3. Summary of Fiscal Year 2001 Results

3.1 Task 1 Study of System evaluation

Toward the hydrogen energy society in the future, the introduction and penetration scenario of hydrogen energy combined with the fuel cell introduction scenario were examined and.cost analysis of fuel cell systems was performed by the learning curve for making the scenario.

As for making the introduction scenario of fuel cell, a maintenance strategy of hydrogen refueling stations in accordance with progress and penetration of fuel cell vehicles by each vehicle type and region was examined. Additionally future costs of fuel cell vehicle and hydrogen refueling station were analyzed by the learning curve and economical efficiency was examined. For stationary fuel cell systems, economical efficiency and carbon benefit by indroducing of fuel cell systems for household were evaluated for making an introduction scenario. Additionally, as for a penetration scenario of hydrogen energy, economical efficiency and possibility of supply and demand of hydrogen energy producing by renewable energy were examined by the long-term energy model.

3.2 Task 2 Study of Safety Measures

While hydrogen has risks for fire and deflagration, we do not have enough experiences in handling it at small-scale and dispersed facilities such as fuel cell vehicles and hydrogen refueling stations. New safety measures should be taken and existing standards and regulations should be re-examined in order to realize installing and operating facilities for production, storage and refueling of hydrogen in towns. So, this task of WE-NET program is aiming to prepare a safe design guideline or a basis for re-examining regulations through carrying out experiments, collecting data on hydrogen behavior and characteristics in leakage, diffusion, self-ignition, flame and deflagration and assessing the hazard risks on the facilities. The maximum overpressure from hydrogen deflagration of stoichiometric mixture without any obstacles was below the safety criteria at 10 m distance from the gas mixture. However, the maximum overpressure exceeded one from methane stoichiometric mixture by a factor of 10. Hydrogen effluence from high pressure through a pinhole did not ignite by itself. Both the length and width of the flames of hydrogen from high pressure were proportional to the diameters of pin holes.

3.2 Task 3 Review and Investigation for International Cooperation

WE-NET project meant a research and development project subject for broad aspects in utilization of hydrogen, which can be achieved through international cooperation. Thus it is vital that the whole concept of the project should be well understood by overseas governmental organizations and other organizations that are involved in the development of hydrogen energy in order to seek their positive cooperation.

Terrorist's attack in New York in September, 2001 certainly adversely affected WE-NET activities due to cancellation of international conferences and seminars or difficulty for participation, etc. However, major activities in this year such as presentation in international conferences(The 11th. General Assembly of Canadian Hydrogen Association, Hypothesis IV, Japan/Korea Symposium, etc.), cooperation with International Energy Agency and developing Part II of the videotape on the safety of hydrogen are conducted.

Regarding rationalization in terms of ISO/TC197, while participation for international conference from Japan has been made only twice in fiscal year 2001 due to an influence of terrorist's attack in September, collaboration to the organization has been continuously underway by submitting reports to various ISO/TC197 secretariats.

In 2001 year, ISO/TC197 registered WG-8「Hydrogen generators using water electrolysis process」.as new item and Japan has also registered in this WG-8.

3.4 Task 4 Development of Power Genaration Technology

A 100kW class single cylinder test engine for an open-cycle hydrogen combustion engine was constructed. And a laboratory building for the testing of the hydrogen combustion engine was constructed and test facilities were installed in the laboratory. A preparation of test for a single cylinder test engine was completed.

Meanwhile, the possibility of the self-ignition of a hydrogen combustion engine with a high compression ratio, measures to improve thermal efficiency and NOx Reduction Measures were investigated. And a test was conducted to confirm the proper functioning of the hydrogen injection unit that was made in FY 2000 for the experimental single cylinder diesel engine and test data were got. Results will be reflected in design of the hydrogen injection unit.

As for the numerical analysis, in order to study the conditions for self-ignition of hydrogen under the air open cycle, combustion analysis of hydrogen jets was conducted. In order to conduct the numerical simulation of the combustion process of the hydrogen jet, a combustion analysis model was conducted, and the calculated results were compared with the laboratory test results to verify the model. As a result it was concluded that the analysis of hydrogen jet combustion for actual engines is feasible.

3.5 Task 5 Development of Hydrogen Fuel Tank System

Based upon the result of rapid filling test for mini-sized MH (Metal Hydride) tanks performed in fiscal 2000, we designed the divided chamber type tank and plate-fin type tank of full size and manufactured experimentally one tank for each type.

We carried out rapid filling tests at the natural gas reforming type hydrogen refueling station in Osaka with the divided chamber type tank and at the PEM electrolysis type hydrogen refueling station in Takamatsu with the plate fin type tank. We achieved filling times of 9.3 minutes and 9.1 minutes for hydrogen of 25 Nm^3 at the reforming type and electrolysis type hydrogen refueling stations, within 10 minutes as the target.

