UDC 621.311.28:[621.352.6:546.185-325] :629.114.5

DEVELOPMENT OF FUEL CELL POWER UNIT FOR VEHICLES

Hiroyuki Tajima
Osamu Yamamoto
Syunsuke Ohga

1. FOREWORD

Application of fuel cells as a power source for transportation, as well as an on-site power source and dispersed power sources, is desired. It will be very helpful to solve the noise and air pollution problems because of its features of low noise, clean exhaust, and high efficiency.

The technical considerations demanded to a fuel cell for power units of vehicles are:

(1) Easy handling of fuel (storage and shipment)
(2) Compact size which allows mounting in a vehicle
(3) Simple operation
(4) Safety
(5) Competitiveness with cost and power of conventional vehicle

Fuji Electric developed a power unit which hybridized a methanol reforming, liquid-cooled phosphoric acid fuel cell with a battery, in cooperation with Englehard Co. of the United States.

Using this technology, Fuji and Englehard manufactured prototype 5 kW fuel cell power unit for forklift-truck and proved that this hybrid power source could be a vehicle power source.

From 1988, Fuji Electric participated in the project of "Research and Development of a Phosphoric Acid Fuel Cell/Battery Power Source Integrated in a Test-Bed Bus" (This project is promoted by the Department of Energy (DOE) of America.) and started the development of a fuel cell/battery power units for small transit buses.

This paper introduces the results of the 25 kW power unit developed by Fuji Electric at Phase I as a first stage of the DOE plan, and the outline of 50 kW power unit for Phase II.

2. OUTLINE OF THE FUEL CELL/BATTERY POWERED BUS PROJECT

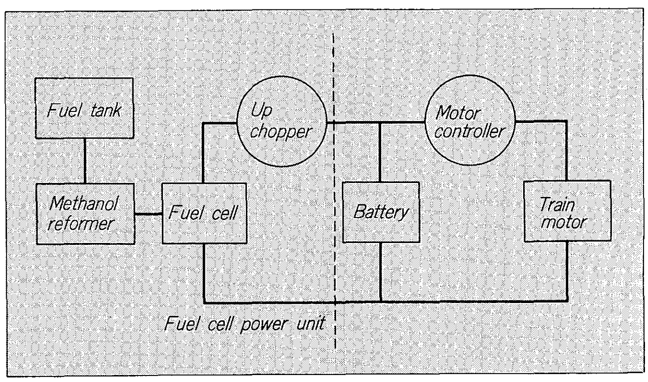
This program was entrusted to Fuji Electric by the Department of Energy (DOE) of America. This program is to develop a phosphoric acid fuel cell/battery hybrid electric bus with methanol as the fuel as a countermeasure of the air pollution brought about by combustion engine, especially diesel engine.

Table 1 shows the plan of this project.

Table 1 DOE/DOT fuel cell/battery powered bus program

Phase I 1988~1989	Proof of feasibility (1/2 scale of TBB: Brassboard system)
Phase II	Proof of Concept (full scale system for test-bed bus)
Phase III	Test-bed bus evaluation (Test and evaluation under a controlled field operations.)
Phase IV	Prototype bus testing (Small fleet evaluation under urban route)

Fig. 1 Fuel cell/battery hybrid system block diagram



A demonstration model of a transit bus will be completed by 1996. Bus manufacturer, system engineering firm, and fuel cell manufacturer expect to participate in this project to develop new electric vehicle.

3. PRINCIPLE OF FUEL CELL POWERED BUS

The propulsion system of a fuel cell/battery powered bus consists of a fuel cell, battery, and a power converter which is used to connect them electrically. The fuel cell and battery supply power to the vehicle propulsion system in parallel as shown in *Fig. 1.* The battery supplies peak power at starting or accelerating of the bus.

Fuel cell recharges the battery during light loads as the bus is running at slow speed or temporarily stops.

