6. Task 6 Development of PEFC Utilizing Pure Hydrogen

6.1 R & D Targets

6.1.1 Development Target for Phase II (FY 1999 to FY 2003) of WE-NET

This R & D work aims at establishing stack technologies for the pure hydrogen PEFC system and demonstrating a stationary 30 to 50 kW class power generating system with the electrical efficiency of more than 45% at HHV basis.

6.1.2 Target for FY 2001

Verification of the reliability of cell stack using a short stack and the design and fabrication of a hydrogen fueled 30 kW class power plant.

6.2 R & D Results in FY 2001

6.2.1 Development of Operating System with High Hydrogen Utilization

In FY 2000, a cell humidified at the cathode side and a divided stack system (serial flow method) consisting of the main and subordinate stacks were developed and the steady performance under high hydrogen utilization up to 96% was verified by using a 5kW short stack .In regard to the stacks for a 30 kW class plant which will be manufactured in FY 2002, it is necessary to verify the stack stability in terms of long hour operation under the start and stop condition with high hydrogen utilization.

6.2.1.1 Verification of Long Term Operation Characteristics

In order to verify the reliability under long term operation, a long term operation test was conducted by a three cell stack manufactured with MEA of FY 2000 specifications. This test has been continuing since FY 2000 under the internal humidification at cathode, the external humidification for anode (ambient temperature : 25°C to 30°C), hydrogen utilization of 85%, air utilization of 40% and current density of 0.2 A/cm^2. Figure6.2.1-1 indicates a stable performance even after 7,000 hours. In addition, a long term test using a 20 cell stack with FY 2001 specifications was commenced in preparation for the manufacture of stacks for 30 kW class plant. Figure6.2.1-2 shows the cell voltage trend. After more than 1,500 hours of operation, the long term operation characteristics of the new stack is similar to those with FY 2000 specification. These two tests will be continued in FY 2002.

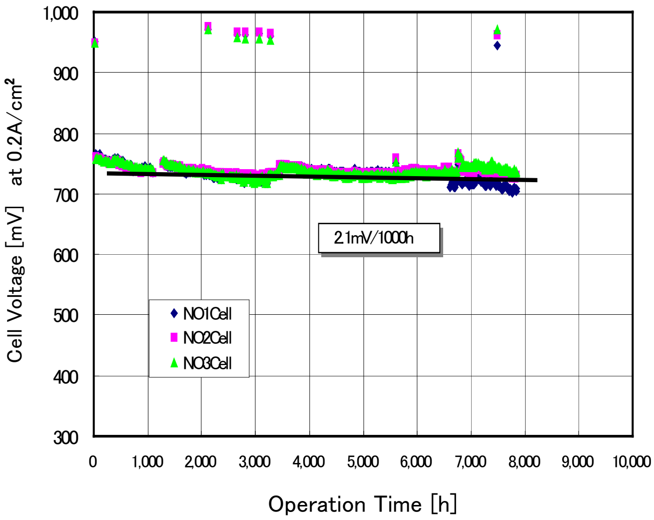

Fig.6.2.1-1 Long Term Test of 3 Cell Short Stack

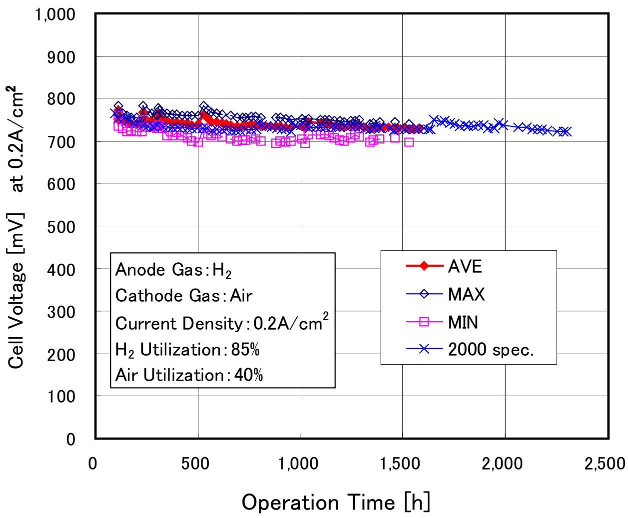

Fig.6.2.1-2 Long Term Test of 20 Cell Short Stack

Figure6.2.1-3 shows the results of the start-stop test using an 85 cell stack with full size cells. The start-stop procedure was simulated to the field plant such as the room temperature start and nitrogen purge after stop. A total of 28 start-stop operations were conducted. In each operation, the system was operated for two hours at the rated load after being started and data was recorded after two hours operation to measure the cell voltage which could be affected by a number of start-stop operations. It was verified that the impact of start-stop operation is minimal and the average cell voltage degradation was 0.39 mV/cycle.

