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Development of a 1000 kW-class MCFC pilot plant in Japan

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Abstract

The development of a molten carbonate fuel cell (MCFC), in Japan, began in 1981, as part of the former Moonlight Program, promoted by the Agency of Industrial Science and Technology of the Ministry of International Trade and Industry (AIST/MITI). In 1987, after the basic research, plans to develop a 1000 kW-class MCFC pilot plant began, first, with the development of 100 kW-class stacks and components. Results from the first developments were applied to the next stage of the project, the operating test of a 1000 kW-class pilot plant. The main objective of this pilot plant is to verify the system connected stacks and components. It includes four 250 kW-class stacks, a reformer, two cathode gas recycle blowers, a turbine compressor, a heat recovery steam generator and so on. At present, the building work, component fabrication and installation are complete. Component adjustments have also been carried out. The process and control test, also known as PAC Test, will start next year, 1998. The operation will come to an end in fiscal year 1999. Following the operation test, will be a test on longer lifetime stacks, and the development of a demonstration plant. The possibility of several MW–several 10s MW output, for this future demonstration plant, will be looked into and very seriously investigated. © 1998 Elsevier Science S.A.

Keywords: Fuel cells; Molten carbonate fuel cells; Pilot plant; Japan

1. Introduction

In Japan, problems relating energy supply and demand, are quite serious. The propulsion and effective use of energy, without the use of oil, and the development of nuclear power, and using coal and natural gas, is needed. It is also needed to promote a counterplan for reducing energy consumption. For environmental conservation, more specifically to prevent the greenhouse effect, development of high efficiency power generation systems will be top priority. MCFC has a high efficiency, in principle, and is available to various kinds of fuels, such as coal and natural gas. In future, MCFC may apply to various sorts of power sources, such as dispersed power and alternative thermal power generation. In particular, MCFC was developed for an integrated coal gasification combined cycle power plant. MCFC development, in Japan, began as part of the Moonlight Program, promoted by AIST/MITI, in the fiscal year 1981.

The basic study was completed in 1986. By 1993, elemental study of the BOP, or Balance of Plant, for 1000 kW-class pilot plant and the actual testing of 100 kW-class stacks were completed. Since then, 1 kW-class, 10 kW-class, 30 kW-class (internal reforming) and 100 kW-class (external reforming) MCFC stacks were developed. The MCFC Research Association was established in 1988, to take complete charge of the entire MCFC research and development program, in Japan, and to promote the development of this pilot plant [1,2]. The Association is made up of people from stack manufacturers, BOP manufacturers, electric power companies, gas companies and so on. In total, 23 companies are presently involved in the research of each theme. Details of development, until today, are shown in Fig. 1. This paper describes the outline, details of the current status of our 1000 kW-class MCFC pilot plant and also describes the future plans for MCFC development, in Japan.

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Moonlight & New Sunshine Program

	1981~1986	1987~1992	1993~1998	1999	2000~
	Moonlight Program		New Sunshine Program		
	1st Phase	2nd Phase/1st Term	2nd Phase/2nd Term		
External Reforming Stacks	Basic Study	10kW 20~50kW 100kW	1000kW(250kW × 4)	1000kW Class Pilot Plant Operation Test	Demonstration Plant
Balance-of-Plant (BOP)		Elemental Study 1000kW Class BOP	BOP for Pilot Plant		
1000kW Class Pilot Plant		Basic Specifications	Design Manufacture		
High Performance Stacks		High Performance Technologies	Longer Lifetime Technologies		Dispersed Power Generation Plant
Internal reforming Stacks		5kW 30kW	200kW		
New Material Technologies		Basic Study	Component Technologies		
Total System		Concept Design	Vision for Introduction		Coal -Fueled Plant
Coal Gas Technology		Elemental Study	System Study		

Fig. 1. Details of MCFC development in Japan.

2. Development of 1000 kw-class MCFC pilot plant

2.1. Concept

The main purpose for developing this pilot plant is to organize an MCFC power generation system that incorporates fuel cell stacks, with a combined BOP and control system, shown in Fig. 2. Prior to the pilot plant design, testing of BOP and system simulation was carried out. The BOP was almost to scale, compared to the one used in the actual pilot plant. The way in which this development was carried out, is quite different from traditional development. The concept for this plant came from the original alternative power plants, with a system towards a several 10s MW-class demonstration plant.