The fire-resistance test was conducted for MH tanks with a fusible plug, which released the internal pressure entirely by melting as temperature increased, and a spring type relief valve as measure for prevention destruction of tanks by heating. It was ascertained that we could prevent an abnormal rise in pressure of the tank, deformation and burst of the container by using a spring type relief valve and a fusible plug together.

With mini-scaled tanks, we tried to clarify degree of effects of various factors on deformation with attention to the structural factor, filter structure, honeycomb structure and separation plates inside tanks. It was proved that the tank with the structure having separation plates and honeycomb combined with plate filter had smaller strain than the tank without it. No crack was found in tanks with tube filters.

3.6 Task 6 Development of PEFC Utilization Pure hydrogen

In order to verify the reliability, a long term operation test was conducted by a cell stack manufactured by FY 2000 specifications. Test data show a stable performance even after 7,000 hours. In addition, a long term test using a cell stack with FY 2001 specifications was commenced. After more than 1,500 hours of operation, test data show a stable performance too. Meanwhile, the results of the start-stop test were satisfactory.

For their integration to a 30 kW class plant, four 170 cells stacks and one 120 cells stack were manufactured as the main and the subordinate stacks, respectively. Moreover, the mass and heat balances of power generation plant were calculated. And the package was designed with its optimum arrangement to ensure compactness, maintainability and safety requirement. The assembly of a power generation plant package was almost completed.

As for the applicability of the dehumidification system by hollow fiber membrane (polymer film) to an actual equipment was examined. As result the hydrogen gas humidity control system by the hollow fiber was designed and the component specifications were decided. Moreover peripheral components specifications for the plant were examined and decided.

3.7 Task 7 Development of Hydrogen Refueling Station

For the natural gas reforming type hydrogen refueling station, the remaining component equipments, such as PSA equipment, metal hydride type of storage equipment, gas storage unit and high pressure dispenser unit, were manufactured. The construction of the station was completed by installation and trial running of component equipments. The designed performance was ascertained through unit and coupled operation of equipments. A rapid filling test to MH model tank (separated chamber type) was conducted. It was ascertained that the target performance of filling hydrogen of 25Nm^3 in ten minutes was satisfied. We filled hydrogen up to the pressure of 25MPaG in four minutes by cascade system using high pressure model tank. It was ascertained that the heating characteristics of the tank due to adiabatic compression did not exceed beyond the safe level.

For the PEM water electrolysis type hydrogen refueling station, the remaining component equipments, such as PEM water electrolyzer and compressor, were manufactured. A remote watching system that the station operation data was transmitted from the central control board inside the station yard with wireless LAN was established. The construction of the station was completed by installation and trial running of component equipments. The trial filling tests combined with the station and model tanks were carried out. As for filling test of hydrogen up to 25MPaG and 35MPaG, it was confirmed that hydrogen of 30Nm^3 was filled into the model tank safely within 5 minutes. As for filling test into the metal hydride model tank(plate-fin taype), it was confirmed that hydrogen was filled into the tank safely within 9 minutes. Safety issues about two types of the hydrogen refueling stations were examined. For safety measures adopted for these stations, fundamental philosophy for safety and mounting locations for sensing devices were investigated. The design review and on-site review on safety measures adopted for these stations by the Task 2 were finished with no problems.

3.7AB Task ７AB Development of Hydrogen Refueling Station

The object of this research and development project is to develop a hydrogen refueling station, into which hydrogen is transported from the outside the station (off-site system). The salt electrolysis plants are source of hydrogen for off-site system hydrogen refueling stations. There are 35 plants in 27 companies dispersed all over the Japan. The annual hydro0gen production in fiscal 2001 was about 1.2 billion Nm^3, and a considerable amount of hydrogen supply is expectable already at the moment.In fiscal 2001, we completed the design of the entire system for the hydrogen refueling station using hydrogen trailers as the hydrogen source. The specification and design of the component apparatuses were also accomplished. We started to manufacture some apparatuses. The investigation on a layout of the station site and installation of utility equipment were made. Further, we developed a dispenser and studied the technology for filling control of hydrogen.

3.8 Task ８ Development of Hydrogen Production Technology

Along with the development of large area electrolysis cell lamination (electrolysis area 1,000cm^2 10 cells) and continuous operation of the electrolyte for commercialization of production technology , manufacturing of electrolysis cell for hydrogen refueling station in connection with the Task 7(the development of hydrogen refueling station) was implemented. Initial testing was carried out.

And, also, a few different type of high temperature resistant molecule electrolytic membrane to be usable in high temperature have been manufactured and evaluated its ion conductivity and electrolysis performance.

3.9 Task ９ Development of Hydrogen Transportation and Storage Technology

(1) Development of Liquid Hydrogen Transportation and Storage Facilities

Continuing from last year, we conducted insulation performance tests and low-temperature strength tests to develop a design database on thermal insulation structure for large-scale storage.

