Development of On-Site Phosphoric Acid Fuel Cell Units

1. Introduction

Fuji Electric is working on the development of phosphoric acid fuel cell (PAFC) with the aim of introducing them to the market. As of the end of December 2000, a total of 95 units of 50kW, 100kW and 500kW fuel cells have been manufactured and delivered. Of that number, 16 units are still now in operation.

The total cumulative operating time has exceeded 1.5 million hours. 17 units have exceeded operating times of 30,000 hours and six units have exceeded times of 40,000 hours. The longest continuous operating time exceeded 10,000 hours. These successful operating records have resulted from the improvement in stability and maintainability utilizing valuable operational experiences of the first-generation power units. It may be safely said that the durability and reliability of PAFC power units have reached a level suitable for commercial use.

Since 1992, Fuji Electric has been working on the development of second-generation power units with the aim of substantially improving reliability and maintainability, and at present, is engaged in the development of low cost commercial units which can be introduced to the market.

This paper introduces the present status of development of 100kW PAFC power units for commercial use to which Fuji Electric is devoting its energies.

2. Development Plan of On-Site Power Units

Further cost reduction is necessary if fuel cells are to thrive in the market. As for on-site fuel cell power units, Fuji Electric is working basically on its own to reduce total costs over the entire range from design and manufacturing to maintenance, focusing on the overall development of 100kW PAFC power units.

2.1 Development of new-type 100kW units

Based on valuable operational experiences of the first-generation units including 100kW and 50kW units, Fuji Electric has developed a second-phase prototype unit aiming at improved reliability and maintainability as a power unit. This unit was installed at Fuji Electric’s Chiba Factory in March 1995, and since then has performed approximately 16,000 hours of operation for evaluation.

Based on the second-phase prototype unit, Fuji Electric has been developing a commercial prototype and the first-commercial-type units through system simplification and unit size reduction.

Figure 1 shows the comparison of external dimensions of various new-type 100kW units and Table 1...
lists the delivery and operational records of the second-generation units.

Fuji Electric delivered the commercial prototype 100kW unit in 1997 and the first of the first-commercial-type 100kW units in 1998, costing half that of conventional units. Since then, the unit has been operating at high availability, proving its high reliability.

Fuji Electric reduced the cost of the first-commercial-type units to 600,000 yen/kW while improving their reliability, and is planning to reduce the cost of the second-commercial-type units to 2/3 that of the first-commercial-type units.

2.2 Development of an improved 50kW unit

Fuji Electric has worked on the development of an improved 50kW unit aimed at enhancing reliability, based on the system of the second-phase 100kW prototype.

The accumulative operating time has reached 32,000 hours (as of the end of December 2000) and the unit is still operating with more than 90% availability, proving its reliability and durability to be at a level suitable for practical use.

3. Second-Commercial-Type Units

3.1 Development of the second-commercial-type units

Fuji Electric is now devoting its energies to the development of second-commercial-type units aiming at reduced cost, improved durability and enhanced functions.

Figure 2 shows an exterior view of a second-commercial-type 100kW unit and Fig. 3 shows a view of the interior.

The first of the second-commercial-type units was installed at Fuji Electric’s Chiba Factory in November 1999, and the accumulative operating time has reached

