FUEL CELL DEVELOPMENTS IN JAPAN

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Overview

Research to develop fuel cells in Japan was initiated by research institutions beginning about 1955 and is therefore backed by roughly 30 years of experience. In the years after 1965, the principal result of research was the commercialization of dissolved fuel type cells using methanol and other substances as the fuel for utilization for use as a compact power source in energizing radio relay stations and other systems. However, it was only during a short span of less than a decade that particularly significant progress was achieved in related research.

Central to research on these fuel cells is the Moonlight Project implemented in 1981 by the Agency of Industrial Science and Technology (AIST) of the Ministry of International Trade and Industry (MITI). At about the same time, research conducted broadly by governmental and private sector research institutions, including the introduction of American made experiment plants, served as the foundation, together with the Moonlight Project, for promoting fuel cell research to today's high level. Intensive research is being advanced in connection with three types of fuel cells: phosphoric acid fuel cell (PAFC), molten carbonate fuel cell (MCFC) and solid oxide fuel cell (SOFC).

Government Research and Development (R&D) — Moonlight Project

The development of fuel cells in Japan is proceeding smoothly. Research on the phosphoric acid type is presently being advanced with a demonstration plant, and research on the carbonate type is approaching the stage of a demonstration system. These development activities are also being advanced by the private sector, but the government's R&D activities to develop related domestic technologies are playing the central role.

AIST started research on fuel cells in fiscal year 1981 as a link to its "Large-scale R&D Projects for Energy Conservation" (Moonlight Project), and is presently engaged in research mainly on the molten carbonate fuel cell, but also on the phosphoric acid and solid oxide fuel cells. Figure 1

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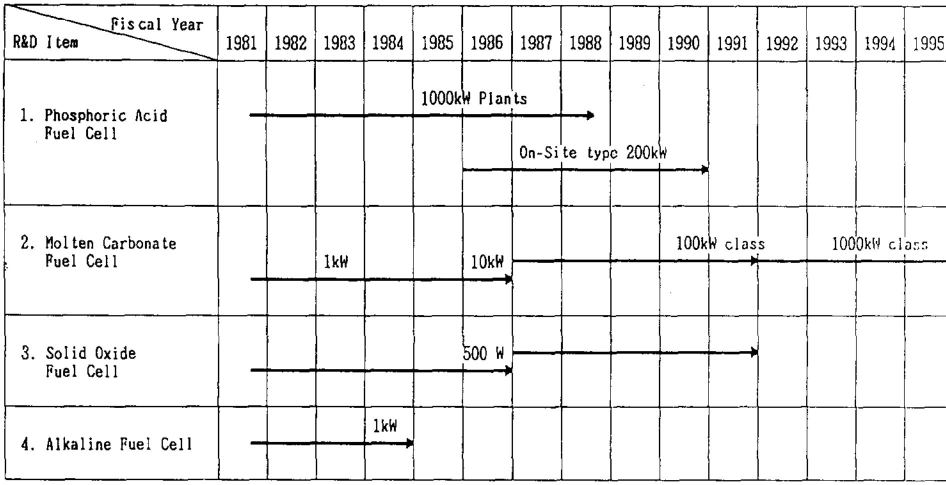

Fig. 1. R&D timetable of fuel cell power generation technology.

shows the R&D program for developing fuel cell power generation technologies.

The fuel cell R&D project had originally been structured on a 10-year program. In March, 1987 the basic plan was changed to a 15-year program up to fiscal year 1995 owing to new development research on the molten carbonate fuel cell. Subsequently, the total R&D budget was increased to about ¥57 billion. In order to advance these R&D activities most effectively, a Fuel Cell Power Generation Subcommittee has been established in the Industrial Technology Deliberation Council, an advisory organ to the Minister of International Trade and Industry. This subcommittee will deliberate on vital matters such as program evaluation and research result evaluation.

