Platinum in Fuel Cell Development

PROSPECT OF POLLUTION-FREE POWER GENERATION ATTRACTS GROWING INTERNATIONAL INTEREST

The National Fuel Cell Seminar held in Long Beach, California, during October 1988 was attended by four hundred delegates, representing fuel cell developers and potential future users. During the four day conference, fifty-three papers and sixty posters were presented on all aspects of fuel cell research, development and commercialisation. A number of the papers emphasised the importance of improved utilisation of platinum electrocatalysts, which was now helping to make both phosphoric acid and solid polymer electrolyte fuel cells a commercial reality.

The conference was organised by the National Fuel Cell Co-ordinating Group, and sponsored by the U.S. Department of Defense, the Department of Energy, the Electric Power Research Institute, the Gas Research Institute and the National Aeronautics and Space Administration, and the presentations provided a summary of worldwide fuel cell activities. Among the attendees were 135 from Japan, reflecting their intense development effort, and 65 from Europe, indicating a growing awareness and interest in these highly efficient and pollution-free power generators.

Phosphoric Acid Fuel Cell Developments

Numerous speakers outlined the rapid technical advances achieved by the developers of phosphoric acid fuel cells. These included the operation of the first two 1 MW power plants in Japan. One was constructed by Fuji Electric Corporation and Mitsubishi Electric Corporation for Kansai Electric Power Company, and was run at 1 MW in September 1987. By July 1988, this unit had produced 380 MWh of power; for a period of 720 hours generation was continuous. The second plant operated at full power in December 1987 and has subsequently supplied over 367 MWh to the grid, at 41 per cent overall efficiency. This was constructed by Hitachi and Toshiba for Chubu Electric Power Company, and its operation was described by T. Ishigaki of Chubu Electric. Testing of both of these plants is being continued.

Walter H. Johnson of International Fuel Cells Corporation outlined their technology development programme. The first fuel cell power plant of 11 MW capacity is under development for Tokyo Electric Power Company. The first of the 10 ft^2 fuel cell stacks, nominally rated at 750 kW, has been assembled and tested at up to 1 MW. Parallel advances are being made with uprated reformer catalysts, giving a reduction from 61 to 30 in the number of reformer tubes required. In addition a design for solid state inverters of 10 to 50 MW capacity has been verified. Their programme to construct 200 kW units for combined heat and power applications has received enthusiastic support from various gas utilities, and sufficient units have been ordered to justify the setting up of manufacturing facilities for this device. Several of these will be sited in Europe for demonstration purposes.

Westinghouse Electric Corporation are proceeding with the development of their air-cooled phosphoric acid fuel cells for the electric utilities. According to J. M. Feret, pressure vessels will contain four cell stacks, each of 100 kW. Westinghouse has now progressed to operating three stacks, individually rated at 32 kW, in both series and parallel arrangements. In addition, cells on endurance tests have displayed decay rates of as little as 2 mV per 1000 hours, using improved platinum electrocatalysts. A major advance has also been made in the form of a new heat exchange reformer concept, developed in collaboration with Haldor Topsøe Inc., and described by N. R. Udengaard. This has been operated in

Houston, Texas, at greater than 80 per cent efficiency over a period of 2 years. The unit can be constructed in modules ranging in size from 200 kW up to 6MW.

Michael K. Bergman, of the American Public Power Association, addressed the problems encountered in commercialising phosphoric acid fuel cells in the United States. Despite recent setbacks in various initiatives to purchase and demonstrate the International Fuel Cells Corp. 11 MW power plant by U.S. electric utilities, the commercialisation of fuel cells remains a commitment of the Association. They supply electricity to 15 per cent of consumers in America, a total of 35 million users, and their 2200 public power systems are mostly quite small, representing an excellent first market for this size of generators.

Platinum Catalysts for Phosphoric Acid Fuel Cells

A paper on high performance electrocatalysts was presented by Tanaka Kikinzoku Kogyo K.K. in collaboration with Stonehart Associates Inc., and Professor M. Watanabe of Yamanashi University. This concept utilises high surface area carbon support material to provide wide spacial distribution for very small crystallites of platinum or platinum alloy. By this means, performances of 735 mV at 200 mA/cm^2 can be obtained with a platinum loading of 0.5 mg/cm^2. With their advanced alloy catalyst, this is improved to 765 mV at the same current density and noble metal loading. The objective for Tanaka Kikinzoku Kogyo is to achieve a voltage of 820 mV at 200 mA/cm^2 within the next five years.

Developments of other platinum alloy catalysts were given in a poster by Nippon Engelhard Inc. Improved utilisation of catalysts, by optimisation of electrode structures using mathematical modelling, was reported in posters by Professor N. Giordano, Institute CNR-TAE, Sicily and by Stonehart Associates.

A poster by C. A. Gibbs of Johnson Matthey considered the potential demand for platinum when phosphoric acid fuel cells reach commercial viability, and emphasised the availability of vast reserves of the metal to meet this demand.