The fuel cell system consists of a phosphoric acid fuel cell, a methanol reformer, auxiliaries to supply fuel and air, and a system control unit. The methanol reformer is controlled at an operating temperature of 260°C and the

Table 2 25 kW Brassboard experimental model specifications

Fuel cell	Liquid cooled phosphoric fuel cell
Gross power	25 kW (DC25.8 V x 480 A)
Efficiency	38% (LHV, auxillary power included)
Fuel	Methanol
Operation	Fully automatic
Configuration	Brassboard (off board)

Table 3 25 kW Brassboard experimental model test results

Gross power	25 kW (DC52.8 V x 480 A)
Net power	23.2 kW
Efficiency	36.6% (LHV base, auxiliary power included)
Composition of exhaust	CO: 30 ppm NO_x: 0.5 ppm C_mH_n: nil

Fig. 2 Fuel cell power unit schematic flow

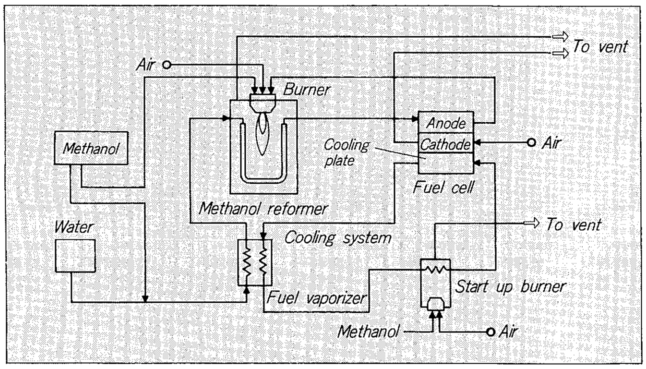
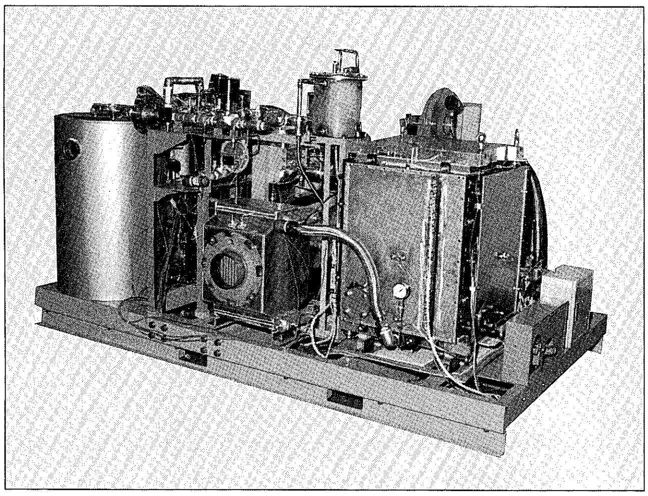


Fig. 3 25 kW Brassboard experimental model



fuel cell is controlled at an operating temperature of 190°C. The reformer catalyst reaction that converts methanol to hydrogen is endothermic, and the electric generation reaction of a fuel cell is exothermic, So the generated heat of a fuel cell can be used for the reforming reaction and the system efficiency can be raised. Fuji Electric realizes this idea by applying liquid cooling system, and also achieves compactness which is suitable for vehicles.

4. PHASE I DEVELOPMENT (25 kW BRASSBOARD EXPERIMENTAL MODEL)

The 25 kW Brassboard is a model plant of approximately 1/2 output power of full size system mounted in the bus. It was manufactured for functional evaluation of the fuel cell/battery hybrid system and propulsion system. This 25 kW Brassboard type as a experimental model was delivered to the United States in June 1989 and the evaluation tests were conducted by the US team.

The specification, configuration, and tests results of this 25 kW Brassboard model are described below.

(1) Specifications and configuration

The specifications of this model are shown in *Table 2*. Its schematic flow is shown in *Fig. 2* and its appearance is shown in *Fig. 3*.

Following is explanation of the system operation.

