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DEVELOPMENT OF ON-SITE FUEL CELL POWER UNITS : GENERATING UNITS

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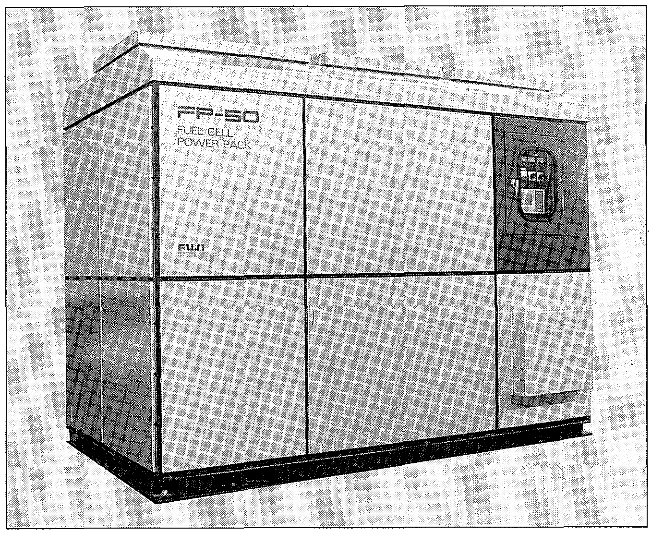
1. FOREWORD

Fuji Electric started developing commercial 50 kW and 100 kW on-site phosphoric acid fuel cell power units using natural gas and LPG as fuel in cooperation with three major gas companies: Tokyo Gas, Osaka Gas, and Toho Gas Cos., Ltd. in May 1989. Since 1987 Fuji Electric has been developing 50 kW on-site fuel cell power units in cooperation with Tokyo Gas Co., Ltd. The results of this development were incorporated in this development.

The development points were size reduction and improvement of reliability of the fuel cell, reformer, electric and control systems, and other main components and cost reduction by establishment of mass production technology. After a trial unit containing newly developed results will be made and put to performance and field tests for operation evaluation, trial mass-produced units are being put to monitor tests in 1991 and 1992. This paper introduces the on-site fuel cell power units, mainly 50 kW units.

Fig. 1 Prototype 50 kW plant



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2. DEVELOPMENT UNIT COMPOSITION

The fuel cell power unit consists of four elements: fuel processor, fuel cell stack, inverter, and controller. It is divided into a section which houses a DC module made up of the fuel processor and fuel cell stack and a section which houses an electric module made up of the inverter and controller. The unit is constructed by mounting these two sections on a common base and housing them in a single package. The prototype 50 kW plant is shown in *Fig. 1*.

The process flow diagram for the 50 kW plant is shown in *Fig. 2*. The fuel processor consists of a desulfurizer, reformer, and one-stage CO shift converter. The fuel cell is one stack. Pipes are connected to the anode, cathode, and cooling plate input and output manifolds. The generated power (DC) is taken from collectors at the top and bottom of the stack and is sent to an inverter.

Waste heat recovery is performed at a heat exchanger (low grade heat exchanger) that cools the reformer combustion exhaust gas and cathode offgas and a heat exchanger (high grade heat exchanger) that recovers the fuel cell cooling system surplus heat. The utility piping consists of six or eight pipes: feed gas, exhaust heat recovery water out and return lines (two each when recovered by dividing into low temperature and high temperature), nitrogen gas, feed water and drain pipes. These pipes are concentrated at one place so that piping arragement and installation work can be performed easily.

The surrounding air is sucked in from the bottom of the outside plate by a ventilation fan and is discharged from an exhaust port at the top and used to ventilate the inside of the package and cool the internal devices. As for the reaction air supplied to the fuel cell and the reformer combustion air, a part of the air sucked into the package is blown into the system by an air blower and is exhausted from the exhaust pipe.

A startup boiler can be installed as an option. This boiler is provided to reduce the power consumption at atartup. At startup, heat is supplied to a steam separator and is used for warning the reformer steam and fuel cell.

The fuel cell power unit one line diagram is shown in *Fig. 3*. The DC power generated by the fuel cell is converted to AC power by an inverter. Part of this power is consumed by the auxiliaries and the remaining power is output from the terminal.

