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Status of Commercial Fuel Cell Powerplant System Development

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National Aeronautics and Space Administration
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Work performed for
U.S. DEPARTMENT OF ENERGY
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STATUS OF COMMERCIAL FUEL CELL POWERPLANT SYSTEM DEVELOPMENT

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Abstract

This paper tells us where we are in the commercial development of fuel cells, where we are headed, and, in the author's opinion, how and when we are going to get there. The paper focuses primarily on the status of the development of commercial Phosphoric Acid Fuel Cell (PAFC) powerplant systems because the PAFC, which has undergone extensive development (both in and outside the U.S.A.), is currently the closest fuel cell system to commercialization. Shorter discussions are included on the high temperature fuel cell systems which are not as mature in their development (the Molten Carbonate Fuel Cell (MCFC) and the Solid Oxide Fuel Cell (SOFC)). The alkaline and the Solid Polymer Electrolyte (SPE) fuel cell systems, are also included, but the discussions are limited to their prospects for commercial development. Currently, although the alkaline fuel cell continues to be used for important space applications there are no commercial development programs of significant size in the U.S.A. and only small efforts outside the USA. The story for the SPE commercial development is very similar.

The bottom line of a commercialization effort is "will it sell?" The results of the first phase of the new joint venture between United Technologies Corporation (UTC) of the U.S.A. and Toshiba of Japan (called International Fuel Cells Corporation, IFC) should tell us a great deal by the early 1990s. In other words, the electric utilities' response to the IFC 11 mW PAFC powerplant (to be bought and evaluated by a number of utility consortia) will reveal what the PAFC powerplant really means to them. Further, the success or failure of this PAFC venture will greatly impact the commercialization of fuel cell powerplants of all types. Therefore, although sizable technology development efforts (which are described in this paper) are still going on in the PAFC programs, the most important PAFC activity is the upcoming evaluation by many utilities of the IFC 11 mW PAFC powerplant. Furthermore, this initial market acceptance phase is as crucial for the Westinghouse Electric Corporation PAFC commercial development as it is for the IFC PAFC commercial development.

The marketplace for fuel cells (utility multimegawatt and multikilowatt (including congeneration); on-site/integrated energy system multikilowatt; traction and transportation; and other applications) and the status of fuel cell programs in the U.S.A. receive extensive treatment. The fuel cell efforts outside the USA, especially the large Japanese programs, are also discussed.

Introduction

Fuel cells achieved a very important milestone in April 1985 when a joint venture was established in the U.S.A. to commercialize Phosphoric Acid Fuel Cell (PAFC) powerplants. United Technologies Corporation (UTC) of the U.S.A. and Toshiba Corporation of Japan formed a fuel cell joint venture called International Fuel Cells Corporation (IFC). Initially, IFC has initiated an offer of 11 mW PAFC powerplants to the electric utility industry based on current UTC technology. The success or failure of this PAFC venture will greatly impact the commercialization of fuel cell powerplants of all types, the near-term low temperature powerplants (PAFC, in particular) as well as the high temperature fuel cell powerplant types, i.e., molten carbonate (MCFC) and solid oxide (SOFC), which are further behind in their development. In other words, market acceptance is fast becoming the key to the commercialization of fuel cells. This first major fuel cell venture will have a great impact upon this.

The Marketplace for PAFC

Multimegawatt/Electric Utility

For the last decade or so, it has been clear that the initial market for terrestrial PAFC powerplants would be in the electric utility area. Although the UTC 4.5 mW powerplant demonstration at a Consolidated Edison (Con Ed) New York City site was apparently premature (beset by many problems, it never produced any power), I believe that it is fair to say that the aims of that first multimegawatt demonstration of a fuel cell powerplant were sound. It is not enough to thoroughly discuss the benefits of fuel cell powerplants with electric utility people and to conduct systems studies which point out numerous advantages of fuel cells over competing energy conversion technologies. These steps are necessary to attract the interest of potential buyers, but not sufficient to get the utilities to buy a new generating technology. The potential utility customers require hands-on experience with the fuel cell powerplant to transform an appealing new concept into reality for them. For example, demonstrating the important siting benefits of the fuel cell to urban utilities was a key feature of the Con Ed PAFC demonstration in New York City.

