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**COMMITTEE OF EXPERTS ON THE TRANSPORT OF
DANGEROUS GOODS AND ON THE GLOBALLY
HARMONIZED SYSTEM OF CLASSIFICATION
AND LABELLING OF CHEMICALS****Sub-Committee of Experts on the
Transport of Dangerous Goods**Twenty-sixth session, 29 November-3 December 2004
Item 3 (c) of the provisional agenda**OUTSTANDING ISSUES OR PROPOSALS OF AMENDMENTS TO THE RECOMMENDATIONS
ON THE TRANSPORT OF DANGEROUS GOODS****Miscellaneous proposals****New entries for fuel cell device and metal hydride cartridges****Submitted by the Expert from Japan****Background**

1. In the field of electronics, increases in the amount of information are causing a dramatic expansion in information processing capabilities, as electronic devices consume more and more power. In the midst of these trends, attention is being focused on hydrogen as a source of energy. Hydrogen is a part of Earth's inexhaustible supply of water, and provides a great deal of chemical energy without emitting hazardous substances. In particular, fuel cells, which produce electrical energy directly, use hydrogen efficiently and can provide a large amount of power.

Hydrogen powered Proton Exchange Membrane Fuel Cell (PEMFC) technology is practical use recently for portable electric equipment such as cell phones, computers, cameras etc. PEMFC use hydrogen gas as fuel and do not burn the hydrogen; they produce electricity through an electrochemical process that combines protons from hydrogen and oxygen. For portable electronic equipment, the fuel is contained in a small removable receptacle which is installed in a fuel cell system. Many portable devices that are now typically powered by batteries may be powered by fuel cells (utilizing PEMFC) in the near future.

2. A schematic diagram of PEMFC is shown in Figure 1 in Annex. Protons and electrons are separated from hydrogen molecules at anode side by catalysis. The electrons pass through the electronic circuit, and then bond with oxygen and protons which pass through Proton Exchange Membrane at cathode side by catalysis, and also bond to oxygen in the air. As a result, water is produced. Those type fuel cells are very clean systems because they produce only water, but no by-product.

Portable electronic equipment used for consumers as dangerous goods should be ensured safely in transportation under the UN requirements. Therefore, safety requirements for transport of the such equipment should be established in the UN Model Regulations.

Introduction

3. Definitions of each item in our proposal are as follows(See Figure 3 & 4 in Annex).

Fuel cell system means fuel cell cartridge containing hydrogen and metal hydride with or without fuel cell power unit as an electric generating device.

Fuel cell cartridge means the refillable receptacle containing metal hydride and hydrogen.

4. The fuel cell cartridge is not merely a fuel receptacle but safe article designed and manufactured for fuel cells. The cartridge is equipped with a valve used to supply hydrogen to fuel cells power unit and allow hydrogen to flow out only at the time when it is connected to the fuel cell power unit. The cartridge and the fuel cell power unit is ensured against any damages during transport by proposed various performance tests , it does not rupture under normal conditions of transport.

5. Entry for the hydrogen in metal hydrides is provided in the Dangerous Goods List , Chapter 3.2 as UN3468 "HYDROGEN IN A METAL HYDRIDE STORAGE SYSTEM." However, this entry does not described capacity and pressure of hydrogen, and the metal hydrides in wide area is possible as class 2.1 due to danger of hydrogen. The fuel cell systems have small capacity and low pressure of hydrogen used as a small size of fuel cell systems. Metal hydride does not have properties of spontaneous combustion when tested in accordance to the Test N2 in UN Manual of Test and Criteria, Part III.

6. Laptop computers need normally 25W of electric power. The result of measurement by the demonstration shows that about 1.7Wh of electric energy can be gained by 0.1g of hydrogen. Thus, 15g of hydrogen is required for that a laptop computer is operated ten (10) hours. In our proposal, the weight of hydrogen containing in the fuel cell cartridge is limited to 15g or less. In the fuel cell power unit, about 0.001g of hydrogen is always remained, but it is extremely low value. Smaller capacity of a fuel cell cartridge is used in cell phones and cameras.