Fig. 2 Process flow diagram for 50 kW plant

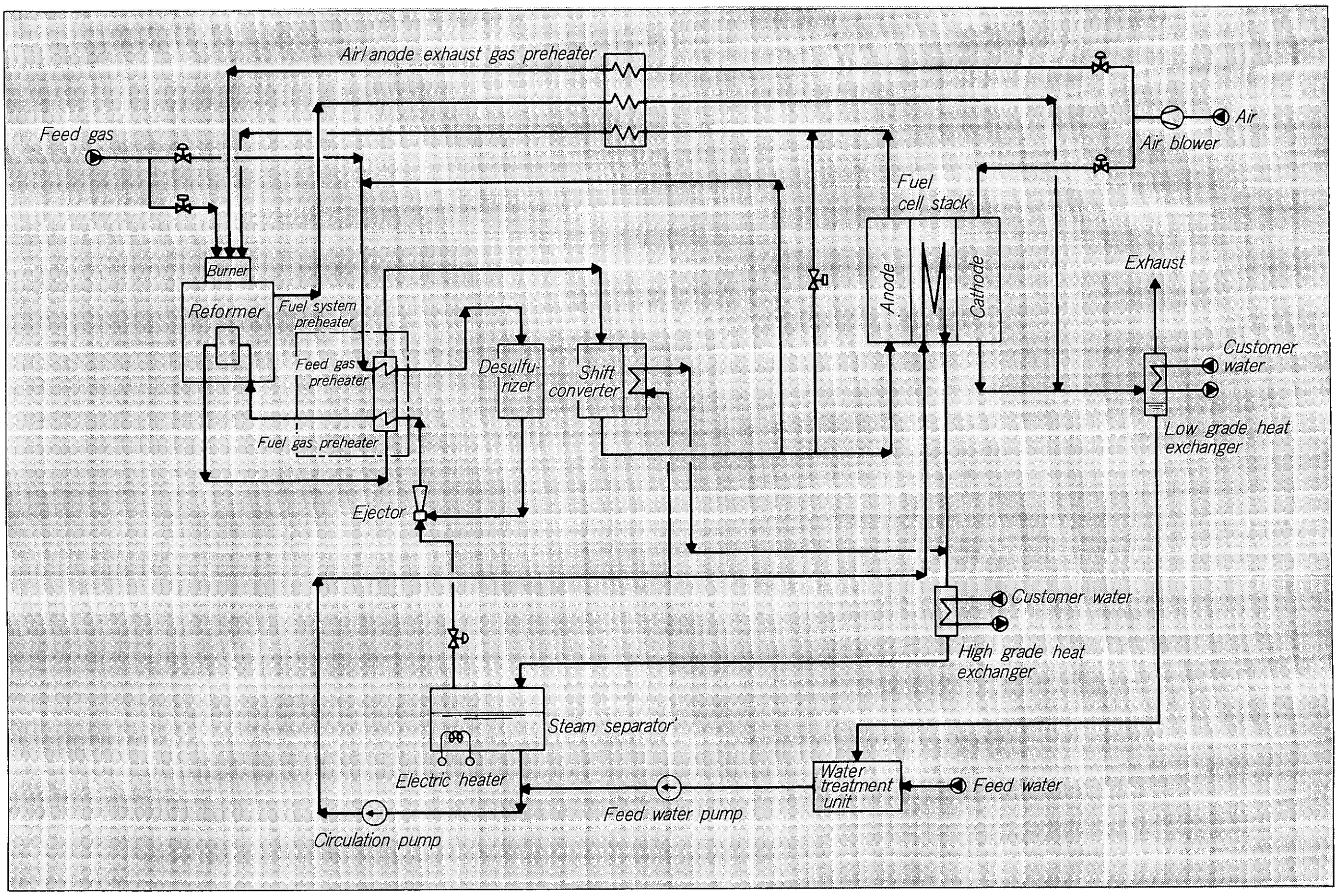
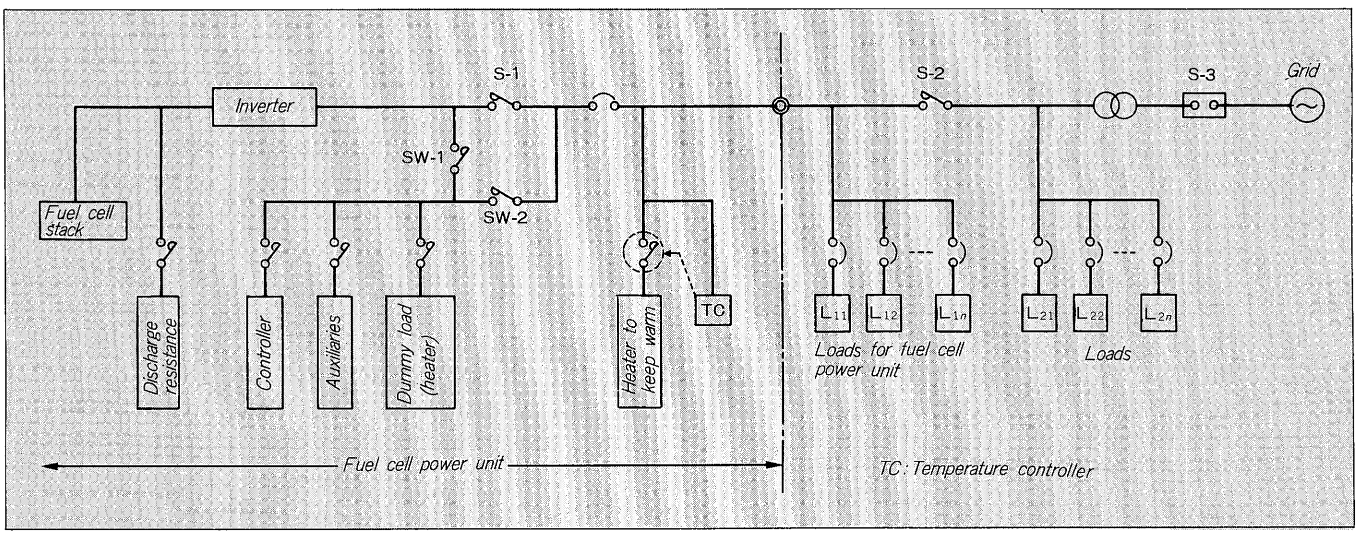