In addition to providing vital information to potential buyers, a demonstration at a user site also provides very helpful information to the fuel cell manufacturer on deficiencies in his product. Such was the case in New York City - even though the whole powerplant never operated - and in Tokyo where the TEPCO 4.5 mW unit, with its improved stack, operated reasonably well.

Consistent with the philosophy of hands-on experience to develop the market demand is the effort, spearheaded by the Electric Power Research Institute (EPRI), for electric utility consortia to purchase and test the early commercial prototypes of the IFC 11 mW PAFC powerplants, (designated the PC-23 by IFC). Current indications are that three electric utility consortia in the U.S.A. will each purchase a PC-23 powerplant and that two PC-23 11 mW powerplants will also be sold in Japan. The intent of this program is to provide utilities with evidence of fuel cell viability, which will enable IFC to make the transition to a bona fide supplier of reliable and economical fuel cell generating equipment. The program addresses a number of characteristics which should prove to be important both to the utilities and to the manufacturer: (1) The initial powerplants will have the characteristics of the production units to follow. (2) The number of initial powerplants will be sufficient to provide an opportunity for a broad segment of utilities to evaluate fuel cells first-hand in order to develop the market for future production orders. (3) Enough hardware will be produced to establish quality standards and document the production costs. (4) Field experience will be sufficient to verify the performance and reliability of the powerplants and its components for utilities and manufacturer. (5) User feedback on any PC-23 deficiencies and on any special powerplant characteristics desired by the utilities will be valuable for improving the fuel cell powerplant both in the near term and in the future.

With delivery scheduled to start in 1990, this should position the PAFC powerplant for the expected rise in electric generating capacity demand in the early 1990s. For instance, the EPRI-sponsored EMA study (1) of the attitudes of 25 utilities toward the potential realizable benefits of fuel cell powerplants on their systems reported an expected rise in demand for PAFC fuel cell powerplants beginning in the 1990-92 period. The report was prepared in cooperation with the Fuel Cell Users Group of the Electric Utility Industry. This very active utility group has long recognized the benefits of the fuel cell powerplant to more closely match load growth than conventional steam cycle or nuclear systems, thus reducing the risk of wasteful capital investment in unused capacity. The fuel cell characteristics that principally make this possible are (1) its ability to be factory-manufactured with short lead times, (2) its modularity, and (3) its availability in quite small sizes with essentially the same characteristics as larger sizes. In a real sense, Westinghouse which is developing its version of a utility size PAFC powerplant, is also banking on the success of the utility market acceptance phase of the IFC venture. A failure to interest the important utility market would spell trouble for all potential fuel cell manufacturers, not just for IFC. In addition, Westinghouse can shorten the time period it is behind IFC by capitalizing on some of the trail-blazing by IFC, such as the utility market acceptance phase. Currently, Westinghouse plans to test a 1.5 mW pilot powerplant prior to testing its full-size 7.5 mW PAFC prototype powerplant at a host utility. Immediately following this, Westinghouse plans to be in a position to meet the utility fuel cell market in competition with IFC.

Spearheaded by a strong Congressional interest, the U.S. Department of Energy (DOE) has carried out development plans for Coal Gasifier (CG) Fuel Cell Power Plants, including the use of the PAFC. One attractive feature of the PAFC-based powerplant system is that it does not require a huge GC/PAFC powerplant system to generate electricity. However, under the current climate of ready availability of natural gas and oil, the latter at depressed prices, it is unlikely that GC/PAFC powerplants will be built other than for demonstration purposes in the near future.