In addition, hydrogen gas pressure in the fuel cell cartridge is limited to 5.0 MPa at ambient temperature of 55 °C. The water capacity of fuel cell cartridge is limited to not exceeding 350ml

7. Comparison of combustion heat between compressed hydrogen gas in the fuel cell cartridge proposed by us, lighters and lighter-refills(UN1057), and 15g of compressed hydrogen gas is shown in Figure 2 in Annex. In the fuel cell cartridge, 93% of hydrogen is absorbed in metal hydride and only 7% of hydrogen is existing as gas. And 1g of hydrogen gas will be released from metal hydride when valve is intentionally opened in the air. As can be seen from the graph, the combustion heat of the gas is 1/2 and 1/14 of a lighter and a lighter-refills, respectively.

The structure of fuel cell cartridge is strong enough, so no leakage was found even at 10.0Mpa, which is 2 times of the pressure stated the above Para. 6 by our pressure test.

8. The expert from Japan proposed that fuel cell system be assigned to Class 9 if they can be shown to meet the requirements of a series of six tests that are intended to minimize the probability of leakage of hydrogen or metal hydride under normal conditions of transport. The test methods proposed by us include an altitude simulation test, an extreme temperature exposure test, a vibration test, a drop test , a crush test and a expansion test are intended to ensure that the fuel cell system are robust, resistant to leakage and afford a high level of safety in transport. Test 1, 2, 3 and 4 simulate environments during transportation. Test 5 ensures strength of fuel cell cartridge against compression. And test 6 ensures strength of fuel cell cartridge against inner pressure caused expansion of metal hydride during absorbing hydrogen where

contents is biased. These tests and the requirements proposed in this paper are intended to ensure that fuel cell system are transported safely including when contained or packed with equipment.

Proposals

9. Add two new entries to the Dangerous Goods List in Chapter 3.2:

- (1) ID #: UN XXXX
PSN: FUEL CELL SYSTEM containing hydrogen and metal hydride
Class: 9
Packing Group: II
Special Provision: AAA
Packing Instruction: P90Y
- (2) ID#: UN YYYY
PSN: FUEL CELL SYSTEM CONTAINED IN EQUIPMENT containing hydrogen and metal hydride
Class: 9
Packing Group: II
Special Provision: AAA
Packing Instruction: P90Y

10. Create a new Special Provision AAA:

This entry applies to FUEL CELL SYSTEM containing hydrogen and metal hydride or FUEL CELL SYSTEM CONTAINED IN EQUIPMENT containing hydrogen and metal hydride. Fuel cell cartridge or fuel cell system contained fuel cell cartridge may be transported under this entry if they meet the following provisions:

- (a) The hydrogen weight is not exceeding 15g;
- (b) The pressure is not exceeding 5.0 MPa at 55°C;
- (c) The water capacity of cartridge is not exceeding 350mL;
- (d) No leakage shall be found even at 10.0 MPa at 55°C;
- (e) The metal hydride does not have properties of spontaneous combustion.
- (f) Each fuel cell cartridge or fuel cell system contained fuel cell cartridge is of the type proven to meet the requirements of the tests specified in the Manual of Tests and Criteria, Part III, Subsection 38.5;
- (g) The testing requirements in Chapter 38.5 of the Manual of Tests and Criteria do not apply to production runs or pre-production prototypes consisting of not more than 100 fuel cell cartridge or fuel cell system contained fuel cell cartridge, when these devices are transported for testing, if:
 - (i) Fuel cell cartridge and fuel cell system contained fuel cell cartridge is transported in an outer packaging that meets the criteria for packing group I packaging; and
 - (ii) Metal hydride in fuel cell cartridge or fuel cell system contained fuel cell cartridge including hydrogen gas shall not exceed hydrogen solid solution phase.