2.2. System configuration

Fig. 3 shows the system flow diagram of the plant, and in Table 1 specifications of major components are shown. It is made up of fuel cell stacks, a reformer, cathode gas recycle blowers, a heat recovery steam generator, electrical equipment and control system. Here two types of fuel cell stacks are used. This plant has four 250 kW-class stacks in total, and each two, of the four stacks, are electrically connected, in series, to a 500 kW-class inverter. Each 500 kW stack-inverter can be operated independently. Detailed specifications of major components are described below.

2.2.1. Fuel cell stacks

The power generation section comprises of four 250 kW-class stacks. Two of which are co-flow type stacks, the other two being of the cross-flow type.

2.2.2. Reformer

A catalytic burner is applied to the reformer, due to the low heat value of the anode outlet gas. The steam/carbon ratio, or S/C, for reforming is planned to be set at 3.5, with allowances to avoid carbon formation and deposition inside the cell.

2.2.3. Cathode gas recycle blower

The cathode gas recycle blower is used to control the stack temperature, while recycling cathode outlet gas to the cathode inlet. It has a high speed motor with magnetic bearings and is operated at high efficiency. The blower has sufficient capacity to allow the appropriate circulation volume, even with an increase in heat generation, for about 3000 h with the 1000 kW.

2.2.4. Heat recovery steam generator

A heat recovery steam generator, or HRSG, for the reformer with a compact arrangement of smoke tubes with fin, has a high heat recovery efficiency.

2.2.5. Turbine compressor

The turbine compressor compresses air for cathode and reformer, driven by the high temperature cathode exhaust

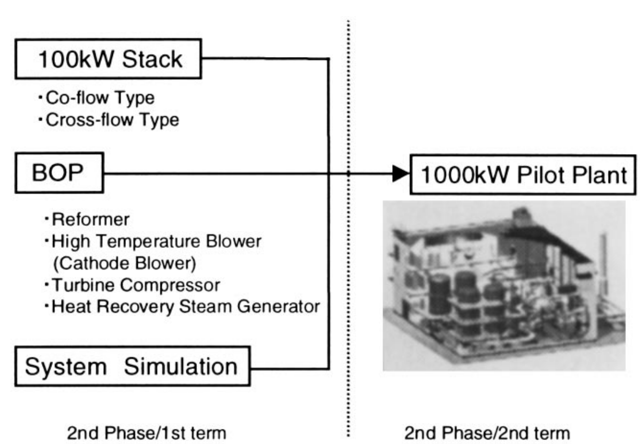

Fig. 2. The symbolic point of development.

Table 1

Specifications of the major components

Equipment	No.	Type	Remarks
Stack A	2	Cross-flow	Cell area 1.21 m^2
Stack B	2	Co-flow	Cell area 1.02 m^2
Reformer	1	2-Stage catalytic combustion	
Cathode gas recycle blower	2	High temperature-high speed motor, magnetic bearing	
Turbine compressor	1	C:Radial × 2 stage T:Axial × 2 stage	
HRSG	1	Smoke tube with fin	
Control system	1	Central control and monitoring	

gas. It has a two-stage compressor and a two-stage axial flow turbine for higher efficiency.

2.2.6. Electric equipment

A pulse width modulation, or PWM, control type inverter is used to obtain high efficiency and to reduce harmonic distortion. A large capacity insulated gate bipolar transistor, or IGBT, is adopted as the inverter device.

2.2.7. Control

The plant is controlled by two operators, from the control room.

2.2.8. Utility facilities and others

There are N_2, CO_2 and H_2 supply facilities in this plant. The control air supply line has a N_2 back-up line in order to maintain operation reliability and safety.

2.3. Plot plan

The pilot plant is presently under construction, at the Kawagoe Thermal Power Station, of Chubu Electric Power Company. Fig. 4 shows the site plan. The main components are placed indoors, except the HRSG and utilities. In the building there are a component's room, electrical equipment rooms and control room located on the second floor of the east area.