Fig. 3 One line diagram



At startup, the auxiliaries are operated by power received from an outside power source and the unit is heated up by an electric heater installed to each unit. The electric heater provided at the steam separator is also used as the load resistor (dummy load) in the standby mode.

3. GENERATING UNIT OPERATION MODES

The generating unit has six operation modes: stop, startup, standby, grid connected, grid independent, and shutdown operation.

Startup is divided into three steps: heating mode 1, 2, and 3. Heating mode 1 is a process that heats the reformer catalyst by burning the feed gas. Heating mode 2 is a process which heats the reformer until the reformed gas reaches the specified stable composition by introducing the fuel gas at the reformation catalyst and burning the generated reformation gas that bypasses the fuel cell stack. Heating mode 3 is a process which heats the fuel cell and other equipment until 100% output becomes possible while generating electricity by introducing fuel and air to the fuel cell stack. In heating mode 1 and heating mode 2, operation is performed by receiving power from the outside. In heating mode 3, the power generated by the fuel cell is consumed in the auxiliaries and dummy load and the unit operates independently from the outside.

The standby mode is the state in which unit operation is electrically independent from the outside. The inverter is operated by AVR control (constant voltage control).

The standby mode is electric output 0 operation and is an operation mode which bridges the startup and grid connected or grid independent mode. Essentially, the end of startup (heating mode 3) and start of shutdown operation (cooling mode 1) are the standby mode.

The grid connected mode is the state in which the unit is connected to the power grid or a separate power supply and operated. The inverter is operated by PQ control (constant power control). The generating unit sending output is controlled so that it becomes the output value (active power and reactive power) specified from the outside. Parallel in grid can be performed by switch inside in the package (S-1 of *Fig. 3*) or by external switch (for example, S-2 of *Fig. 3*). Since the switch is closed when the voltage and the phase of output power from fuel cell unit are matched to them of the grid by controlling inverter, connection is performed without disturbing the electric grid. When parallel in by external switch is desired, voltage signals (voltage and phase) of the output power from fuel cell and the grid must be given to the generating unit. The parallel in switch (S-1 or S-2) must be selected beforehand.

The grid independent mode is the state in which the generating unit supplies the power to the load independently from the grid. The inverter is operated by AVR control.