Outline of Government R&D activities

A project to develop a phosphoric acid type 1000 kW class power generation system is being advanced with the aim of developing fuel cell power systems for electric utilities. Two systems have been fabricated and installed — one for dispersed power generation (at Kansai Electric Power Co.'s Sakaiko Power Station) and the other for use as a substitute thermal power plant (at Chubu Electric Power Co.'s Chita 2nd Thermal Power Plant). The former was successfully put to 1000 kW power generation tests in September 1987, and the latter was put to the same tests in December 1987. Since then operation experiences were conducted and successfully terminated for both systems by the end of October and September 1988 respectively. As far as the generating power time was concerned, the former was over 2000 h, the latter over 1000 h. The achievement made by both plants during the operation research is shown in Table 1.

TABLE 1

Operational performance of 1000 kW pilot plant

Item	Dispersed generation use	Centralized generation use
Total power generation time	2045 h	1018 h
max. cont. gen. time: 4 stacks	[118 h (500 ~ 750 kW)]	[440 h (300 kW)]
2 stacks	[705 h (250 ~ 500 kW)]	
No. cells per stack	515	485
Optimum temperature and pressure	190 °C 4 atm.	205 °C 6 atm.
Generated power output	697151 kW h	367583 kW h
No. generation	40	46
Reformer temperature rise time	3614 h	2410 h
Generating efficiency (1000 kW, HHV)	37.1%	38.4%
Start up time (hot start) (Catalyst temperature at start up)	5 h 1 min (250 °C)	4 h 20 min (359 °C)
Load following characteristics (load band)	±11%/m (125 ~ 450 kW)	±10%/m (150 ~ 400 kW)
Stopping time: ordinary	47 min	60 min
emergency	10 s	10 s
NOx (at 1000 kW)	10 ppm	8.5 ppm
Noise (A level: at 1000 kW)	58 ~ 71 dB	59 ~ 74.5 dB

A project to develop a phosphoric acid type 200 kW class power generation system has been in progress since fiscal year 1986. This 5-year program is aimed at developing an on-site type fuel cell which would permit power systems to be installed flexibly in various kinds of power demand regions. Specifically, two systems are under development — one using methanol as the fuel and designed to provide power systems for remote isolated islands, and the other using city gas as the fuel and designed to provide power systems for cogeneration. The former system will lend itself to a parallel operation with a diesel power generator using closely-matched load following characteristic methanol reformer, while the latter system will feature concurrent electricity heat supply, compactness and high reliability, for use by commercial establishments such as hotels and restaurants.

Meanwhile, with regard to the molten carbonate fuel cell, the New Energy Development Organization (NEDO) in 1986 succeeded in generating an output of 10 kW with a matrix type electrolyte (developer Hitachi Ltd.) and with a paste type electrolyte (developer Toshiba Corp.). The successful development of a 10 kW fuel cell offered some promising prospects for the enlargement and performance improvement of these fuel cells with existing materials and manufacturing technologies, raising the operating pressures, improving gas utilization efficiencies and enabling large-scale stacks. The second-phase program for developing the molten carbonate fuel cell is to start at the beginning of fiscal year 1987 in the Moonlight Project. The plan is to strive to resolve these previously mentioned technological problems while developing a 100 kW fuel cell stack in the first half 5-year period up to fiscal 1991. This will be followed by the development of technologies for fabricating a power generation plant system on the basis of these results, and in the latter 4-year period up to fiscal 1995, to develop a 1000 kW class pilot plant.

In January 1988, the Technology Research Association for MCFC Power Generating System was established for the purpose of developing the system technology of a 1000 kW class pilot plant including peripheral equipment, balance of plant and other related technology.

The internal reforming system capitalizes on the high temperature that is a distinct characteristic of the molten carbonate fuel cell, which enables fuel gas for utilization in power generation to be generated through catalytic reforming of natural gas inside the cell, making the use of a separate reformer unnecessary. The development of this internal reforming system still lies in the laboratory experimental stage compared with external reforming systems, however NEDO envisages the IR-MCFC development of a few 10 kW scale in the second-phase program.

The Government Industrial Research Institute in Osaka is conducting research in search of new fuel cell materials and developing technologies for evaluating the properties of various kinds of materials.