European Fuel Cell Efforts

The growing European involvement with fuel cells was described by P. Zegers of the Commission of the European Communities. Recognising the advanced state of development of phosphoric acid fuel cells, the Commission is encouraging the demonstration and the purchase or licensing of phosphoric acid fuel cell technology. In parallel, research efforts on the more speculative molten carbonate, solid oxide and direct methanol fuel cells are being sponsored. A 1 MW power plant will be installed in Milan, jointly sponsored with the Italian Government under Project Volta. The plant will be constructed by Ansaldo using a Haldor Topsøe reformer and phosphoric acid fuel cell stacks supplied by International Fuel Cells. It will be operated by the state generating utility.

Fuel cells are being developed for space applications by the European Space Agency. The programme, described by F. Baron, is initially to construct cells for the Hermes space shuttle, requiring a mean power of 4 kW, with a maximum weight of 80 kg. The effort, co-ordinated by Dornier Systems, includes contributions by Siemens and Varta of Germany, and Elenco of Belgium. It is also planned to develop a combined electrolyser/fuel cell system for the Columbus space station.

Proton Exchange Membrane Fuel Cells

The choice of Richard Klimisch, from the General Motors Technical Center, as keynote speaker reflected the growing interest in fuel cells and in particular proton exchange membrane systems for a variety of applications, including motor vehicles, heavy trucks, buses and even railway locomotives. The current 15 per cent efficiency for internal combustion engines leaves considerable scope for improvement, and General Motors sees fuel cells as offering higher fuel utilisation efficiency, environmental benefits and an alternative fuel capability; these being U.S. Government goals for mobile power systems. There is an estimated market for 1 million electric vehicles per annum in the U.S.A., provided limitations on vehicle performance and range can be overcome.

Ross A. Lemons of Los Alamos National Laboratories pointed out that transportation accounts for 60 per cent of U.S. petroleum consumption, which could potentially be replaced by methanol. Studies have been carried out to compare various fuel cell systems for transportation, and solid polymer electrolyte fuel cell technology has been developed for this application. Work has focused on reducing catalyst loading and cost, increasing the power density, and operating the cells on hydrogen from reformed methanol. As part of the studies improved reformers have been developed, and fuel cell performance enhanced by making them tolerant of carbon monoxide in the fuel stream. The platinum loading for the proton exchange membrane has been reduced to 0.55 mg/cm^2 compared to the 8 mg/cm^2 typically required for aerospace applications, while increasing the performance to 0.9 W/cm^2 on hydrogen/air.

Improvements in methanol reformer design were given in a separate talk by N. E. Vanderborgh of the Los Alamos National Laboratories, in conjunction with workers at the Delco Remy Division of General Motors. Advances in polymer membrane electrode design were detailed by S. Gottesfeld also of Los Alamos, who pointed out that despite the significant advances currently being reported for proton exchange membrane cells, especially using modified electrodes to concentrate the noble metal at the electrode/electrolyte interface, only a small proportion of the platinum is currently being utilised, leaving considerable room for improvement. By adding small amounts of oxygen (2 to 5 per cent) to the reformate fuel fed to the fuel cell, poisoning by carbon monoxide can be substantially reduced, giving improved performance.

Proton exchange membrane cells are also being developed by Ballard Technologies Corporation, Canada, and performances of over 5 A/cm^2 have been demonstrated using an advanced membrane material produced by Dow. Several 2 kW stacks have been constructed by Ballard and are being evaluated for Autonomous Underwater Vehicles. J. K. Hoadley described the efforts by the Treadwell Corporation to construct proton exchange membrane cells for various aerospace and military applications.

Conclusions

Although the development of fuel cells has proven to be more difficult and slower than anticipated, the potential benefits of higher efficiency and freedom from pollution are becoming more apparent in an increasingly environmentally-conscious world. Commercialisation of the 200 kW combined heat and power unit offered by International Fuel Cells may trigger a much wider demand for fuel cells, and so help to speed up their implementation. The Japanese commitments to fuel cell technology, and the current success of their programmes, can be expected to result in further worldwide interest D.S.C.

Surface Area of Catalyst Gauzes

The surface restructuring and metal removal that results from catalytic etching of platinum alloy gauzes used for ammonia oxidation, or hydrogen cyanide production by the Andrussow process has been investigated on many occasions. However, no quantitative data has been published about the surface area changes that result.

This has now been remedied with the publication of a paper describing a cyclic voltammetric technique which enables many of the features associated with catalytic etching to be studied, and the surface area of platinum alloy gauzes to be measured accurately ("Catalytic Etching of Platinum Alloy Gauzes", D. R. Anderson, *J. Catal.*, 1988, **113**, (2), 475–489). Results presented show that the top gauze in a catalyst pack has the highest surface area, and the gauze surface areas decrease progressively through the pack. Values of 250 cm^2/g and 35 cm^2/g are quoted for the top and bottom gauzes, respectively, based upon the weight of a new gauze having a geometric area of 25 cm^2/g.