Multikilowatt/On-site Integrated Energy

It is surprising to many fuel cell onlookers that the types of fuel cell systems making the most efficient use of the fuel (through waste-heat utilization) are not the leading candidates for commercial development of the PAFC. This attitude was especially true during the period of great concern over the availability of oil, driven up in price by the then very powerful OPEC oil cartel. A similar concern over natural gas existed for quite a few years. But for potential fuel cell customers, fuel efficiency of the fuel cell was only one of the attractions, but not the top one.

As discussed in the previous section, for most of the electric utility industry, siting and the ability of the fuel cell to closely match load growth are more important attractions than is fuel efficiency.

However, as most know, it was the gas utility industry that initiated, at UTC, the development of small-sized PAFC on-site powerplants intended for the commercial market, first strictly as electrical generators (TARGET Program), and then together with DOE as on-site PAFC powerplants with provisions for waste heat recovery. (The totally integrated system which Engelhard Corporation has been pursuing was dubbed the On-Site/Integrated System (OS/IES) by NASA Lewis Research Center, the managers of the DOE PAFC Program). The $34M, 3-1/2 years, 40 kW Field Test Program, sponsored by GRI (Gas Research Institute) and DOE and managed by NASA Lewis, can be regarded a success. Approximately 50 powerplants were manufactured and field-tested at a variety of sites throughout the United States and Japan. Four were at military sites under DOD sponsorship. The 13-month test period is complete for all of the participants. Two powerplants are still operating at military bases. In general, the powerplants performed well. The fuel processor and fuel cell stack performed as they were supposed to. The basic design of the power conditioner was verified; however, power conditioner problems were encountered in the control card area.

Correction of identified design deficiencies, mostly in the control cards and water treatment subsystem, will make it possible to increase considerably the average powerplant availability from the respectable 63 percent of the field test. Regardless of the ability of IFC to correct the technical deficiencies of its 40 kW powerplant, it is on record stating that it cannot produce an economical 40 kW PAFC on-site powerplant at the annual production rates the early market is likely to support. Its 200 kW Technology Development Program, sponsored by GRI and by DOE, is aimed at developing advanced lower cost technology that will be offered in a PAFC powerplant significantly larger than 40 kW to also take advantage of economy of scale. IFC strategy is to build up a demand by initially offering the more economical multikilowatt sized PAFC on-site powerplant. With sufficient demand it can later offer both smaller and larger sizes, at competitive prices. It remains to be seen whether the price in the initial IFC offer to the gas utilities (under GRI Contract) will be low enough to attract enough buyers to prompt IFC to enter the PAFC on-site business at the same time they are producing the 11 mW powerplants for their electric utility PC-23 joint venture. Engelhard's apparent strategy to market PAFC powerplants could be considered to be the reverse of IFCs, i.e., they are planning to start marketing the smallest sizes (5 to 10 kW in their case) and then follow with larger sizes, whereas IFC is planning to do the reverse. In reality, both strategies are fundamentally the same. Engelhard Corporation (U.S.A.) has established a joint venture with Fuji Electric (Japan) to produce PAFC fork-lift trucks, thereby commercializing fuel cells where they feel they have a market for their PAFC technology. They would then build on the acceptance of fuel cells by industry and on their new commercial fuel cell business to move into new commercial markets for their PAFC system, in particular the OS/IES applications, which require 25 kW powerplants and larger.

Other Applications

The interest in the potential of low temperature fuel cells (PAFC, alkaline, Solid Polymer Electrolyte (SPE), and even the commonly called alternate acid electrolytes, e.g., fluorinated sulfonic acids) for transportation applications by DOE has been longstanding. The Los Alamos National Laboratory has been actively investigating the possible application of fuel cells for automobiles, busses, trucks, railroads, and ships for over a decade. For the passenger car, the barriers of high fuel cell system cost and large installation volume have thus far not been overcome.