11. Insert a new packing instruction P90Y as follows:

P90Y	PACKING INSTRUCTION	P90Y
This instruction applies to UN Nos. XXXX and YYYY		
Packaging shall conform to the packing group II performance level and are authorized, provided the general provisions of 4.1.1 and 4.1.3 are met.		
When fuel cell systems are packed with equipment, they shall be separately packed in inner packaging. When fuel cell cartridges included in Class 9 are contained in equipment, the equipment shall be packed in strong outer packaging in such a manner as to prevent accidental operation during transport.		
The valve of fuel cell cartridge is designed or securely sealed, taped, or otherwise fastened to prevent operation or leakage of contents during transport.		
Additional requirement:		
When fuel cell cartridges are transported installed in fuel cell systems they shall be protected against short circuit and the fuel cell system must be protected from inadvertent operation.		

12. Proposed tests (to be incorporated in the Manual of Tests and Criteria, Part III, Section 38.5.) for fuel cell cartridge or fuel cell system contained fuel cell cartridge.

38.5 Fuel cell cartridge or Fuel cell system contained fuel cell cartridge

38.5.1 Purpose

This section presents the procedures to be followed for the classification of fuel cell cartridge or fuel cell system contained fuel cell cartridge (see UN XXXX and applicable special provisions of Chapter 3.3 of the Model Regulations.)

38.5.2 Scope

38.5.2.1 Fuel cell cartridge or fuel cell system contained fuel cell cartridge shall be subjected to the tests, as required by special provision AAA of Chapter 3.3 of the Model Regulations prior to the transport of a particular type of these articles. Fuel cell cartridge or fuel cell system contained fuel cell cartridge which differ from a tested design types by a changes that would materially affect the test results shall be considered to be new design types and shall be subjected to the required tests.

38.5.2.2 For the purposes of classification, the following definitions apply:

Fuel cell system means fuel cell cartridge containing hydrogen and metal hydride with or without fuel cell power unit as an electric generating device.

Fuel cell cartridge means the refillable receptacle containing metal hydride and hydrogen.

Fuel cell power unit means an electric generating device without a cartridge.

38.5.3 Preparation of cartridge for testing

Cartridges shall be contained hydrogen of 95% or more of its designed volume.

38.5.4 Procedure

Each type of fuel cell cartridge or fuel cell system contained fuel cell cartridge shall be individually subjected to tests 1 to 3 in sequence on the same samples. Tests 4, 5 and 6 should be conducted using not otherwise tested samples or undamaged samples previously used in Tests 1 through 3. Ten (10) representative samples of the same type of fuel cell cartridge or fuel cell system contained fuel cell cartridge shall be tested.

38.5.4.1 *Test 1: Altitude Simulation*

38.5.4.1.1 Purpose

This test simulates air transport under low-pressure conditions.

38.5.4.1.2 Test procedure

Test samples of fuel cell cartridge or fuel cell system contained fuel cell cartridge shall be stored at a pressure of 11.6 kPa or less for at least six hours at ambient temperature (20 ± 5 °C).

38.5.4.1.3 Requirement

Fuel cell cartridge or fuel cell system contained fuel cell cartridge meets this requirement if there is no leakage after the test is performed.

38.5.4.2 *Test 2: Extreme temperature exposure*

38.5.4.2.1 Purpose

This test assesses structure of fuel cell cartridge and fuel cell system contained fuel cell cartridge and valve integrity using rapid and extreme temperature changes.

38.5.4.2.2 Test procedure

Test samples of fuel cell cartridge or fuel cell system contained fuel cell cartridge shall be stored for at least 2 hours at a test temperature of 75 ± 2 °C, followed by storage for at least 2 hours at a temperature of -40 ± 2 °C. This procedure is to be repeated 10 times, with no more than a 30-minute maximum time interval allowed between each temperature extreme.

38.5.4.2.3 Requirement

Fuel cell cartridge or fuel cell system contained fuel cell cartridge meets this requirement if there is no leakage after the test is performed.

