Growth in Fuel Cell Technology

A REPORT OF THE UNITED STATES NATIONAL SEMINAR

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The 1982 National Fuel Cell Seminar held at Newport Beach, California in November, marked the steady evolution of fuel cell activity as an emerging engineering technology likely to become a commercially viable reality within the next few years. The present objective of the governments involved in fuel cell support and the efforts of the many major international companies involved, is to demonstrate in practice that fuel cells work reliably, economically and with minimum maintenance. To this end, many fuel cell trial programmes have been arranged which will yield an increasing volume of operating data, much of which will be useful in producing more economic designs.

Two hundred and fifty-six delegates attended the seminar, many drawn from countries outside America, confirming the growing international interest in fuel cells. This is particularly evident in the case of Japan where government sponsored programmes, private venture research and trials programmes in conjunction with American companies have already commenced. Despite this increasing international interest, it is still evident from the contributions to the seminar that the United States of America has by far the most advanced fuel cell technology, and although large cuts have been made in U.S. Department of Energy budgets, G. Hagey disclosed that there is as yet a sum of 268-million dollars unappropriated in the fuel cell budget.

On-Site Trial Programmes

A major programme has commenced testing "on-site" forty-nine 40kW phosphoric acid fuel cells, manufactured by United Technologies Corporation (U.T.C.) with platinum-containing catalyst supplied by Johnson Matthey Inc. Several papers reporting early progress were presented.

The trial programmes are being administered by NASA Lewis Research Centre on behalf of the On-Site Fuel Cell User Group which includes the Gas Research Institute, the Department of Energy, and over twenty gas supply utilities. Many of the fuel cells in these trials will be connected as cogenerators, transferring surplus electricity to the local power grid in order to achieve maximum efficiency.

The first 40kW fuel cell to commence trials in the U.S.A. was started up in April 1982 in an Oregon laundry. C. A. Roberts of Northwest Natural Gas Company reported that the electrical power produced is used in washing equipment, ironing and pressing; waste heat from the cell is absorbed in the water storage tanks and at weekends the excess electricity is fed to the power grid. Apart from minor corrosion problems which have interrupted operation, the fuel cell has given trouble-free running and is expected to be a reliable power source.

The second trial is being carried out at Vernon, Connecticut, by Northeast Utilities at the Central Office of the Southern New England Telephone Company. This building houses computer controlled telephone switching equipment providing a service for about 20,000 telephone customers, and is typical of many other Bell System exchanges spread across America. The electrical power from the fuel cell will be used on the electric switchboard; the thermal energy from the cell will be used for space heating. The cell is also connected to the local power grid to effect cogeneration.

The Japanese 40kW trials being carried out

by Tokyo Gas and Osaka Gas commenced in March 1982 and K. Kikuchi and Y. Santo reported that these have already produced useful operating data. Some early problems with electronic controls and the water cooling system were encountered, but these are now resolved and several months of operation have been achieved. The Tokyo Gas trial site is a swimming club in Yokohama, the Osaka Gas site is in a restaurant in Sakai.

Many of the remaining 40kW trial sites are in course of preparation and a great deal of practical operating data can be expected over the next two or three years.

The multi-megawatt demonstrator trials on 4.8 MW phosphoric acid fuel cell power plants installed in New York City by Consolidated Edison Company, and in Goi, Japan, by the Tokyo Electric Power Company are now in the pre-operational check phase. The delays which have occurred to date have been due to simple engineering problems, such as water freezing in heat exchangers causing leaks, corrosion particles causing filter blockages, and the usual crop of problems to be expected with newly installed instrumentation. Both plants are expected to be operating early in 1983.

In a paper on the status of megawatt fuel cell power plants it was predicted by L. M. Handley and R. Cohen of U.T.C. that the cost of the ultimate commercial power plant must be less than $1,000/kW installed.

National Aeronautics and Space Administration

The NASA view presented by D. W. Sheibley and H. McBryar is that fuel cells will continue to have a major role in space power generation and storage. These future applications will require ten to twenty times more power than previously needed. The main application seen by NASA for fuel cell technology is in low earth orbit satellites such as unmanned platforms and manned operation centres. The aim will be to develop regenerative fuel cell-electrolysis systems dependent on photovoltaic solar arrays for primary power. The programme is being carried out as a combined effort by the Johnson Space Centre and the Lewis Research Centre. A breadboard model will be built in 1984 and an engineering model by 1986.