2.4. Development targets

Development targets for this pilot plant, are shown in Table 2.

2.5. Verification items

Verification items, for the pilot plant, are described below.

1. Confirmation of stack performance and decay rate.
2. System verification of basic process, control system and operation characteristics towards commercialization.
3. To acquire design data for demonstration plant.

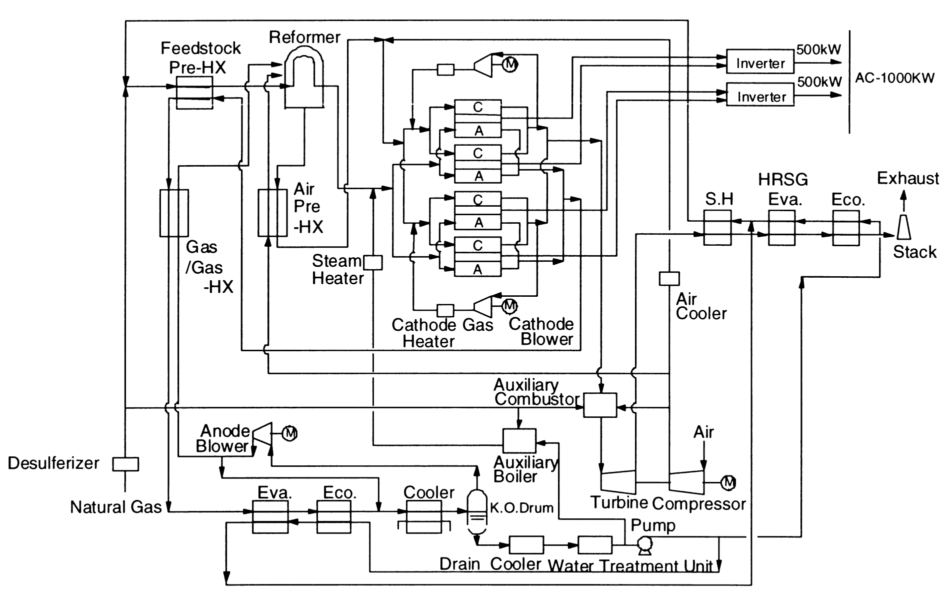

Fig. 3. Process flow diagram for the 1000 kW-class pilot plant.

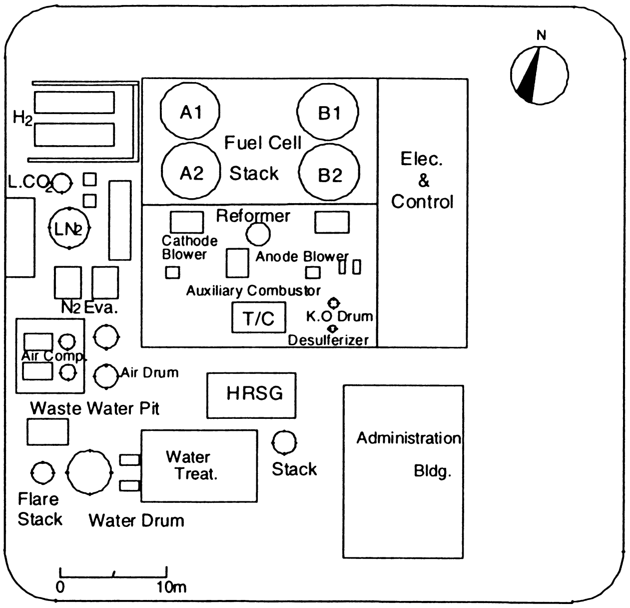

Fig. 4. Plot plan of the 1000 kW-class pilot plant.

2.6. Symbolic point of development

2.6.1. Fuel cell stack

The 250 kW-class stacks have almost the same specifications as 100 kW-class stacks tested in the 2nd phase/1st term, shown in Fig. 1. Table 3 shows the specifications of both the 250 kW-class stacks and the 100 kW-class stacks. The number of cells per stack, is increased, in order to increase the output per stack. To prevent carbonate salt from corroding, the material of separators are changed to SUS316L, from SUS310S.