Shutdown operation has two steps: cooling mode 1 and cooling mode 2. Cooling mode 1 is a mode provided because exposing the cell to high temperature and high potential states is not desired. It is a process that slowly lowers the temperature of the cell in the generating state. Cooling mode 2 is a process which stops generation and purges the fuel processor and anode and cathode with nitrogen gas and lowers the cell voltage by connecting a discharge resistor and decreases the cell temperature to the specified value by forcefully cooling the cell cooling water.

4. GENERATING UNIT SPECIFICATIONS, CHARACTERISTICS, AND PERFORMANCE

(1) Type

The type of fuel cell is phosphoric acid, the operating pressure is atmospheric pressure (several hundreds mmAq), and the cooling method is water cooling. The maximum working pressure in the fuel processor is up to 1 kg/cm^2.

(2) Construction

The generating unit has a package construction and can be transported without disassembling. The entire unit is covered by a metal panel and is protected so that the internal devices cannot be touched with the hand.

(3) Dimensions and weight

The dimensions of the 50 kW plant are length 3.1 m, width 1.75 m, and height 2.2 m. Its weight is 6.5 t. The design values for the 100 kW plant are length 3.5 m, width 2.3 m, and height 3.2. The weight is 11 t.

(4) Fuel

The kinds of fuel used are city gas (13A) or LPG. The supply pressure is 200 mmAq, but use within the low pressure gas supply standard (100 to 250 mmAq) is possible.

(5) Electric output

The rated output is 50 kW and 100 kW at sending end. The voltage is 3-phase 200 V or 220 V and the frequency is 50 Hz or 60 Hz. The power factor is 1.0, but operation up to ±0.85 is possible at the rated load.

(6) Efficiency (LHV base)

The generating efficiency of the 50 kW plant is 36% to 40% at sending end and its overall efficiency is 80%.

(7) Exhaust heat recovery

65 °C hot water is standard. (Return water temperature 40 °C)

Since the high temperature exhaust heat recovery amount of the 50 kW plant is small, it is made hot water output only, but since the heat recovery amount of the 100 kW plant is large, we plan to install a reaction air preheater to raise the high temperature recovery ratio and to output usefull steam or 80 to 90 °C hot water.
high temperature water.

(8) Operation system

Operation is made automatic so that unmanned operation is possible. Protective device is installed and the unit is automatically stopped safely when an abnormality occurs.

And installation of signal line for remote supervision and control is possible.

(9) Operation modes

Grid connected and grid independent operation are possible.

In the grid connected mode, when an abnormal grid voltage or abnormal grid frequency is detected, the unit is disconnected automatically. In the grid independent mode, when an abnormality (overload, overcurrent, etc.) is detected at the load side, the unit automatically shifts to the standby mode.

(10) Startup time

Cold startup 3 hours and warm startup 1 hour are standard.

If a startup boiler is provided, cold startup 1.5 hours is also possible.

(11) Electric power for startup

For the 50 kW plant, 30 to 35 kW is necessary. When a startup boiler is provided, 7 kW is sufficient.

(12) Feed water

During rated operation, water feed is unnecessary. When the heat used is small, since the water is insufficient, water feed becomes necessary. City water is used as the feed water. This water is purified by a water processor inside the unit and the purified water is supplied to the cell cooling water system.

(13) Nitrogen gas

Nitrogen gas is used as the inert gas which removes the fuel gas, etc. inside the cell and fuel processor. Supply from a nitrogen cylinder is standard, but, when available, a nitrogen supply source can be used.

Automatic shutdown is possible by sending a low nitrogen gas amount or low supply pressure signal to the generating unit.

(14) Safety

When an abnormality was detected, or when a stop signal was received, the generating unit stops automatically.

Since the inside of the generating unit is constantly ventilated by a ventilation fan as an explosion-proof countermeasure, even if flammable gas leaks, it does not remain in the unit. A flammable gas detector is also installed in the unit. For indoor installation, the room must be ventilated.

5. CONCLUSION

To commercialize on-site fuel cell power generating units, a unit that is compact, easy to operate, highly reliable, and low cost must be developed. Efforts are being made to realize such a unit at an early date. Finally, the authors would like to thank the Tokyo Gas, Osaka Gas, and Toho Gas Cos. Ltd. for their guidance and cooperation in this development and ask for their assistance in the future.