38.5.4.3 Test 3: Vibration test

38.5.4.3.1 Purpose

This test simulates vibration during transport.

38.5.4.3.2 Test procedure

Test samples of fuel cell cartridge or fuel cell system contained fuel cell cartridge is firmly secured to the platform of the vibration machine without distorting the fuel cell cartridge or fuel cell system contained fuel cell cartridge in such a manner as to faithfully transmit the vibration. The vibration shall be a

sinusoidal waveform with a logarithmic sweep between 7 Hz and 200 Hz and back to 7 Hz traversed in 15 minutes. This cycle shall be repeated 12 times for a total of 3 hours for each of three mutually perpendicular mounting positions of the fuel cell cartridge or fuel cell system contained fuel cell cartridge.

The logarithmic frequency sweep is as follows: from 7Hz a peak acceleration of 1 g is maintained until 18Hz is reached. The amplitude is then maintained at 0.8mm (1.6 mm total excursion) and the frequency increased until a peak acceleration of 8 g occurs (approximately 50 Hz). A peak acceleration of 8 g is then maintained until the frequency is increased to 200 Hz.

38.5.4.3.3 Requirement

Fuel cell cartridge or fuel cell system contained fuel cell cartridge meets this requirement if there is no leakage after the test is performed.

38.5.4.4 Test 4: Drop test

38.5.4.4.1 Purpose

This test simulates possible impacts to a fuel cell cartridge or fuel cell system contained fuel cell cartridge during transport.

38.5.4.4.2 Test procedure

Test samples of fuel cell cartridge or fuel cell system contained fuel cell cartridge is dropped from a height of 1.5 m onto a rigid (e.g. concrete) surface in three orientations: valve up, valve down and horizontal. Three separate drops shall be conducted on each sample. Prior to conducting the drops, 5 of the samples shall be stored for at least 2 hours at 50 ± 2 °C, and 5 of the samples shall be stored for at least 2 hours at -18 ± 2 °C.

38.5.4.4.3 Requirement

Fuel cell cartridge or fuel cell system contained fuel cell cartridge meets this requirement if there is no leakage after the test is performed.

38.5.4.5 Test 5: Crush (compressive loading) test

38.5.4.5.1 Purpose

This test simulates possible crushing force applied to a fuel cell cartridge or a fuel cell system contained fuel cell cartridge.

38.5.4.5.2 Test procedure

Test samples of fuel cell cartridge or fuel cell system contained fuel cell cartridge are to be placed between two flat wooden blocks of approximately 240 mm (10 inches) long, 100 mm (4 inches) wide and 12.7 mm (1/2 inch) thick. The crushing force is to be applied to the exposed surfaces of the enclosure gradually at a rate of 12.7 mm/minute (1/2 inch/minute). Each force applicator is to exert 100 kg on the sample for one minute. Test samples are divided into two groups; 5 tested on the wide side and 5 tested on the narrow side. Each sample is to be subjected to only a single crush. Separate samples are to be used for each crush.

38.5.4.5.3 Requirement

Fuel cell cartridge or fuel cell system contained fuel cell cartridge meets this requirement if there is no leakage or mass of loss after the test is performed.

38.5.4.6 Test 6: Expansion test

38.5.4.6.1 Purpose

This test simulates possible combinations of stresses from the hydrogen gas pressure, the alloy expansion, particle fragmentation phenomena and the particle density growth due to vibration applied to a fuel cell cartridge or fuel cell system contained fuel cell cartridge.

38.5.4.6.2 Test procedure

Test samples of fuel cell cartridge or fuel cell system contained fuel cell cartridge shall be tested with one hundred (100) cycles of absorption and release of hydrogen between 95% and 5% of design hydrogen capacity at ambient temperature of $20 \pm 5^\circ$. However, vibration according to Test 3 shall be performed at each twenty cycles at the state that hydrogen is released completely from a fuel cell cartridge or fuel cell system contained fuel cell cartridge. The vibrations shall be added under the condition that is considered to be the worst direction where contents may be biased.