2.6.2. Basic specifications of the pilot plant

The basic specifications of the pilot plant, have changed, as shown here in Table 4, which compares the specifications that were made at the elementary study, 2nd phase/1st term, to the specification of the actual pilot plant. Operation

Table 2

Development target of the 1000 kW-class MCFC pilot plant

Item	Target
Power output	1000 kW (AC)
Power generation efficiency	45% (HHV)
Fuel	LNG
Operation hours	5000 h
Stack decay rate	1%/1000 h
Environmental effect	Less than regulated value

Table 3

Specifications of the 250 kW-class and the 100 kW-class stack

	Co-flow		Cross-flow	
	100 kW	250 kW	100 kW	250 kW
Number of cells/block	51	70	22	25
Blocks/stack	2	4	4	12
Electrode				
Anode	Ni–Cr	NiAl–Cr	Ni–Co–Al	Ni–Co–Al_2O_3
Cathode	Advanced NiO	Advanced NiO	NiO–Ag	NiO–Ag
Separator	SUS310S	SUS316L	SUS310S	SUS316L
Electrolyte	Li–K	Li–K	Li–K	Li–K

Table 4

Comparison of the specifications of the plant

Item	2nd phase/1st term	2nd phase/2nd term
Operating pressure (ata)	3	5
Steam/carbon ratio	3	3.5

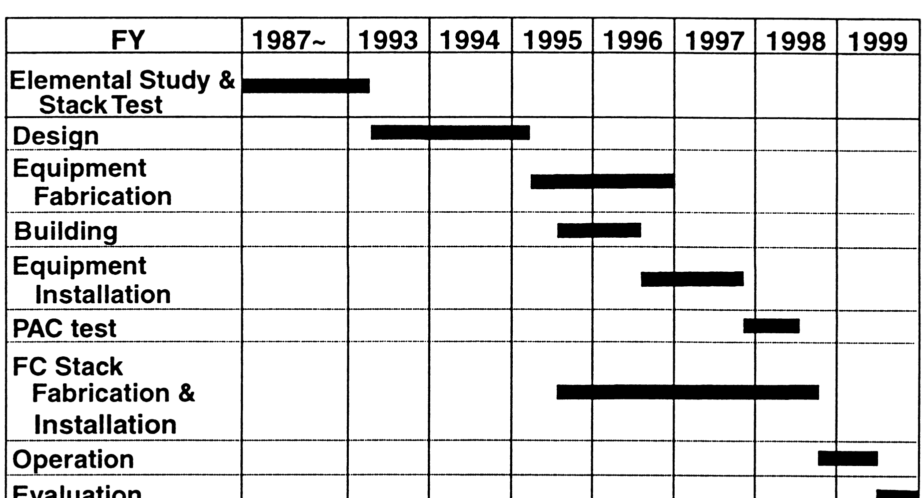

Fig. 5. Development schedule for the 1000 kW-class pilot plant.

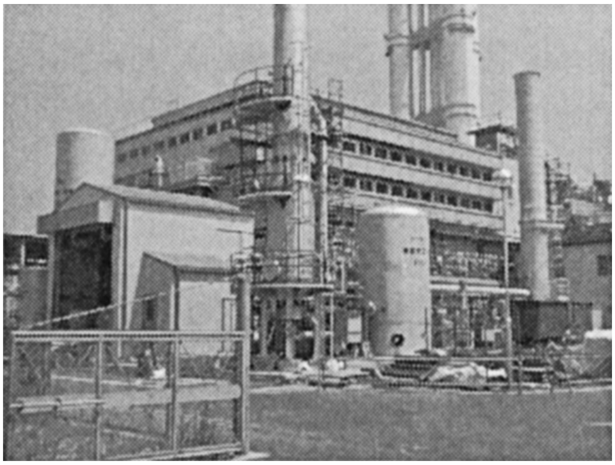

Fig. 6. The recent photo of the 1000 kW-class pilot plant.