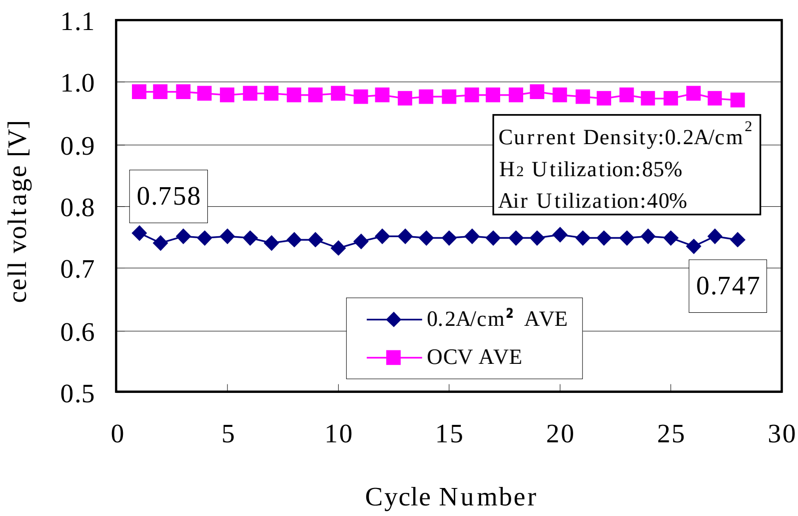

Fig6.2.1-3 Start-stop Test of 85 Cell Short Stack

6.2.1.2 Verification of Multi-Layer Stacks

For their integration to a 30 kW class plant, four 170 cell stacks and one 120 cell stack were manufactured as the main and the subordinate stacks, respectively. For assembly of multi-layer stacks, 20 cell subordinate stack units were firstly assembled and the leakage test was conducted for each unit to verify that the external leakage and cross leakage met the allowable limit. In the second step, the 20 cell stack units were piled together to make a 170cell stack. Figure 6.2.1-4 shows the external view of the 170 cell stack and Figure6.2.1- 5 shows the power generation test results of 170 cell stack.

Fig.6.2.1- 4　170 Cell Stack

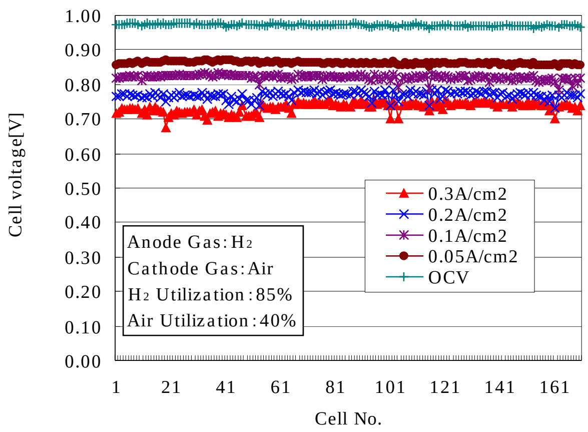

Fig.6.2.1- 5　Power Generation Test of　170 Cell Stack

6.2.2　Design and Manufacture of 30 kW Class Plant

6.2.2.1 System and Equipment Design

The ambient pressure operation was adopted to satisfy such basic performance requirements as improved electric efficiency, cost reduction and reliable operation, and the mass and heat balances were calculated. The design balance are shown in Figure 6.2.2-1. A electric efficiency of 50% (LHV) was achieved under the conditions of a fuel cell efficiency of 60%, inverter efficiency of 93%, auxiliary equipment efficiency of 91% and hydrogen utilization of 98%. The plant safety was secured by providing the plant with a package ventilation function, discharged fuel dilution function, combustible gas detection function and combustible gas purge function. Figure 6.2.2-2 shows the safety measures for fire by hydrogen.

