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Energy saving system using by-product hydrogen

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Abstract

The authors in conjunction with Shikoku Electric Power and Toagosei have been developing a new energy saving system using by-product hydrogen assisted by the Agency of Industrial Science and Technology (AISI) of the Ministry of International Trade and Industry (MITI) since 1993. The main unit of the system is a 100-kW class phosphoric acid fuel cell (PAFC) utilizing by-product hydrogen. The development technology of this hydrogen PAFC system include the following items; (1) recycling technology for using unreacted exhaust hydrogen at the anode outlet (2) safe processing technology of exhaust hydrogen. The system was constructed at the Tokushima plant of Toagosei and has operated from December 1996. The total operating time reached over 3000 h as of June 1997. The demonstration test will be conducted from 1996 through FY 1998. Published by Elsevier Science S.A.

Keywords: Energy saving system; By-product hydrogen; Recycling technology; Exhaust hydrogen

1. Introduction

Hydrogen is generated as a by-product of manufacturing processes in electrolysis and petroleum plants. In this study, we examine and develop systems for the effective utilization of this by-product. As the first stage, we developed a 100-kW phosphoric acid fuel cell (PAFC) that uses hydrogen as the fuel source, and a verification test of this system is currently underway in an electrolysis plant. This project has been supported by the AIST of MITI since 1993.

2. Content of research

Fig. 1 shows a system construction of the demonstration plant. The demonstration plant is constructed using a 100-kW hydrogen PAFC in which the electrical output generated is boosted to 3.3 kV and transmitted to the power distribution system in the plant, and the exhaust heat from the cell is converted to low pressure steam in a steam generator. The generated steam is supplied to the process steam network in the plant.

Fig. 2 shows a block diagram of the process. Fuel processing systems such as reformers are not required when utilizing highly pure hydrogen generated in an electrolysis plant. Instead, a processing technology for the release of unreacted hydrogen must be installed at the exit of the fuel electrode. Thus, we developed a hydrogen recycling technology using a variable ejector in which the pressure energy of the fuel is used as the driving power, and more than 90% of the unreacted hydrogen at the exit of the fuel cell is recycled to the inlet of the fuel electrode using a variable ejector. Thermal efficiency has been improved by introducing this technology while maintaining the hydrogen utilization rate of the cell at 80%. The cell characteristics are expected to deteriorate due to the concentration of impurities in the source fuel, thus, some of the unreacted hydrogen at the outlet of the fuel electrode was released from the processing system. During release, the concentration of hydrogen was maintained at a level below a half of the low explosion limit