<table>
<thead>
<tr>
<th>Item</th>
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<td>Improved 50kW unit</td>
<td>Mikuni Heights via The Kansai Electric Power Co., Inc.</td>
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<td>Town gas</td>
<td>33,600 h</td>
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<td>Improved 50kW unit</td>
<td>Kamishiro substation of Chubu Electric Power Co., Inc.</td>
<td>Nov. 1996</td>
<td>LPG</td>
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<td>Snow melting</td>
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<td>Commercial prototype 100kW unit</td>
<td>Headquarters Factory, Toyota Motor Corp. via Toho Gas Co., Ltd.</td>
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<td>23,600 h</td>
<td>Heating of cleaning water</td>
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<td>Improved 50kW unit</td>
<td>TGS Akabane Bldg. via Tokyo Gas Co., Ltd.</td>
<td>July 1998</td>
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<td>First-commercial-type 100kW unit</td>
<td>Nagoya Sakae Washington Hotel Plaza via Toho Gas Co., Ltd.</td>
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<td>Town gas</td>
<td>15,500 h</td>
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</tr>
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<td>First-commercial-type 100kW unit</td>
<td>COOP Himeji Shirahama Store via Osaka Gas Co., Ltd.</td>
<td>March 1999</td>
<td>Town gas</td>
<td>15,800 h</td>
<td>Air conditioning</td>
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<td>First-commercial-type 100kW unit</td>
<td>Shonan Fujisawa Campus, Keio University via Tokyo Gas Co., Ltd.</td>
<td>April 2000</td>
<td>Town gas</td>
<td>5,400 h</td>
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<td>First-commercial-type 100kW unit</td>
<td>Fundamental Technology Laboratory of Tokyo Gas Co., Ltd.</td>
<td>June 2000</td>
<td>Town gas</td>
<td>4,400 h</td>
<td>Water heating desiccator</td>
</tr>
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<td>First-commercial-type 100kW unit</td>
<td>Fundamental Technology Laboratory of Tokyo Gas Co., Ltd.</td>
<td>June 2000</td>
<td>Town gas</td>
<td>4,200 h</td>
<td>Water heating desiccator</td>
</tr>
</tbody>
</table>
7,500 hours (as of the end of December 2000). Verification tests are being conducted with the goal of shipping product by 2001.

Improved durability will extend the interval between overhauls, leading to a reduction in running cost.

In order to expand the use of waste heat, a water-fired chiller (10-ton refrigerator, 35kW) was installed at the Chiba Factory and is scheduled to undergo a combined test with a second-commercial-type 100kW unit in the future.

As optional enhanced functions to expand the application of fuel cell power units, Fuji Electric is scheduled to develop a system to extract steam directly from a steam separator for the purpose of improving the quality of waste heat, and a fuel switching system aimed at improving power supply reliability with a duplex fuel supply.

With a fuel switching system, in case of an emergency, the fuel can be switched from town gas, the fuel for normal operation, to liquefied petroleum gas (LPG), the back-up fuel. This system allows for a continuous power supply.

3.2 Features of second-commercial-type units

3.2.1 Fuel cell

Fuji Electric has developed a new-series of fuel cells, eliminating the need for phosphoric acid replenishment after a period of 60,000 hours, improving the corrosion resistance of cooling pipes for higher reliability, and determining an optimum cell size for stable operation, efficiency and low cost power units.

3.2.2 Fuel processor

To achieve higher reliability and lower cost of fuel processors, Fuji Electric has developed a new series of fuel processors consisting of compact reformers with built-in heat exchangers to preheat fuel gas, and combined desulfurizer/CO shift converter units with built-in heat exchangers. Cubic-type combined desulfurizer/CO shift converter units were adopted for an effective use of inside space, compactness and cost reduction of power units.

3.2.3 Auxiliary devices (balance of plant)

To reduce costs and ensure reliability, selection of the optimum types of auxiliary devices in a power unit and reduction of the number of their parts are performed based on past operational records. Fuji Electric has independently developed a heat exchanger, a steam separator and a steam ejector to substantially reduce their size and cost and to improve maintainability, without sacrificing the compactness of their optimum arrangement.

Figure 4 shows a configuration of a second-commercial-type 100kW unit.

At the front of the unit are installed main devices such as the fuel cell, reformer and its associated devices. Even when the unit is installed indoors, those devices are arranged such that they may be drawn out to a front-side service area using a manually operated lifter. At the rear are installed devices that require easy access for regular maintenance. The ventilation fan capacity was optimized for lower noise. In addition, development is being conducted on an option to reduce nighttime noise to the targeted 55 dB(A) through the optimization of ventilated air volume by controlling fan revolution corresponding to daily or seasonal change in atmospheric temperatures.