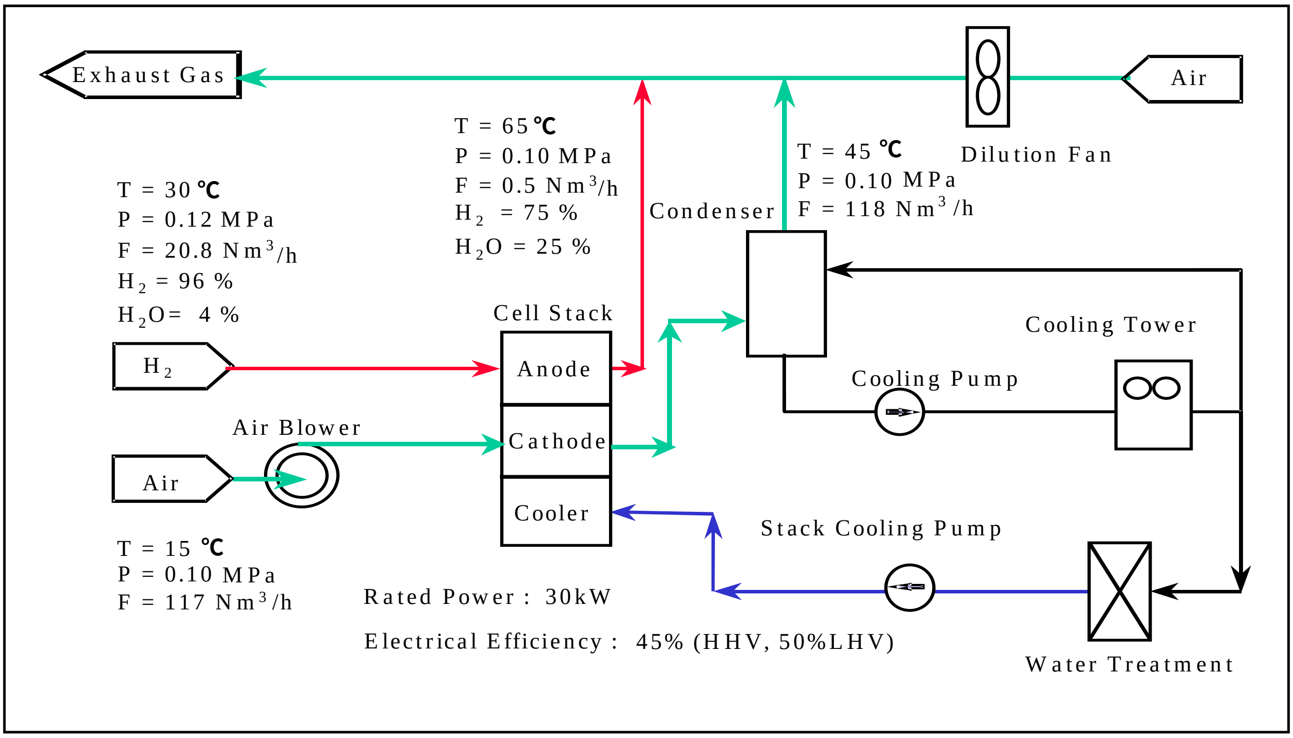

Fig.6.2.2-1 Mass & Heat Balance of 30kW Class Power Plant

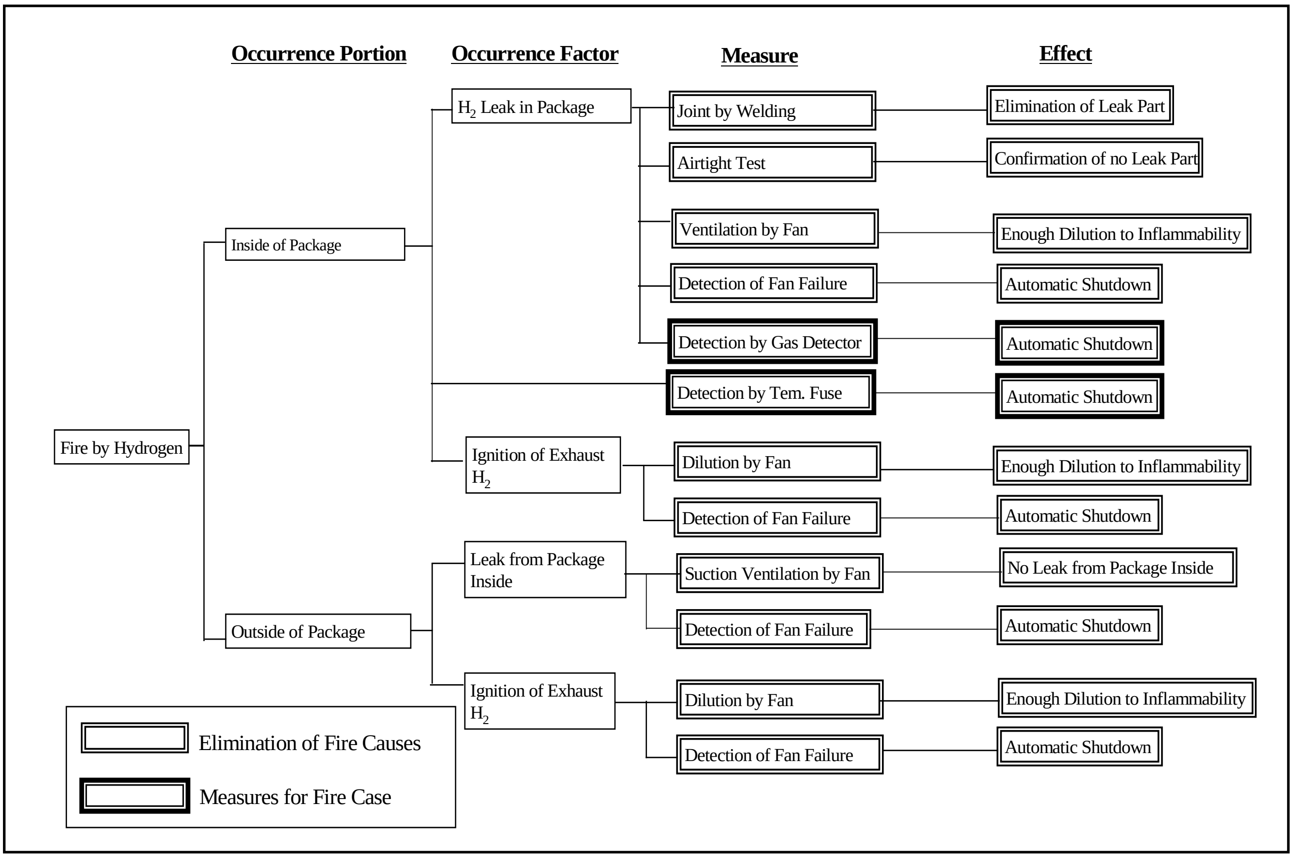

Fig.6.2.2.-2 Safety Measures for Fire by Hydrogen

6.2.2.2 Manufacture of 30 kW Class Plant

In order to ensure the compactness and maintainability of the package, the optimal equipment layout was designed. Figure 6.2.2-3 illustrates the internal layout of the package and Figure6.2.2-4 shows the external view of the package. Four main stacks units were placed in the highest position for easy management of the humidifying water and drain. In addition, the rotating machines were placed near the air intake and outlet to improve their accessibility from outside and their cooling effects. Moreover, the package consists of two compartments of combustible gas treatment section and electrical component section which were separated by the cathode exhaust gas condenser, and combustible gas detectors were installed at the air intake and outlet to improve the safety features.