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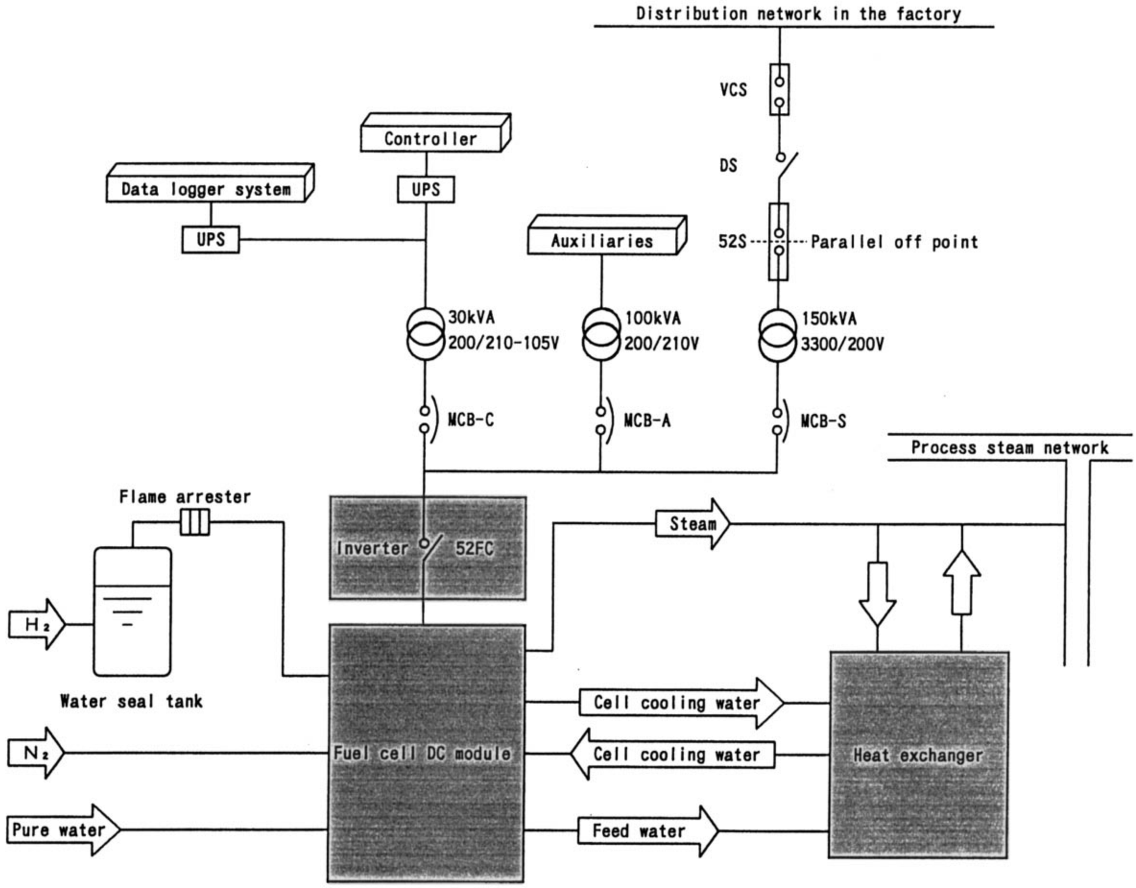

Fig. 1. System construction of the demonstration plant.

by mixing with process exhaust gas, thus, the systemz was carefully designed to prevent explosions. Furthermore, we also developed a system which incorporated a bi-directional heat exchanger in the water cooling system of the fuel cell. Using this system, the steam generated in the plant could be used to heat the fuel cell, thereby reducing power consumption during start up. The heat exchanger is also used as a steam generator during normal operation such that low pressure steam is produced using the high temperature waste heat from the fuel cell as the heat source, and the produced steam is sent to the process steam network of the plant.

Fig. 3 shows an illustration of the demonstration plant. Since the verification plant is located in a hydrogen-generating chemical plant, measures for the prevention of hydrogen explosions have been introduced at various points in the plant. For example, the inverter section is separate from the process section, and is located inside a building which also houses the power receiving/transforming systems. In addition, backfire relief devices such as a water seal pot and a flame arrester are incorporated. Furthermore, exhaust gas is released and diffuses into the atmosphere at a high position, and the operation sequence changes when the operation of fuel cells is terminated.

3. Results

The initial performance characteristics of the demonstration plant were confirmed by adjustment tests performed in November 1996, and complete operation began in December 1996. Table 1 shows the actual initial performances of the demonstration plant. Since the test was conducted soon after the inauguration of the plant, the cell voltage was higher than the designed value; in addition, the use of auxiliary power was reduced, therefore, the generation efficiency at the transmission terminals of the fuel cell was

Table 1

Specifications and initial performances

	Specifications	Initial performances
Rated output	l00 kW	
Efficiency (HHV)		
Electrical	38%	40.5%
Thermal	30% (steam)	33% (steam)
	10% (hot water)	9% (hot water)
Fuel	By-product hydrogen (>99.9%)	
Start-up time	<1.5 h (cold start)	
Manufacturer	Fuji Electric	