The much-talked-about application of fuel cells to industrial processes has never really been realized because of the apparent disinterest of industry. There were no industrial companies or users groups, as there are representing the utility industries, to lead the development of fuel cells for the benefit of any of the vast segments of industry. Perhaps this will soon change with the recent formation in the U.S.A. of the Industrial Fuel Cell Association.

Status of PAFC Programs

Multimegawatt/Electric Utility

International Fuel Cells is supporting design work (principally at Toshiba and IFC) and commercialization activities to get their 11 mW PC-23 ready for sale. They have retained the Bechtel Company as their Architect and Engineering company. At the same time, DOE and EPRI are sponsoring technology development work in support of the PC-23 chiefly in the cell and stack, the reformer, and the inverter areas. Over the last decade, NASA Lewis has managed the DOE-sponsored work as well as coordinated the work with that sponsored by EPRI. The important first test of a full height stack (700 kW) is scheduled to be completed (4500 hr of operation) by November 1987. In addition, a limited amount of DOE funding will, for a few years, carry the technology somewhat beyond that of the PC-23, principally in the cell structure area. The next major milestone the Westinghouse DOE/NASA PAFC Project must achieve before it can conduct its 1.5 mW pilot powerplant test is to verify, in 1989, its 375 kW stack module. In parallel with the work necessary to achieve these milestones is a very heavy schedule of materials and components technology, stack and module engineering and design, endurance testing, and manufacturing methods development. In coordination with the DOE-funded effort is the EPRI-funded development of a natural gas reformer, which is being successfully carried out by Haldor Topsoe, and a Westinghouse development of a power conditioner.

Finally, both IFC and Westinghouse are courting the electric utilities and EPRI for additional support for their respective PAFC electric utility programs. The firm utilities commitment to participate, as consortia, in the field-testing of IFC 11 mW powerplants is scheduled for the summer of 1987. The EPRI commitment to provide substantial subsidy to the utilities for this crucial first phase of IFC commercialization has been made. Westinghouse is in the process of lining up electric utility support for the test of their 1.5 mW pilot powerplant test as well as for the 7.5 mW powerplant that follows.

Multikilowatt/On-site Integrated Energy

The IFC on-site technology effort is to culminate under NASA Contract DEN3-289 in an approximately 9-month verification test (ending early 1988) of the 200 kW powerplant system. Except for the advanced power conditioner, which will not be included in the verification test, it will provide a meaningful test in an integrated powerplant mode of all of the commercializable components and subsystems developed under the contract, as well as the water treatment system developed under the companion GRI contract. In addition to final verification of the technology improvements, developed under the cost reduction technology development effort, the NASA contract will provide IFC and the sponsors with very valuable IFC stack cost-tracking information. The marketing and commercialization efforts for the IFC PAFC on-site powerplant, (dubbed PC-25 by IFC), are intensifying in the private sector. Included in these activities are discussions on the additional technology needed to make the PC-25 more attractive to potential customers via lower cost and other features.

The Engelhard OS/IES technology development effort, supported by NASA Contract DEN3-241, is also scheduled to be completed in 1988 with a 25 kW PAFC on-site powerplant system test. In this case, the fuel processor and power conditioner required for the test are being developed with nongovernment funds under the direction of Engelhard. As in the case of the IFC PC-25 on-site powerplant, commercialization activities will intensify and reside in the private sector. In the past, Engelhard had stated that, following the PAFC on-site powerplant test, it planned to test a complete OS/IES, (i.e., a PAFC on-site powerplant together with HVAC equipment to fully utilize the waste heat) at a user site.

Status of High Temperature Fuel Cell Programs

For approximately the decade after the establishment of DOE (as ERDA originally) which brought about the sharp rise in funding (both government and nongovernment) of fuel cell development for terrestrial applications, the MCFC and the SOFC high temperature systems were labeled as the second and third generation systems, respectively. (The low temperature PAFC was regarded as the first generation system.) This type of label suggests that a considerable advantage is foreseen in the next generation system, but that considerable development will be required before successful commercialization is achieved. For the case of the MCFC, it is still believed that its development is 5 to 10 years behind that of PAFC systems. However, approximately 2 to 3 years ago, Westinghouse departed from the prevailing wisdom and stated that it felt that the SOFC would be of broad value to the U.S. economy 10 to 15 years earlier than was previously believed. Furthermore, Westinghouse, the only U.S. manufacturer pursuing the commercial production of SOFCs, predicted that competitive commercial offerings can be made in the early 1990's.