With regard to the solid oxide fuel cell, the Electrotechnical Laboratory is engaged in research to develop a 500 W scale cell based on the tubular concept, while repeating experiments to increase the cell's durability by improving the cell's structural soundness of components, and upgrading the cell's performance by developing high quality elementary materials. Meanwhile, the National Chemical Laboratory for Industry is conducting research to develop the planar type in the same project. More specifically, research is being advanced to develop a composite three-layered film combining anode, cathode and electrolyte in a compact assembly. NEDO started the feasibility study on SOFC development in a three-year program for the purposes of manufacturing high power density cell/stacks, compact SOFC concept and long-life performance. Figure 2 shows the R&D setup in the Moonlight Project.

Private sector R&D activities

Research on PAFC in Japan is being advanced by the private sector with electric power companies and gas companies assuming the central roles. Tokyo Gas Co., Ltd and Osaka Gas Co., Ltd. participated in America's GRI

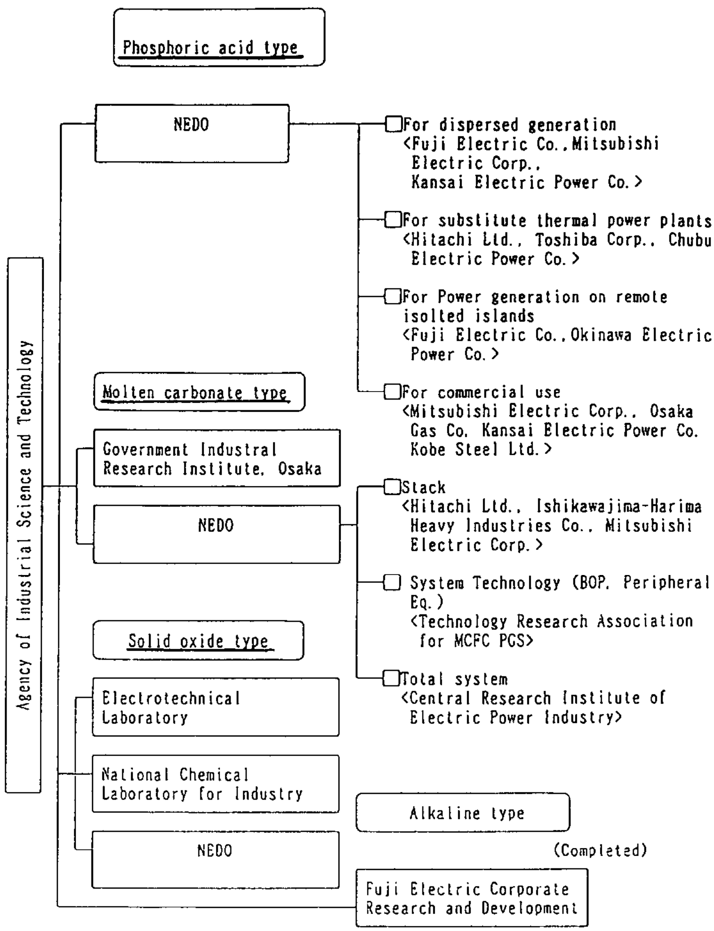

Fig. 2. R&D setup in Moonlight Project.

Project, and were engaged in operational research on fuel cells as the field test program. Osaka Gas, in particular, has completed the operational test in a family restaurant; the plant had run for 15 600 h. Meanwhile, Tokyo Electric Power Co., Inc. has conducted running tests since 1983 on a 4.5 MW fuel cell system developed by UTC (U.S.A.) and achieved the system's rated output.

R&D activities are being advanced intensively by various corporations to develop domestic fuel cells; for example, Tohoku Electric Power Co. is using 50 kW PAFC developed by Fuji Electric Co. and Hokkaido Electric Power Co. is using methanol fueled 100 kW PAFC by Mitsubishi Electric Co., and by introducing fuel cells developed in the United States; one typical example is Tokyo Electric Power Co. with a IFC 200 kW on-site fuel cell. Table 2 shows the outline of private utilities fuel cell power plant activities.