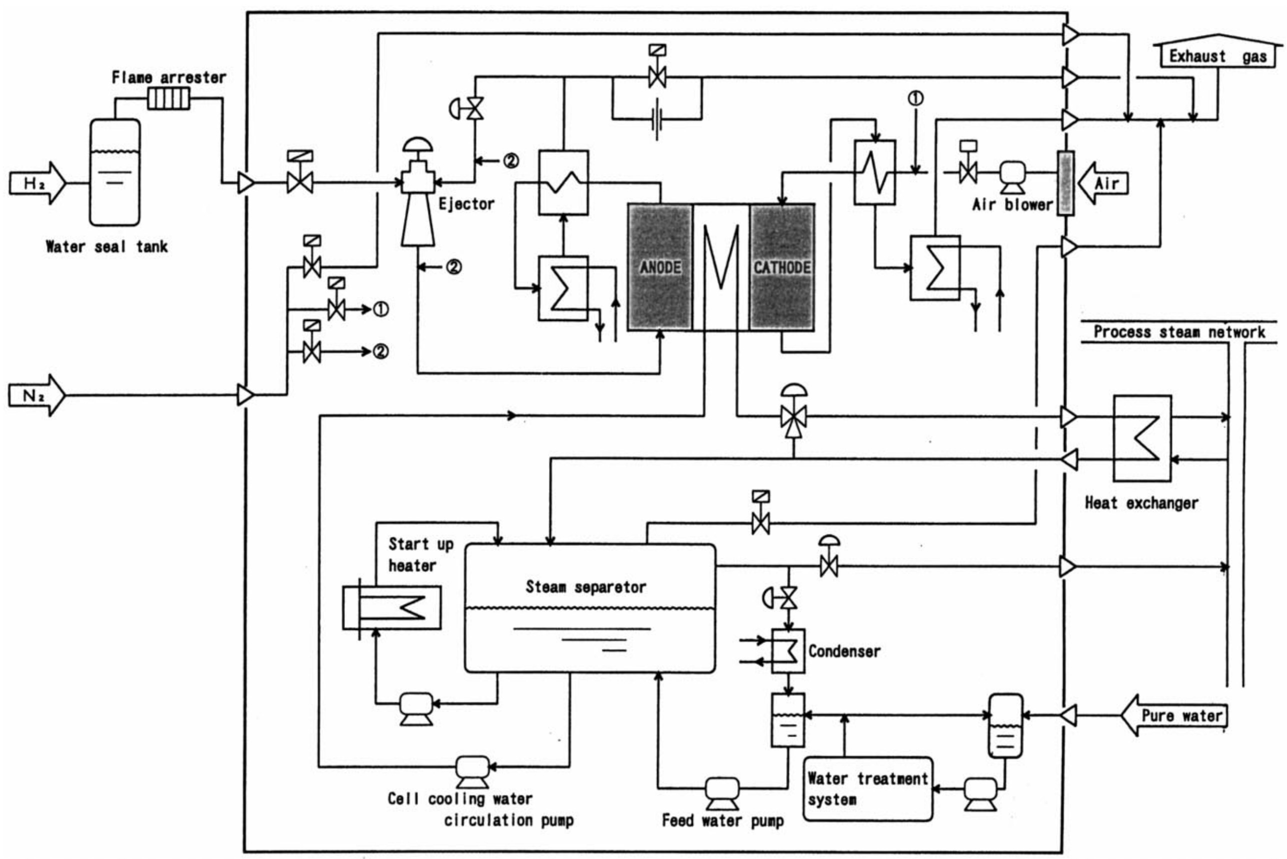

Fig. 2. Block diagram of the process.

2% higher than the target value, demonstrating the excellent performance of the system. Also, the amount of steam recovered was almost 10% higher than the target value. Furthermore, since the system does not include devices such as reformers and desulfurizers whose start-up speeds are limited by the temperature conditions of the environ-

Fig. 3. Illustration of the demonstration plant.

ment, the start-up time under cold temperature conditions was less than 1.5 h. Thus, the characteristic features of hydrogen utilizes phosphoric acid type fuel cell power generations systems have been maintained. So far, the plant has been operated for approximately 3000 h, and no problems relating to the development technology have developed (end of June 1997). However, during the early stage of operation of the plant, several problems, including the malfunction of the data transmission system due to system noise developed which led to the emergency termination of operation. Sourcing of the components required to resolve these problems was time consuming, but all the problems were fixed by March 1997.

4. Conclusions

We plan to continue the test operation for two years to demonstrate that these development technologies can perform as expected under actual operating conditions. We now face the emergence of global environmental problems and the uncertainty of petroleum supply, and in examining future energy issues, the task of energy saving is important. As part of these efforts, energy saving through the use of by-product hydrogen must be regarded as an important measure. We hope that the new technology will be widely used and will contribute to advance energy saving technology.