However, in spite of the technical accomplishments in SOFCs in recent years and the increased support of SOFC systems by both government and non-government sponsors, there remains too much to be done technically and programmatically to achieve so large a leap forward in the SOFC commercialization schedule. That is, even if all the technical, cost (including manufacturing) and design questions were apparently settled, system scaleup and verification (including endurance) would be too lengthy and expensive for the SOFC system to achieve significant market penetration by the early 1990's.

Nevertheless, the progress over the last few years in the development of the SOFC system has enabled it to begin to challenge the MCFC system as the second generation system. For example, (1) a series of technical accomplishments have led to improved materials and processing that have resulted in stable cell performance at high power density. (2) Westinghouse has built and begun testing of their first 5 kW generator. (3) The DOE and Westinghouse have increased their spending for SOFC (from \$2M to \$5M from '84 to '87 by DOE). (4) GRI has recently started to inject significant development funds for SOFC, e.g. \$2.6M for a 21 month contract with Westinghouse. (5) The Argonne National Laboratory SOFC Monolith concept, which it is pursuing for space applications (for DOD), should benefit the development of SOFCs for terrestrial applications.

It is predicted that while the increase in SOFC R&D activity will lead to greater advances it will also lead to a greater exposure of problems. For example, in spite of the very considerable delays in the PAFC terrestrial development programs the development of the MCFC system is still 5 to 10 years behind that of PAFC. The performance of the MCFC improved partly from the development of the thinner tape cast electrolyte (compared to the pressed tile) and partly from an increase in cell pressure. Pressurization, however, adversely affected the long-term stability of the NiO cathode. Another example is that the introduction of the fine-pore electrodes brought with it the sintering and creep problems of the anode. Although, over the years, many advances have been achieved in the design and fabrication of MCFC stacks (by IFC and by Energy Research Corporation, ERC) MCFC stack life is still below 10 000 hr.

In summary, the potential of high temperature fuel cell systems for terrestrial applications has been widely acknowledged. The efficiencies of these systems, especially with the use of the high temperature waste heat, are very attractive especially at the estimated capital cost and predicted COE's. But the MCFC system must overcome its problems with electrolyte loss and corrosion, in addition to those problems cited in the previous paragraph, before commercialization plans are on solid footing. And as was also briefly discussed previously, the SOFC system - which is a simpler system than the MCFC system - has many barriers to overcome before it can be confirmed that it has not only caught up to the schedule of the MCFC system, but is "breathing down the competitive neck" of the PAFC system as Westinghouse's prediction of early 1990 SOFC commercialization implies.

Status of Supporting Advanced Research and Technology

In the 1980's, the DOE/NASA PAFC AR and TD program, the largest U.S. effort by far (compared with that of EPRI and GRI) was focused to clearly address technical issues that support the large PAFC technology development projects of IFC, Westinghouse, and Engelhard. Consequently, research efforts were focused by Giner, Inc., Stonehart, ECO, Lawrence Berkeley Laboratory, and Los Alamos National Laboratory on electrocatalysts (primarily Pt alloys), catalyst support corrosion resistance, and electrode structure. While much of this AR and TD work has ended, technology development on carbon components by Great Lakes Research Corporation (in cooperation with an EPRI contract with GLRC) is still active. In addition, fuel cell modelling and analysis support work, including Coal Gasifier/PAFC Powerplant studies, are being carried out at NASA Lewis (with the support of Cleveland State University).