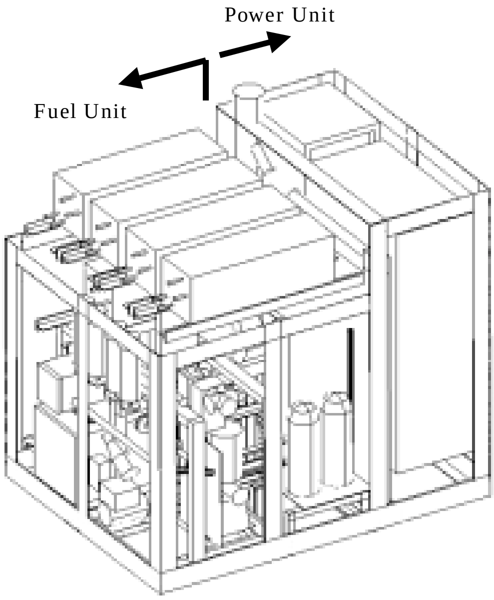

Fig. 6.2.2-3 Bird-eye View of 30kW Class Power Plant Package

Fig. 6.2.2-4 The external view of 30kW Class Power Plant Package

6.2.3 Humidity Control System for Hydrogen Gas Feed

6.2.3.1 Dehumidification Method by Hollow Fiber Membrane

Applicability of a dehumidification system by hollow fiber membrane (polymer membrane) to this power system was examined as a more economical and compact dehumidification method than the one by granular absorbent. This dehumidification system by hollow fiber membrane utilizes the selective permeation and separation of water vapor through the membrane. The one selected this time is fluorocarbon separation membrane from the standpoint of its high selectivity and compactness. Figure6.2.3-1 shows the principles of dehumidification by hollow fiber membrane. At this system, pressurized wet air is fed to the inside, and dry air is fed to the outside of the hollow fiber tube. The water vapor in wet air permeates the membrane due to the partial pressure difference of water vapor through the membrane. This system, therefore, has such characteristics as maintenance free due to the absence of mechanically moving units, a simple system configuration and good controlabrity to the aimed de-humidification level.

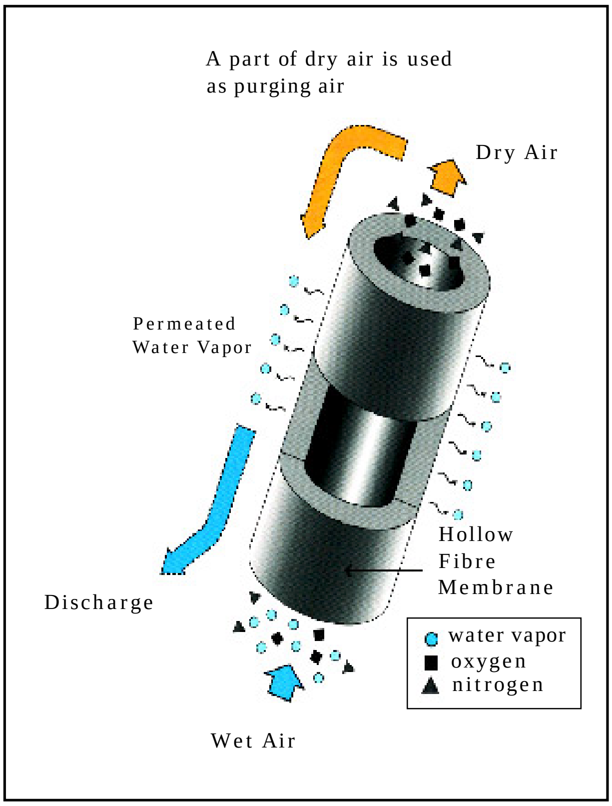

Fig.6.2.3-1 Principles of Dehumidification by Hollow Fiber Membrane

6.2.3.2 Preliminary Test of Dehumidification System by Hollow Fiber Tube

The dehumidification unit applied to an actual some equipment is an air dryer designed to dehumidify wet air. Therefore there is uncertainly regarding to the permeation of hydrogen gas through the membrane together with water vapor. A simple test to simulate the dehumidification system was conducted to measure quantitatively the amount of permeating hydrogen through the membrane. The results were that the amount of permeating hydrogen is small and the higher the pressure of feed hydrogen the higher the flow rate of purging gas become, the larger the dehumidification effect becomes resulting in small amount of permeating hydrogen and large amount of permeating water vapor.

6.2.3.3 Design of Hydrogen Gas Humidity Control System

Based on the Preliminary test, a hydrogen gas humidity control system was designed to maintain the required specifications for fuel cells. In this system, the by-product hydrogen gas supplied from the adjacent factory is supplied through water sealed safety tank. The wet hydrogen with water droplet is dehumidified by the hollow fiber membrane dehumidification unit. Figure6.2.3-2 shows a schematic diagram of hydrogen gas humidity control system.