TABLE 2

Outline of private utilities activity

Name of company	Outline of plant	Manufacturer	Remarks
Tokyo Electric Power Co.	220 kW, NG, air cooling 200 kW, NG, water cooling	Sanyo Elec. IFC	Aug.'86 construction Sept.'87 operation Oct.'88 operation study
	200 kW, NG, water cooling	IFC	Feb.'89 heat suppling test
	11 MW, NG, water cooling	Toshiba/IFC	Oct.'89 fabrication Apr.'89 installation Dec.'90 operation start Jan.'91 demo operation
Tohoku Elec. Power Co.	50 kW, NG/LPG, 190 °C, boiling water cooling	Fuji Elec.	Oct.'85 construction Mar.'87 100% operation Mar.'90 be terminated
Hokkaido Elec. Power Co.	100 kW, methanol, 190 °C, boiling water cooling	Mitsubishi Electric	Nov.'87 - Mar.'89 operation Accumlated OP. hours 4575 h 330 MW h, co-generation use
Tokyo Gas Co.	50 kW, NG, 190 °C, 1 atg, boiling water cooling	Fuji Elec.	Very compact design Grid connected
	100 kW, NG, 190 °C, 1 atg, boiling water cooling	Hitachi Ltd.	Same as above
Osaka Gas Co.	200 kW, NG, 190 °C, 1 atg, boiling water cooling	IFC	Mar.'89 installation Apr.'89 operation Mar.'91 be terminated

On the other hand, the molten carbonate fuel cell technology is advancing with stack manufacturers presently engaged in research to develop their own unique 10 kW fuel cell systems in the same manner as the Moonlight Project.

During the period from the end of March through April of 1987, three companies Ishikawajima-Harima Heavy Industry, Mitsubishi Electric and Fuji Electric Co. R&D, which were engaged in the development of related elementary technologies, also succeeded in developing a unique 10 kW fuel cell stack. This feat advanced domestic research on the molten carbonate fuel cell from the stage of laboratory experiments to the stage of full scale development of commercial type fuel cell. This brought Japan up to approximately the same technological level with the United States which, up to this point, had a good head start.

The successful development of the 10 kW fuel cell offered some attractive prospects for the enlargement and performance improvement of these fuel cells with existing materials and manufacturing technologies. However, various problems still remain to be resolved, including the development of technologies for extending service life expectancies, raising the operation pressures, improving gas utilization efficiencies and enabling large scale stacks.

The second-phase program for developing the molten carbonate fuel cell is to be started beginning fiscal year 1987 in the Moonlight Project.

In solid oxide fuel cell research and development, some private concerns are also very active. Mitsubishi Heavy Industries, for example, has developed a fuel cell capable of generating an output of about 10 W with a single cell unit, and is scheduled to conduct evaluation experiments over a period of one year jointly with the Tokyo Electric Power Co. The company has also drafted a plan to venture into research to develop kilowatt class unit cells within the next few years.

Incidentally, Tokyo Gas and Osaka Gas concluded a contract in 1986 with Westinghouse for purchasing stacks, and they have conducted demonstration tests on a 3 kW stack since the end of 1987.

Recently some developers such as Fuji Electric Co., Fujikura and Sanyo have begun elemental research work for SOFC.

Conclusions

It is quite meaningful that the domestic technology on the phosphoric acid fuel cell power generation system has been rapidly upgraded from the 10 kW scale to the 1000 kW scale in a short period of time, getting closer to the highest technological level in the world, obtaining much necessary information in the development of commercial applications and clarifying the position as the fourth power generation method.

A lot of information obtained from the national R&D Project is considered to be utilized not only in the development of PAFC but also in the development of other fuel cells.

Hereafter, the second generation and third generation fuel cells should be encouraged more in the R&D Program for future high power and high efficiency generation methods.

The prospect for steady development of the phosphoric acid fuel cell power generation system for utility use and commercial application has become clear from the national R&D Project. Also, overseas nations have great expectations of Japan's move toward the development of fuel cell commercial applications. Therefore, it is necessary to clarify the next project plan — multi-MW demonstration plant — soon and accelerate activities toward the development of commercial applications under much closer cooperation among industry, academia and government than ever before.