OVERVIEW OF THE NEW COMBINED GASOLINE/HYOROGEN SUPPLY STATION AND RELEVANT REGULATIONS IN JAPAN

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ABSTRACT

When a hydrogen supply station is to be installed in Japan, three fundamental laws must be taken into consideration: the High Pressure Gas Safety Law, the Building Standards Law, and the Fire Service Law. The High Pressure Gas Safety Law in particular regulates procedures for safety concerning hydrogen supply stations. This law came under review accompanying consideration of the potential utilization of fuel cell vehicles and hydrogen stations. At that time, the Japan Petroleum Energy Center (JPEC) investigated safety technology for hydrogen supply stations and prepared a draft of the law.

Since then, a new combined gasoline/hydrogen supply station compliant with the revised law was established on December 2006. There are a large number of safety precautions incorporated into this station model which conform to the law. As a result of these modifications, it was possible to reduce the safe setback distance. In this paper we present an overview of the new hydrogen supply station model, the safety precautions, and the regulations the station is based on.

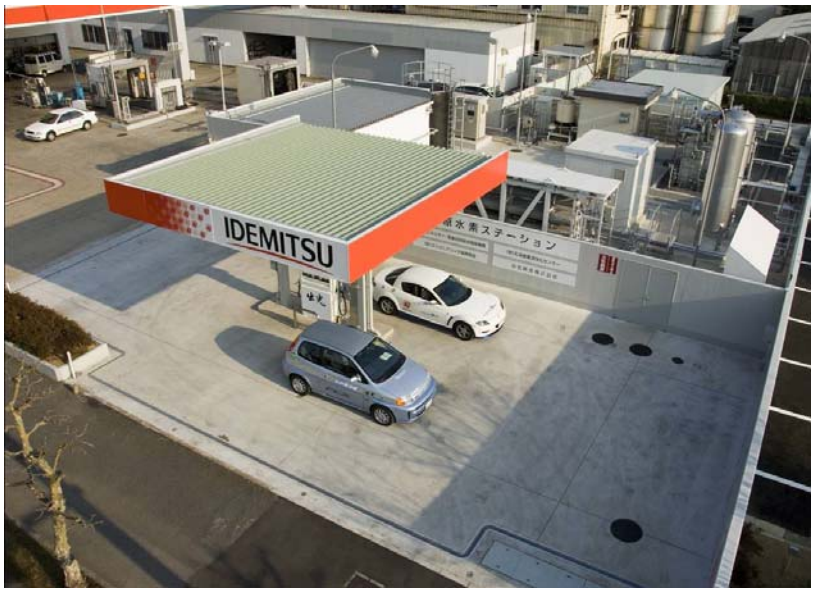

Figure 1. A view of the combined hydrogen/gasoline supply station

1. INTRODUCTION

The use of hydrogen energy is attracting attention all over the world as a potential energy source which has less impact on the environment than fossil fuels. Therefore, the widespread use of fuel cell vehicles and hydrogen supply stations can be expected in the future. The Japanese Government decided that 28 items were in need of review to make the use of fuel cell vehicles and hydrogen supply stations practical. Thanks to the energetic efforts of a large number of organizations and experts, new

laws which include the 28 items under review came into force. JPEC was able to be involved in the review of regulations regarding hydrogen stations and drew up drafts for regulations.

In December 2006 we then established a new combined gasoline/hydrogen supply station model which conforms to the revised law. We plan to verify the safety measures system of this model and to investigate further safety measures using this hydrogen station in the future. In this paper we look at this combined gasoline/hydrogen supply station model and present an overview of Japanese regulations for hydrogen supply stations. Future issues of hydrogen supply stations are also described.

2. OVERVIEW OF REGULATIONS CONCERNING HYDROGEN SUPPLY STATIONS

2.1 High Pressure Gas Safety Law

A hydrogen supply station which handles compressed or liquid hydrogen in Japan must conform to the High Pressure Gas Safety Law. The purpose of this law is to prevent potential disasters caused by the volatile nature of high pressure gas. This law prescribes technical standards for the location, structure and equipment of facilities handling high pressure gas of 1MPa or over. Incidentally, this law aims to secure safety of high pressure gas and specifies the required performance for achieving this objective. Details of this law are indicated in the General High Pressure Gas Safety Regulations Relating to Exemplification Standards issued by The High Pressure Gas Safety Institute of Japan (KHK). These safety measures will be elaborated on further in the latter half of this paper.