38.5.4.6.3 Requirement

The distortion generated in a fuel cell cartridge or fuel cell system contained fuel cell cartridge shall not exceed elastic deformation. And due to cycles of filling and releasing, distortion generated in a fuel cell cartridge or fuel cell system contained fuel cell cartridge shall not increase and keep constant. There is no leakage after the test is performed.

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Annex

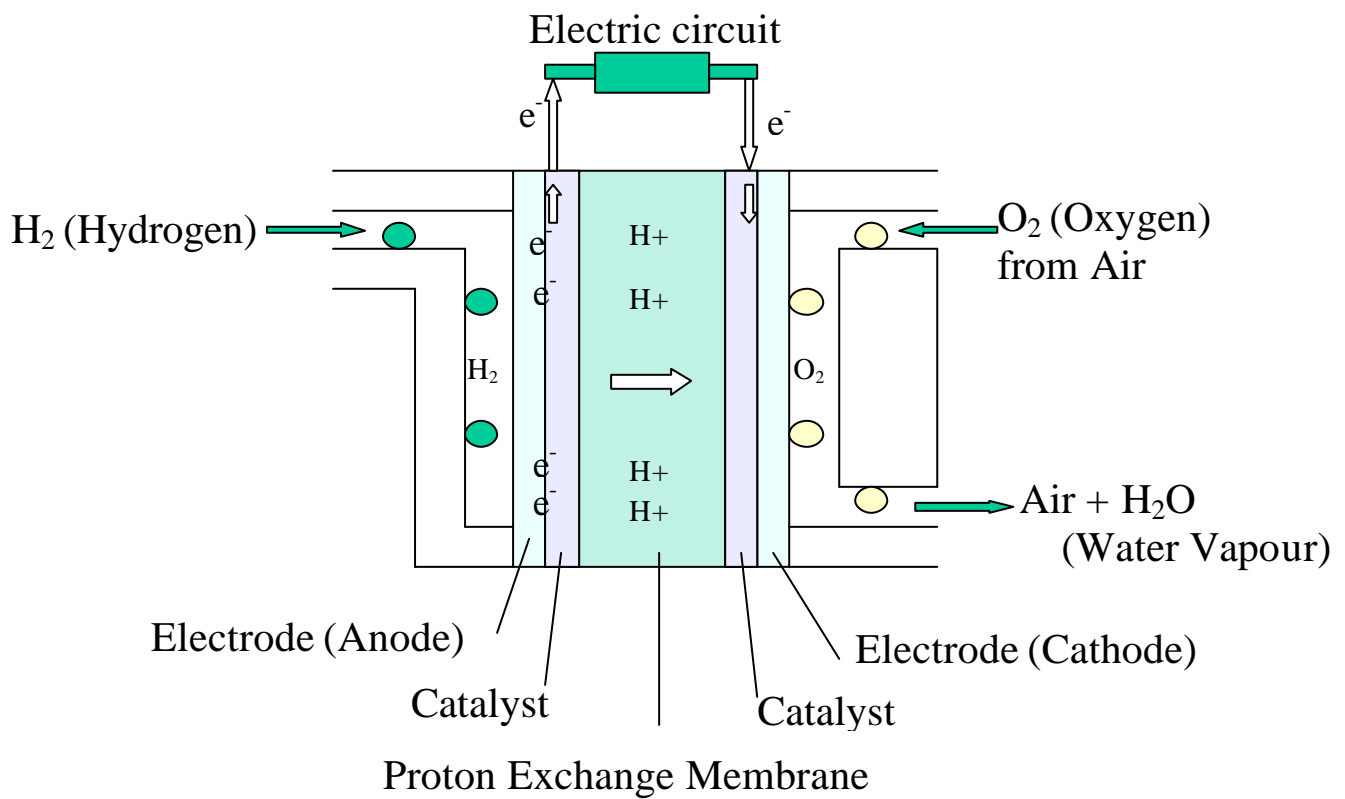
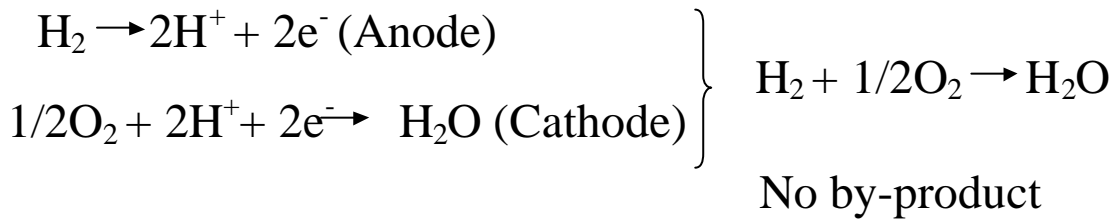
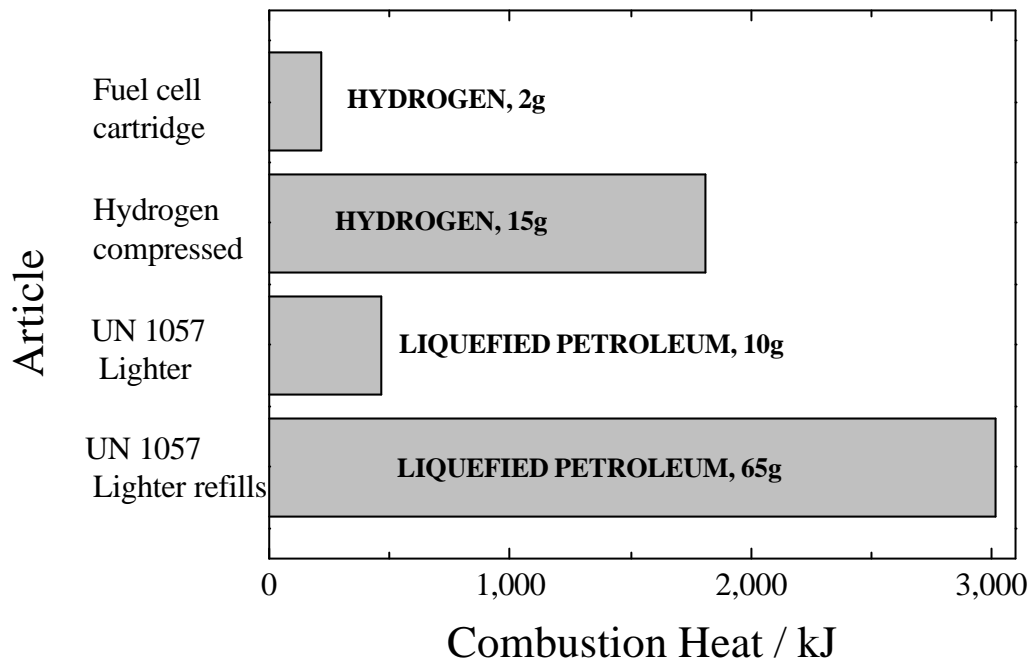
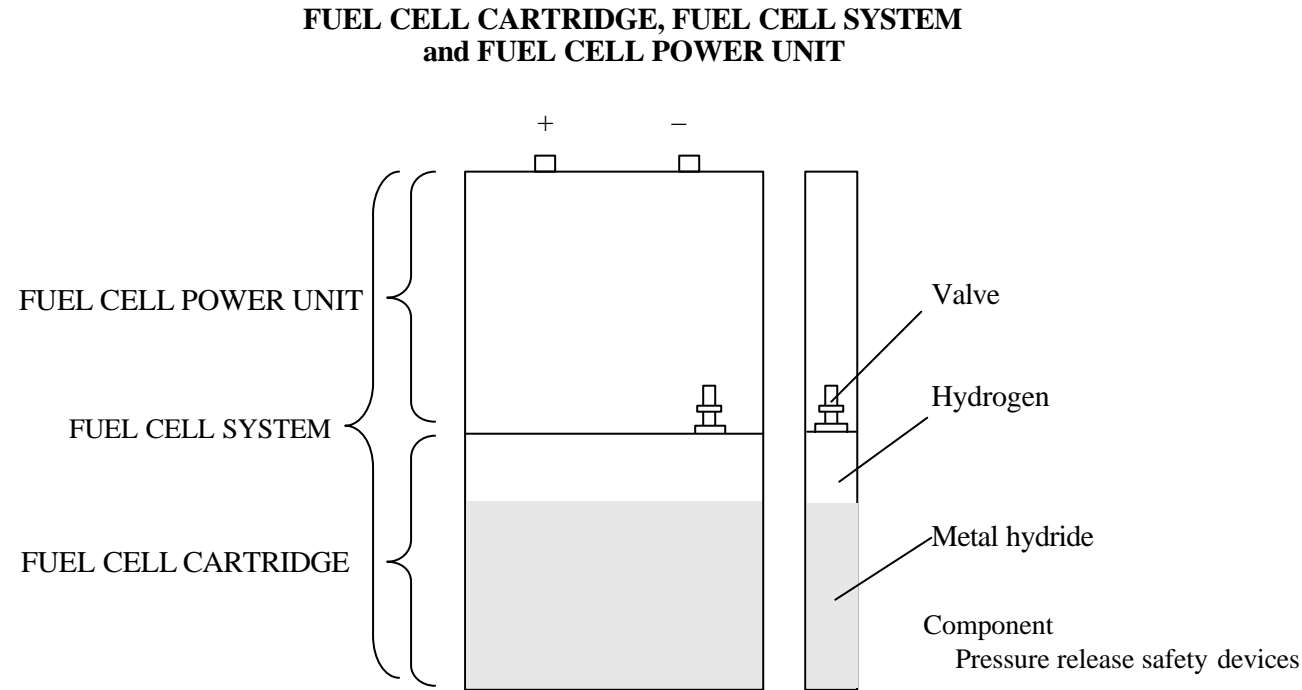


