named ONSI has received orders for 53 200-kW systems with deliveries to begin in 1992. The initial price per kilowatt will be $2500, and as manufacturing experience is gained, the price is expected to decline to $1500, and a further drop to $1000 is possible. On a capital cost basis, these prices are higher than those of large gas turbine plants for production of electricity but are economic for cogeneration. The most attractive applications for near-term fuel-cell technology are on-site cogeneration. Fuel-cell plants would be located to serve energy requirements of restaurants, retail stores, apartment buildings, or hospitals. In addition to electricity, the plants could furnish hot water, space heat, steam, and absorption cooling. Space requirement for a 200-kW plant is modest: 3.2 m high, 7.6 m long, and 2.5 m wide. The plants will require practically no supervision and will be noiseless. Other attractive features of the technology are flexibility in size and number of modules. The equipment can rapidly follow changes in load. Efficiency is virtually constant as a function of demand in the range of 30 to 100% of rated capacity. The dc output of the cells is converted into ac, which can or need not be connected to a major power grid.

Flexibility with respect to size is proving particularly attractive to the American Public Power Association. Many localities cannot afford to buy a large conventional generator. They now must purchase power from private utilities or use diesel generators.

Development of the molten carbonate fuel cell is not so far along as the PAFC. However, a number of fuel cells and fuel-cell stacks have shown satisfactory performance, and enthusiasm for MCFC is increasing. Costs for the systems are projected to be less than those for PAFC. Their efficiency is better, and by-product heat at 650°C has superior usefulness.

If current concerns about air pollution and global warming were to become paramount, fuel cells would become a technology of choice. They have negligible emissions of NO_x and SO_2 and emit less CO_2 per kilowatt-hour than steam power plants. If a carbon tax were enacted to reduce CO_2 emissions, MCFC could become the most economical method of producing both small and large amounts of electricity.—PHILIP H. ABELSON