The hydrogen supply station is provided for under Article 7-3 of this law. Two types of hydrogen stations are regulated under this article. One is the long-distance type which is meant to be built in the suburbs; the other is a short-distance type which is meant to be built in urban areas. Table 1 shows the main points of these regulations. Article 7-3 provides for hydrogen stations to 40MPa, which supply compressed hydrogen gas to fuel cell vehicles that have 35MPa tanks. At present there is no rule for 70MPa hydrogen supply stations; therefore JPEC is studying the risk assessment and is preparing a draft.

Table 1. Article 7-3 of the High Pressure Gas Safety Law

Safety measures	Long-distance type	Short-distance type
Distance from high pressure facility to another building	more than 11.3m	6m
Distance from dispenser to the road	more than 11.3m	6m
Fire offset distance	6m	6m
Firewall surrounding to the station	-	necessary
Shut-off valve near cylinder	one	two
Excess flow valve	-	necessary
Place storage and shut-off valve in the same frame	-	necessary
Safety valve	necessary	necessary
Hydrogen leakage detector and automatic shut down	necessary	necessary
Fire detector around dispenser and accumulator	-	necessary
Sprinkler above the accumulator	-	necessary
The barrier between the compressor and the accumulator	-	necessary
Preventive measure of excess filling	necessary	necessary

2.2 Building Standards Law

The kind of building which can be built in each area is determined by The Building Standards Law in Japan. For example housing is allowed only in areas designated as residential areas. Before deregulation in 2005, construction of hydrogen supply stations was allowed only in industrial areas, and the establishment of hydrogen stations in semi-residential areas, adjacent commercial areas, commercial areas and semi-industrial areas became possible.

The maximum volume of hydrogen storage is also regulated in each area. Since there are houses in residential areas and factories in industrial areas, the storage volume of high-energy density material such as hydrogen or gasoline should differ in each area. Table 2 shows the maximum hydrogen storage volume in each area. A business or party wishing to store hydrogen in excess of the allowed volume is required to hold a public hearing in the neighborhood or area of planned storage.

Table 2. Maximum hydrogen storage volume

Areas	Hydrogen Volume(Nm3)
Industrial areas	unlimited
Semi-Industrial areas	3,500
Commercial areas	700
Semi-residential areas	350

2.3 Fire Service Law

Liquid fuel, such as gasoline or diesel oil, is classified as a hazardous material, and is regulated by the Fire Service Law. Gasoline stations therefore are also regulated by it. On the other hand, the High Pressure Gas Safety Law mentioned above regulates hydrogen stations because hydrogen is not categorized as a hazardous material under the Fire Service Law in Japan.

We want to utilize existing gasoline stations effectively to popularize fuel cell vehicles and hydrogen supply stations. It was not possible to establish combined gasoline/hydrogen stations in the past but the deregulation of 28 items enabled the building of combined gasoline/hydrogen stations from 2005.

There are several types of gasoline stations allowed under the Fire Service Law but only one type of gasoline stations was allowed for hydrogen supply stations at that time. The Fire and Disaster Management Agency studied to deregulate the types of gasoline stations which could be combined with hydrogen stations. The committee discussed many issues such as the identification of hazards when the supply of both fuels was combined, examination of safety measures, and simulations (using computer fluid dynamics) of the possibilities of hydrogen accumulating under the canopy over the dispenser if hydrogen were released. After the long study, they reported the types of gasoline stations which can be built in combination with hydrogen stations [1]. Table 3 shows the types of gasoline stations which may be built with hydrogen stations.

Table 3. The types of gasoline stations which can build with hydrogen station

Gasoline station	Hydrogen station	Build together
Outdoor-type (It has a small canopy.)	Compressed hydrogen	YES
Indoor-type 1 (It has a large canopy and has second floor of its office building.)	Compressed hydrogen	NO
Indoor-type 2 (It has a large canopy and does not have second floor of its office	Compressed hydrogen	YES
Full service gasoline station	Compressed hydrogen	YES
Self service gasoline station	Compressed hydrogen (Employees must refuel hydrogen.)	YES

3. OVERVIEW OF THE NEW COMBINED GASOLINE/HYDROGEN SUPPLY STATION

3.1 Purpose of its Establishment

The purpose of this combined station is to verify the validity of safety measures. For example, as the overall systems of the facilities in the hydrogen station, aspects such as operation stability and durability are verified. Continuity running tests or non-destructive inspections will also be done to shorten the inspection period of each facility.