During the startup, the methanol is burned by the startup burner and the coolant is heated with this heat. This coolant is circulated through the fuel cell stack and heat it. For the reformer, the methanol is burned by an internal burner and the reformer catalyst is heated up to the operating temperature. On the other hand, when the fuel cell begins to generate electricity, the heat generated by it is removed by the cooling system and is utilized to vaporize the methanol and water which is used as fuel. This vaporized mixture fuel is converted to hydrogen by steam reforming reaction on the catalyst of the reformer. This hydrogen reacts electrochemically with the oxygen supplied separately into the fuel cell and generates electricity.

The unreacted hydrogen (surplus hydrogen) inside the fuel cell is burned by the reformer burner and is used as the heat needed for the reforming reaction. The generated DC power is supplied to the load through an up chopper.

(2) Test Results

The test results of the 25 kW Brassboard experimental model conducted in the United States are given below.

These tests were performed by the participating United States team by using a battery monitoring and load pattern simulation system. *Table 3* shows the test results at the rated output.

These results satisfied the specifications and passed the DOE witness test. Particularly, the NO_X concentration in the exhaust gas was very low, less than 0.5ppm. This shows that the fuel cell bus has a great capability of improving the air pollution problem.

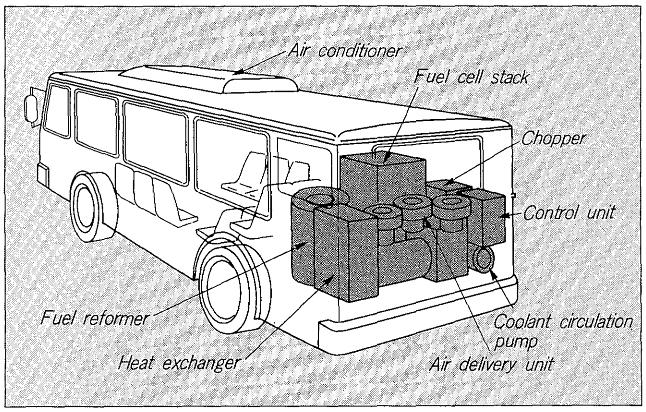
The fuel cell stack was developed to be more compact, 50% less in weight and 40% less in volume, than conventional one and was highly evaluated by DOE.

The results proved that the fuel cell/battery hybrid system was feasible and that the Fuji Electric fuel cell power unit could be applied to a bus.

Table 4 50 kW fuel cell subsystem for bus (Phase II)

Output	48 kW
Efficiency	38% (LHV)
Fuel consumption	Methanol: 23.6 kg/h Pure water: 20.0 kg/h
Startup time	Within 25 mins
System	Dimensions (mm): 1,300 (L) x 2,100 (W) x 1,450 (H) Weight: Approx. 1,300 kg

Fig. 4 Fuel cell/battery powered bus



5. PHASE II DEVELOPMENT PLAN (50 kW FUEL CELL SUBSYSTEM)

In Phase II, a full-size fuel cell subsystem integrated in a bus will be developed and a dynamo test will be performed by combining it with the bus propulsion system. Thereafter, the subsystem will be mounted in a bus and test running will be conducted and the first overall evaluation as a fuel cell powered bus will be performed. We plan to develop it with the following items as the main topics:

(1) Development of less weight and more compact power unit

(2) Improvement of safety and reliability

The specifications of the 50 kW fuel cell subsystem for bus are shown in *Table 4*. The fuel cell/battery powered bus is shown in *Fig. 4*.

6. CONCLUSION

It was proved that the methanol reforming, liquid-cooled phosphoric acid fuel cell power unit let out extremely small NO_X, the unit was compact and highly efficient, and was feasible for bus use. We plan to develop the power unit for vehicles furthermore and put it to practical use. At the same time, the application of fuel cell for portable power unit through these features can be also planned.

Reference:

(1) Romano, S. et al.: Design Considerations for a Fuel Cell/Battery Powered Transit Bus. Electric Vehicle Association EVS-9 (1988-8)

(2) R,J. Kevala: Development of a Liquid-Cooled Phosphovie Acid Fuel Cell/Battery Power Plant for transit Bus Applications, 25th IECEC 1990

(3) Yamamoto, O. et al.: Fuel Cell Power Pack for Fork-lift Trucks, Fuel Cell Seminar (1988-10)