In 1987, Congress reduced the AR and TD budget for PAFC to zero because it believed that the PAFC system had already been commercialized, and thus warranted no further AR and TD support. This position is contrary to the millions in government funds that had been spent to support technology long after initial commercialization; the commercial aerospace industry is a good example. Currently, DOE PAFC AR and TD efforts are supported either by previous year carryover funds or by subcontracts to the large PAFC technology development contracts. To try to change this situation, a DOE position paper (2) has been prepared for Congress recommending that a PAFC basic technology program be supported in the coming years.

Work carried on under the DOE AR and TD high temperature fuel cell budget is largely directed at materials research at Westinghouse, ANL, and at smaller laboratories. In addition, ANL and NASA Lewis are also conducting systems analyses of high temperature fuel cell systems. EPRI and GRI are also supporting some high temperature fuel cell AR and TD as well as the major technology development efforts.

PAFC Technology Development Outside the U.S.A.

PAFC R&D in Japan is being carried out both under government auspices (NEDO) as a national project (as part of the "Moonlight Project" starting in 1981) and under private auspices. At this writing, the two 1 mW demonstration tests, one a dispersed PAFC generator, the other a central station generator, are progressing as planned. It is not surprising that so much of the Japanese PAFC technology resembles that of the U.S. PAFC developers. That, for example, of Sanyo is done under license to ERC. A most interesting case is that of Toshiba. Toshiba is working on PAFC both under the

Moonlight Project and in the IFC joint venture with UTC. However, under the terms of both agreements, the Toshiba effort for NEDO and the Toshiba-IFC joint venture are completely independent.

High temperature fuel cell work in Japan under the Moonlight Project is centered on technology development of 10 kW MCFCs. However, some Japanese industrial firms will be evaluating SOFC generators supplied by Westinghouse.

The European fuel cell R&D efforts (in Germany, Sweden, France, and the USSR) had been strongly focused on alkaline fuel cells. Recently, a renewed interest in the MCFC system has occurred in the Netherlands. The Italians have also shown interest in the MCFC as well as in the PAFC systems. The Dutch MCFC program is a significant 3-year effort ($8M in cooperation with IGT, IIT, and EPRI) culminating in the testing of a 1 kW stack in 1989. However, plans exist for a 2-year extension to the 100 kW size MCFC stack.

Concluding Remarks

The bottom line of a commercialization effort is "will it sell?" The results of the first phase of the new PAFC joint venture (IFC), in which utilities are to purchase and test 11 mW early commercial prototypes, should tell us a great deal before too long. In other words, the electric utilities will be able to determine what a fuel cell powerplant really means to them.

In addition to the references cited in the text, others (3-6) that should be of interest to the reader are also included.

REFERENCES

1. Pang, C.K., Lee, S.T., Lee, K., and Imamura, D.T., "Application of Fuel Cells on Utility Systems, Vol. 1: Study Results," EPRI-EM-3205-vol. 1, Electric Power Research Institute, Palo Alto, CA, Aug. 1983.

2. "Feasibility of a Phosphoric Acid Fuel Cell Basic Technology Program," DOE/METC-87/6075, Feb. 1987.

3. Penner, S.S., "Assessment of Research Needs for Advanced Fuel Cells," DOE/ER-30060/TI, July 1985.

4. Curry, B.E., "The Fuel Cell: Electric Utility Planning Perspectives," Report for the Fuel Cell Users Group of the Electric Utility Industry before the New England Conference of the Public Utilities Commission, 36th Annual Symposium, Farmington, CT, June 14, 1983.

5. Warshay, M., "Status of Commercial Phosphoric Acid Fuel Cell Power Plant System Development in the United States," Progress in Batteries and Solar Cells. Vol. 5, JEC Press, Cleveland, OH, 1984, pp. 7-12.

6. Warshay, M., "Fuel Cell Power Plant Systems," Science and Technology of Coal and Coal Utilization, Cooper, B.R. and Ellingson, W.A., eds., Plenum, New York, 1984), pp. 339-380.

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16. Abstract

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