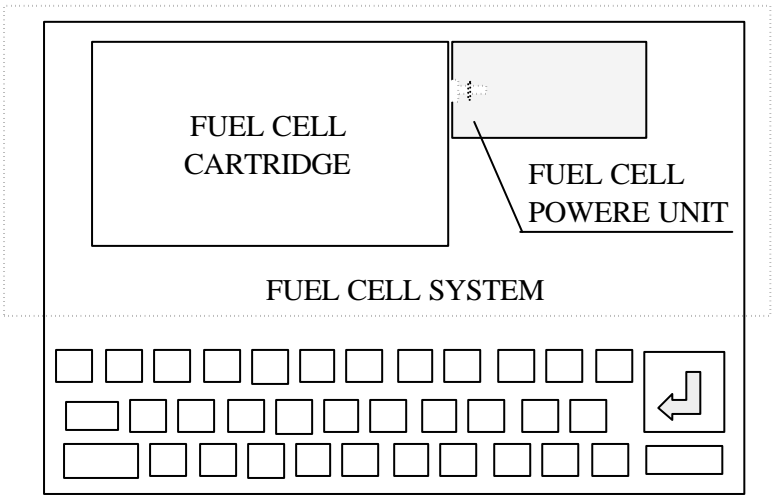
Figure 1: Schematic diagram of PEMFC



**Figure 2: Comparison of combustion heat
between liquefied petroleum gas and fuel cell**



**FUEL CELL POWERED EQUIPMENT,
CONTAINING FUEL CELL SYSTEM**



**Figure 3: Schematic diagram of FUEL CELL SYSTEM and
FUEL CELL POWERED EQUIPMENT**