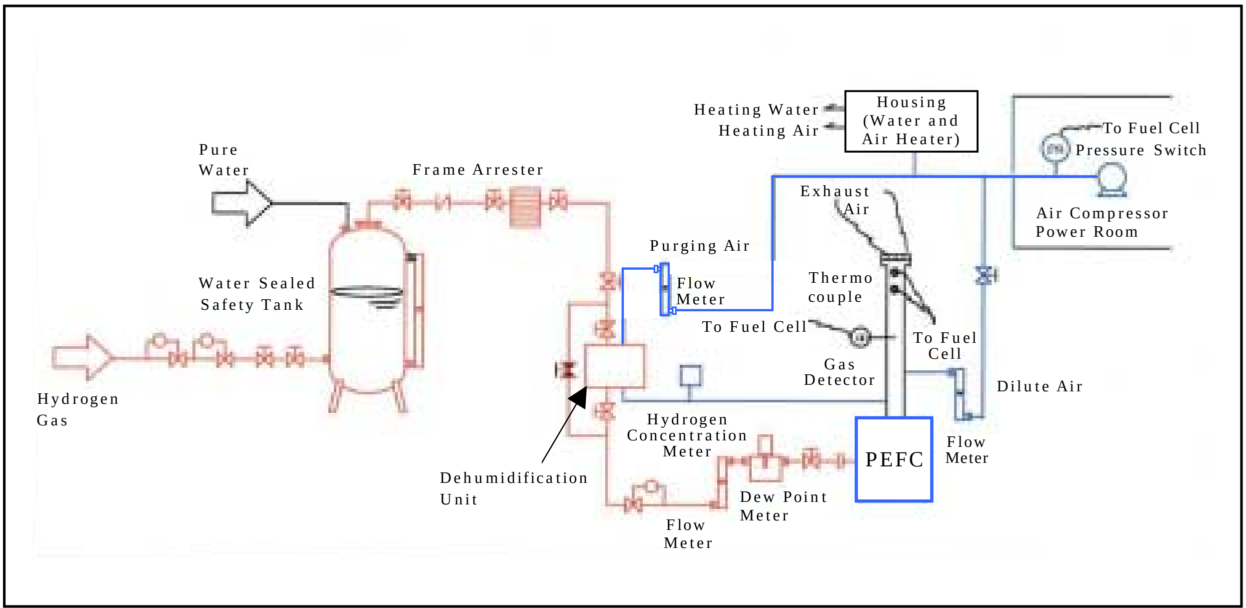

Fig. 6.2.3-2 Schematic Diagram of Hydrogen Gas Humidity Control System

6.2.3.4 Design of Peripheral System

The remote monitoring system was examined to combine the old data gathered by the existing system with the new data gathered by this demonstration plant. Moreover, the safety items of our system were examined and their contents were approved at the experts meeting for disaster prevention in the factory where our new plant will be installed. Based on the contents approved by the factory, design work was conducted to dismantle or remodel some parts of the existing equipment.

6.2.4 Conclusions

The results in FY 2001 are as follows.

(1) A low pressure loss-type separator which will contribute to improve plant efficiency was developed and verified. The 20 cell stacks were manufactured in combination with the low pressure loss-type separator and the FY 2001 specification MEA designed to improve performance further at high hydrogen utilization. The initial performance and durability characteristics for 20 cell stack were confirmed.

(2) Based on the performance confirmation of the 20 cell stack, a 30 kW class stack was manufactured. Prior to its integration to the system, the power generating tests of these stacks were conducted and the small dispersion of the cell voltages were confirmed.

(3) The package design with its optimum arrangement to ensure compactness, maintainability and safety requirement were completed.

(4) The assembly of a 30 kW class plant package incorporating the full stacks and components was almost completed.

(5) The applicability of the dehumidification system by hollow fiber membrane (polymer film) to an actual equipment was examined and verified. The hydrogen gas humidity control system by the hollow fiber was designed and the component specifications were decided.

(6) The contents of the safety measures for the demonstration plant were examined and the specifications for the remote monitoring system were decided by examining the input and output signals at the existing power panel and at the new data acquisition system.

6.3 Future R & D Tasks

(1) Continuation of the long hour test of the three cell stack and 20 cell stack to verify the steady performance over long hours.

(2) Factory test of 30 kW class plant to verify its performance and operability.

(3) Field test of the 30 kW class plant at the by-product hydrogen gas production site to verify the field performance and reliability .