Mention was made by L. S. Murgia of the failure of the fuel cell on the second shuttle flight due to malfunction of the water separation system, flooding of several cells causing a severe drop in voltage output. Relatively simple modifications have cured the fault which has not recurred in the last two successful flights.

The NASA Lewis Research Centre has retained Arthur D. Little Inc. to explore and review new applications for fuel cells not previously studied in detail by others. The major markets will include 500 MW annual capacity power plants for mining applications for both coal and rock, power for remote settlements and Third World countries, transportation and Third World industrial installations, especially food processing plants.

Japanese Activities

The fuel cell activity in Japan was reported in some detail and many of the major Japanese companies are now vigorously active in this field. The Japanese government is now promoting a research and development project through the Agency of Industrial Science and Technology, and the Ministry of International Trade and Industry on fuel cell power generation, commonly called the "Moonlight Project". The objectives of the project are to develop highly efficient fuel cells capable of using natural gas, methanol or coal derived gas, to reduce dependency on oil imports. About two-thirds of the budget, perhaps 30-million dollars, will be spent on phosphoric acid fuel cells, the remainder on less well advanced systems.

A joint project to verify serviceability of fuel cell power plants in electrical systems was described by M. Yonehara of Kansai Electric Power Company Inc. and R. Anahara and K. Suzuki of Fuji Electric. A 30kW phosphoric acid fuel cell plant has been built and is under test, having been connected to the ancillary power house of the Sakai-ko Thermal Power Station near Osaka in April 1982. Mitsubishi Electric Corporation has also built and has on

test a phosphoric acid fuel cell generating 35kW as part of a programme which has now been incorporated into the Moonlight Project and which will eventually lead to a 1 MW fuel cell design. In the low power output range, Hitachi has developed a methanol/air fuel cell intended to power a television set.

Canadian Proposals for Hydrogen

The probable role of fuel cells in Canada's future energy supplies was described by D. S. Scott, Institute for Hydrogen Systems, University of Toronto. Unique among the developed countries, Canada has an electrical supply industry entirely based on sustainable non-hydrocarbon energy sources, a situation the envy of the major oil importing countries. Hydroelectric power supply is long established and is now augmented by one of the world's most successful nuclear fission technologies in the CANDU reactor. Consequently, Canada now seeks to extend the use of sustainable energy beyond the normal range of usage of the grid electrical supply, and recent economic analyses indicate that in about one decade nuclear manufactured hydrogen could be less expensive than steam methane reformed hydrogen. Two uses for this hydrogen are proposed, first the upgrading of uneconomic hydrocarbon fossil fuel deposits, and secondly, and much longer term, the use of fuel cells in transportation projects, locomotives and Great Lakes' ships; and other applications which would exploit the availability of cheap hydrogen.

The Institute of Hydrogen Systems is being established as a research ancillary of the University of Toronto and the Canadian government has given 10-million dollars to support the project. Emphasis is likely to be placed on potassium hydroxide fuel cells supplied with liquid hydrogen with the possible use of methanol as a hydrogen storage liquid.

Apart from the interest in North America and Japan, Mexico was reported to have ordered a 40kW cell, and Italy may become involved. Mention was made of the phosphoric acid fuel cell activity by Siemens and by A.E.G. in West Germany, and by ELENCO, Holland, and of government activity in Belgium and Sweden, though no papers were presented directly.

Second and Third Generation Cells

The variety of papers given on molten carbonate fuel cells shows that the active interest in this system continues. P. S. Patel, H. C. Maru and B. S. Baker of Energy Research Corporation reported on the DIRECT molten carbonate fuel cell in which methane is introduced directly to the fuel cell electrode, thus avoiding the cost of the reformers, heat exchangers and associated control equipment needed for other types of fuel cell, while improving efficiency. The efficiency claimed for the molten carbonate fuel cell is 60 per cent.

Papers on cell stack design, fuel cell testing, new cathode materials to improve efficiency, together with reports on operating experience and contaminate studies, occupied two conference sessions. Part of a third was taken up by papers on solid electrolyte technology, but practical fuel cells based on this are clearly some way from commercial development.