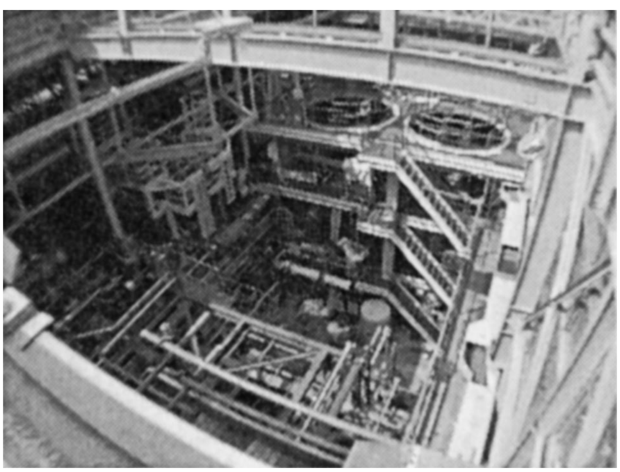

Fig. 7. The photo of the machine room (ground floor).

pressure was changed to 5 ata, from the original 3 ata because the pressure of the demonstration plant is expected to be 7–8 ata, or even higher. As a result of this change, the volume of flow is reduced and the components are made more compact. Again, the steam/carbon ratio is changed from 3 to 3.5, to avoid carbon formation and deposition within the cell.

2.7. Development schedule

Fig. 5 shows our development schedule of the 1000 kW-class MCFC Pilot Plant. The project began in 1993 and by the end of the fiscal year 1996, we completed the building work, fabrication of the plant's components, and are presently installing those components. Component adjustments will begin this December 1997. The process and control test, or PAC Test, will commence within the fiscal year 1997. Immediately following the PAC Test, the installation of the fuel cell stacks will begin. With any luck, we should be ready for operation by the start of the fiscal year 1999. Just now, we are investigating the evaluation program of PAC and operating test. Pictures of fabrication and equipment are shown in Figs. 6–9.

3. Commercialization

In order to better market or commercialize MCFC, we must give more effort to the following:

1. extend the lifetime of FC stacks;
2. improve stack performance;
3. improve on the reliability of the stacks and system;
4. reduce cost.

Today in Japan, research and development of long lifetime stacks take precedence over many other R&D programs. The several 10s kW long lifetime stack, with a projected capability of 40 000 h, is scheduled to be developed by the 1999. NEDO is now considering future projects for R&D, after the fiscal year 1999.

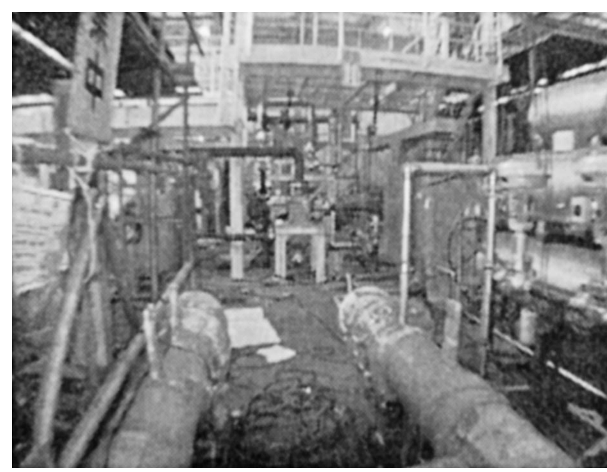

Fig. 8. The photo of the machine room (first floor).

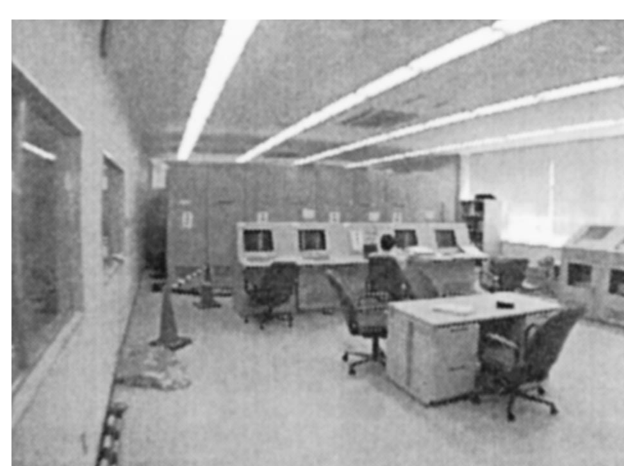

Fig. 9. The photo of the control room.

Acknowledgements

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