Small-capacity liquid hydrogen transportation and storage system was studied for the purpose of supplying hydrogen to hydrogen stations. In the study, conceptual design of tanks with capacity of 30m^3 and 15m^3 were produced. And a marine transportation system was studied with Tokyo Bay area as a model case of medium-sized hydrogen supply.

(2) Development of Devices for Common Use

We evaluated hydrostatic bearing, which is a non-contact bearing similar to magnetic bearing, by bearing rotation test for application in small-scale liquid hydrogen pumps. Then, we carried out the basic plans for pump specifications, motor specifications and bearing specifications.

Also, we conducted studies on recovery and utilization of boil-off hydrogen gas generated during storage on a hydrogen station. Consequently, re-liquefaction was found to be very inefficient. On the other hand, it was found that boil-off hydrogen gas yielded sufficient power to cover power consumption for the entire station when used as fuel for fuel cells, and also it would be effective to supply as high pressure hydrogen gas to vehicles.

(3) Conceptual Design of Hydrogen Liquefaction Facilities

We studied hydrogen expansion turbines for power recovery, and utilizing the cryogenic heat of LNG for power reduction in hydrogen liquefaction machine.

We selected and reviewed radial turbine with three-dimensional rotor blades as expansion turbine. Under the assumptions for this study, outer diameter of rotor blades was under 40mm for 5t/d turbine on high temperature side as well as for 1t/d turbine on high and low temperature sides, which are smaller than generally used centrifugal turbo type hydrogen expansion turbines. There is a possibility here that effects of leakage flow may relatively increase, so that actual performance may be lower than the estimated performance based on calculation.

Utilizing LNG cooling is very effective in reducing required power based on result of studies.

3.10 Task １０ Development of Cryogenic Materials Technology

To evaluate the low temperature material used for liquid hydrogen transportation and storage vessels, material property evaluation tests were conducted in temperatures ranging from the room temperature to low temperatures including the temperature under liquid hydrogen environment. We have evaluated new welding methods effective in improving toughness at a low temperature by expanding the scope of the metal types to be applied. This has led to the following findings:

Reduced pressure electron beam welding of stainless steel has been shown to provide the same high toughness at a low temperature in high-strength SUS316NL as in other types of steel. No influence of hydrogen charging was observed.

Perfect γ-weld metal TIG welding method of stainless steel has also shown to provide a high degree of toughness. No influence upon hydrogen susceptibility was observed.

The application of the friction stir welding to the A5454 aluminum alloy of low-magnesium content has been found to ensure a drastic improvement in the low-temperature toughness.

For aluminum alloys, we could also extend our knowledge on the strength/toughness balance by magnesium content.

3.11 Task 11 Development of Hydrogen Storage Materials

In order to apply to mobile and stable hydrogen container, research and development for promising substances with the following WE-NET target are performed.

- Effective hydrogen storage capacity : more than 3 mass%
- Temperature for hydrogen desorption : less than 100 ℃
- Durability : hydrogen storage capacity more than 90 % of the initial capacity after 5,000-cycle use

Works for improvement of capacity and endurance of V-base and Ti-Cr base alloys developed in the previous year are put forward, and researches for next generation alloys with more than 5 mass% capacity are commenced.

Two types of chemicals, such as hydrogen complex compound and naphtenes, are studied as 5-8 mass% hydrogen storage materials that can be used repeatedly.

Following in the wake of last year's accomplishment of this working group, in which we had established accurate measurement techniques, we investigated hydrogen storage capacity in several carbon materials, including carbon nanotubes.

3.12 Task 12 Investogation and Study of Inovation & Leading Technology

(1) Assessment of FY 2001 Feasibility Study Results

We conducted 6 feasibility studies as follows: ①A study on the storage of hydrogen using an iron oxide as a medium ②A study on a hydrogen production system by partial oxidation of biomass and waste used as raw materials ③ Search for new hydrogen-storing inorganic and organic composite materials ④ A study on gas turbine systems coupled with non-equilibrated methane reforming process ⑤A technical study on a hydrogen storage system using new decalin/naphthalene hydrogenation and dehydrogenation processes based on a superheated liquid membrane method ⑥A study on the method of producing hydrogen without generating carbon dioxide, using natural gas as raw materials, and an assessment of by-products

(2)Assessment of the Results of a Basic Study

We conducted「A Basic Study of the Magnetic Refrigeration Technology for Liquefaction of Hydrogen」that had started in FY 2000.

We manufactured a regenerator for the 1st stage and examined its characteristics such as thermal conductivity. We are planning to manufacture the world first 10kg/day prototype hydrogen liquefaction system based on the magnetic refrigeration method in the next fiscal year.

4. Future Development

Research, basic investigation, study of elementary technologies, and other investigations will be carried out continuously to obtain necessary information for the optimum design of the total system, in order to confirm establishment of technologies required to design and construct a pilot plant.