Construction of the frames and panels of the unit was simplified and their weight reduced. Together with system simplification, the weight of the second-commercial-type unit was reduced by 2,000kg compared with first-commercial-type units.

3.2.4 Inverter

The design of the inverter stack was optimized using Fuji Electric manufactured IGBT (insulated gate bipolar transistor). A water-cooled cooling system has replaced the air-cooled system to reduce inverter size and noise. Heat pipes are used in the cooling system to shield a portion of the inverter panel and to improve its environmental resistance.

3.2.5 Control system (for plant control)

A Fuji Electric manufactured programmable controller is used for unit control to simplify the construction and to reduce costs. As in the case of the inverter panel, heat pipes are used in the cooling system of the control panel to shield a portion of the panel and to improve its environmental resistance.

In addition, remote data monitoring using public telephone lines is available for preventive and routine
3.3 Improved durability of second-commercial-type units

In order to improve durability of power units, the targeted replacement interval for main devices is an extension of the interval from the current 40,000 hours to 60,000 hours. Based on analysis of the useful life of auxiliary devices and consumable parts of second-generation units, Fuji Electric has the goal of extending the replacement interval of auxiliary devices such as pumps, blowers and valves from two to three years. In the second-commercial-type units, extension of the replacement interval allows a substantial reduction in maintenance costs.

4. Heat Utilization Technology

Concurrent with device development, a heat utilization system is under development to utilize waste heat yielded during power generation. Effective use of waste heat from fuel cells includes a water-fired chiller, a waste-heat-driven direct-fired absorption chiller and a refrigerator, leading to total cost reduction of the power units.

4.1 Hot water utilization system

A cogeneration power plant was installed at the Chiba Factory to directly feed 85°C to 95°C hot water to a water-fired chiller for air conditioning and the plant is undergoing performance evaluations for system simplification and energy-saving operation. Figure 5 shows a hot water utilization system flow.

In summer and winter times, the testing field is air-conditioned by operating a water-fired chiller that utilizes hot wastewater from the power unit.

4.2 Waste heat treatment equipment

During periods of light heating load such as in spring, autumn and at night, it is necessary to cool excess waste heat from the fuel cells. For this purpose, water-cooled coolers such as cooling towers were used in the first-generation power units.

In the second-commercial-type power units, enclosed air-fin coolers are scheduled to be used as maintenance-free coolers. An enclosed air-fin cooler is currently installed at the Chiba Factory and is undergoing performance evaluations.

Figure 6 shows a waste heat treatment equipment.

The air-fin cooler is slated for performance examination and its size and costs will be reduced.

The cooling water pump and valves can be housed under the air-fin cooler, leading to reduced on-site installation time and lower construction costs.

4.3 Steam utilization system

With the second-commercial-type units, excess
waste heat from a fuel cell can be recovered by directly extracting 160°C steam from the steam separator in a power unit and feeding it to a steam header.

When steam is extracted, the electrical conductivity of external return water is likely to increase, and hence some countermeasures are necessary to prevent degradation of the water quality. An electric deionizer has been installed beside the power unit in the factory and is undergoing performance evaluations.

5. Conclusion

On-site phosphoric acid fuel cell units seemed to have reached a commercial level in terms of performance and reliability, but further cost reduction is essential for their full-scale proliferation.

On the other hand, phosphoric acid fuel cells have the advantage of utilizing biogas from garbage and by-product hydrogen from factories, leading to a reduction in carbon dioxide and recycling of wastes. With increased consciousness about the environment and enforcement of laws promoting the exploitation of alternative energy including fuel cells, desire for the introduction of fuel cells is rising.

Fuji Electric is determined to do its utmost in creating the market for and in commercializing on-site fuel cell power units through improving reliability, reducing costs of fuel cells and expanding their new applications in the future.

Finally, special thanks must be given to the authorities concerned and users for their cooperation and guidance. Their continued support would very much be appreciated.
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