New Concepts in Fuel Cells

From the Brookhaven National Laboratory, W. E. O'Grady, J. McBreen and E. Findl reported that new ideas on fuel cell operation involving the platinum group metals are being assessed. A detailed investigation to understand the enhancement of the oxygen reduction on platinum in trifluoromethane sulphonic acid (TFMSA) is being carried out, stimulated by several previous reports indicating that oxygen reduction takes place more readily on platinum in TFMSA than in other acids.

A second major investigation is also in hand to develop a fuel cell capable of using synthesis gas directly in the cell.

An attempt to develop an alkaline cell unaffected by carbon dioxide was abandoned in favour of a quasi invariant alkaline electrolyte produced by reversibly absorbing and desorbing carbon dioxide in a cyclical flow scheme. Fuel cell studies using the quasi invariant electrolyte and nickel plaque electrodes with platinum and palladium catalysts loadings $<1 mg/cm^2$, were

shown to be unsatisfactory for the oxidation of carbon monoxide or $HCOO^-$. However, studies of the $HCOO^-$ oxidation have shown a 20 palladium-80 platinum catalyst to give excellent results, far better than single palladium or platinum catalysts. The conclusion is drawn that a fuel cell system using a quasi invariant alkaline electrolyte is both practicable and feasible, and could provide a major state-of-the-art improvement in chemical energy conversion of carbon based fuels.

New catalysts and electrodes were also reported by P. N. Ross, University of California, Lawrence Berkeley Laboratory. Their study of the mechanism of enhancement of oxygen reduction in phosphoric acid electrolytes by platinum on refractory metals is unfinished. Nevertheless, sufficient work has been done to indicate that the "ageing" or thermal annealing, known to improve activity causes an increase in platinum crystallite size, and the addition of the refractory metal to the standard catalyst prevents coarsening during thermal annealing, resulting in optimum size and morphology. It is also proposed that some degree of intermetallic bonding is present between platinum and the refractory metal and that the ligand effect alters the catalytic properties. In a further study of new electrolytes, the superior kinetics of oxygen reduction on platinum in TFMSA are acknowledged, but the disadvantages of TFMSA, namely high volatility and wetting contact with PTFE, have suggested some promising directions for molecular engineering to produce an improved TFMSA type compound as a stable, non-wetting support for a platinum catalyst.

The evaluation of platinum-ruthenium electrode performance in phosphoric acid fuel cells carried out by the U.S. Army Mobility Equipment Research and Development Command was presented by A. A. Adams, A. J. Coleman, L. S. Joyce and J. A. Joebstl. A greater tolerance to carbon monoxide at low operating temperatures was established than for conventional electrodes, giving improved high performance lifetime. The research programme is directed towards understanding the interaction and relationship of catalyst and electrolyte and the reaction kinetics and mechanisms of electrode reactions.

Transportation Applications

Advanced fuel cell systems for use in transportation are being studied at Los Alamos National Laboratory sponsored by the Department of Energy, J. R. Huff, J. B. McCormick, D. K. Lynn, R. E. Bobbett, G. R. Dooley, C. R. Derouin, and H. S. Murray. The aim of the programme is to exploit the efficiency, and hopefully the better economics of fuel cell replacements for petrol driven engines and diesel or diesel electric heavy duty transport applications in trains and inland waterway boats. Both the phosphoric acid and the solid polymer electrolyte fuel cells look promising for the future as vehicular power plants.

Work done by Westinghouse Electric Corporation for the United States Air Force on the application of phosphoric acid fuel cells in tactical mobile applications in providing ground support for Tactical Aircraft and providing power to Forward Air Control Radar was described by W. D. Pouchot. The study concludes that substantial fuel and cost savings can be achieved.

The small military fuel cell programme being undertaken by Energy Research Corporation continues to evaluate the portable 3 and 5kW designs and useful test data are being assembled.

Conclusions

The continued active progress made in fuel cell technology reported at this seminar and the major commitments at a time of deep world-wide economic depression of various national governments and major industrial companies, particularly those in electrical and gas energy supply, supports the view that the commercial viability of fuel cells is seen as fully capable of achievement. The concentration of effort on phosphoric acid fuel cells employing supported platinum catalysts is beginning to create a need for platinum, and there appears to be every prospect of a substantial usage developing over several decades ahead.