3.2 Overview of the Facility

This hydrogen station is the first combined gasoline/hydrogen station in Japan. Idemitsu Kosan Co., Ltd.(IDEMITSU), Engineering Advancement of Association in Japan (ENAA), and JPEC installed this hydrogen station together in December 2006. New Energy and Industrial Technology Development Organization (NEDO) commissioned it. The hydrogen supply station is integrated into an existing gasoline station and supplies gaseous hydrogen for fuel cell vehicles. Hydrogen is produced on site via a reformer that uses kerosene and is stored in a compressed form. Figure 2 shows the basic flow of processes at the hydrogen station and Table 4 describes the main specifications.

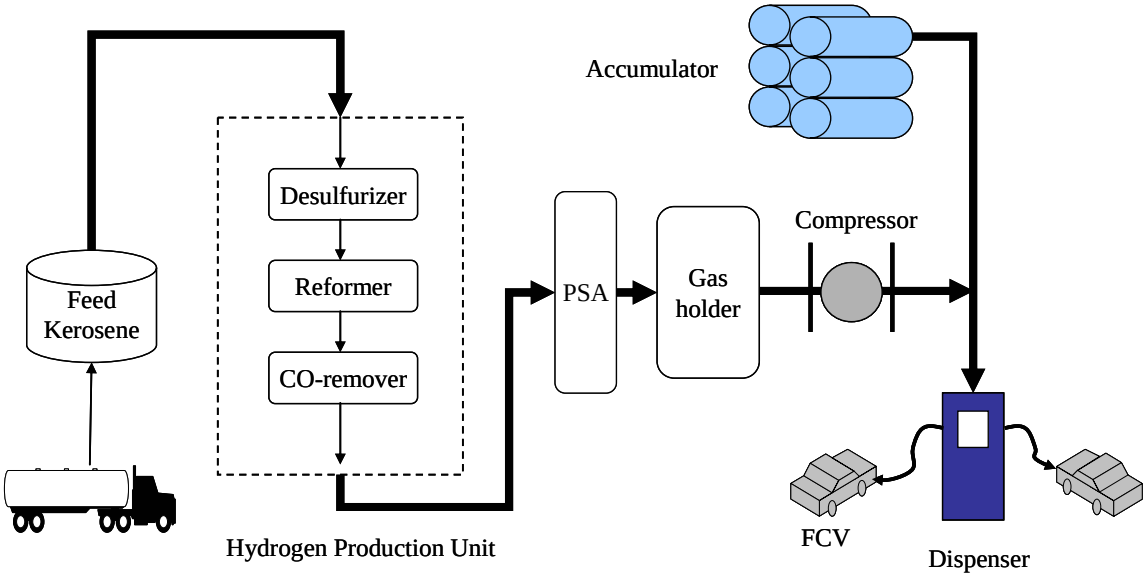

Figure 2. Flow of processes of the kerosene reforming hydrogen supply facility

Table 4. Specifications of the hydrogen station

Site	Ichihara city Chiba prefecture
Space	726m2
Feedstock	Kerosene
Process	Steam reforming with desulfurization of kerosene + PSA purification
Production capacity	50Nm3/h
Hydrogen purity	More than 99.99% in volume (CO less than 1ppm)
Refueling capacity	Pressure : 25MPa(3,600psi) and 35MPa(5,000psi) Capable to refuel 5 passenger vehicles continuously

4. MAJOR SAFETY MEASURES

4.1 Hydrogen Supply Stations in General

As mentioned above, dedicated hydrogen supply stations conform to the High Pressure Gas Safety Law, but hydrogen supply stations operating in tandem with gas stations must conform to both High Pressure Gas Safety Law and Fire Service Law regulations. It goes without saying that both types of hydrogen stations must also conform to construction regulations and the volume of hydrogen which may be stored under the Building Standards Law. In this section, safety measures distinctive to hydrogen stations will be discussed next.

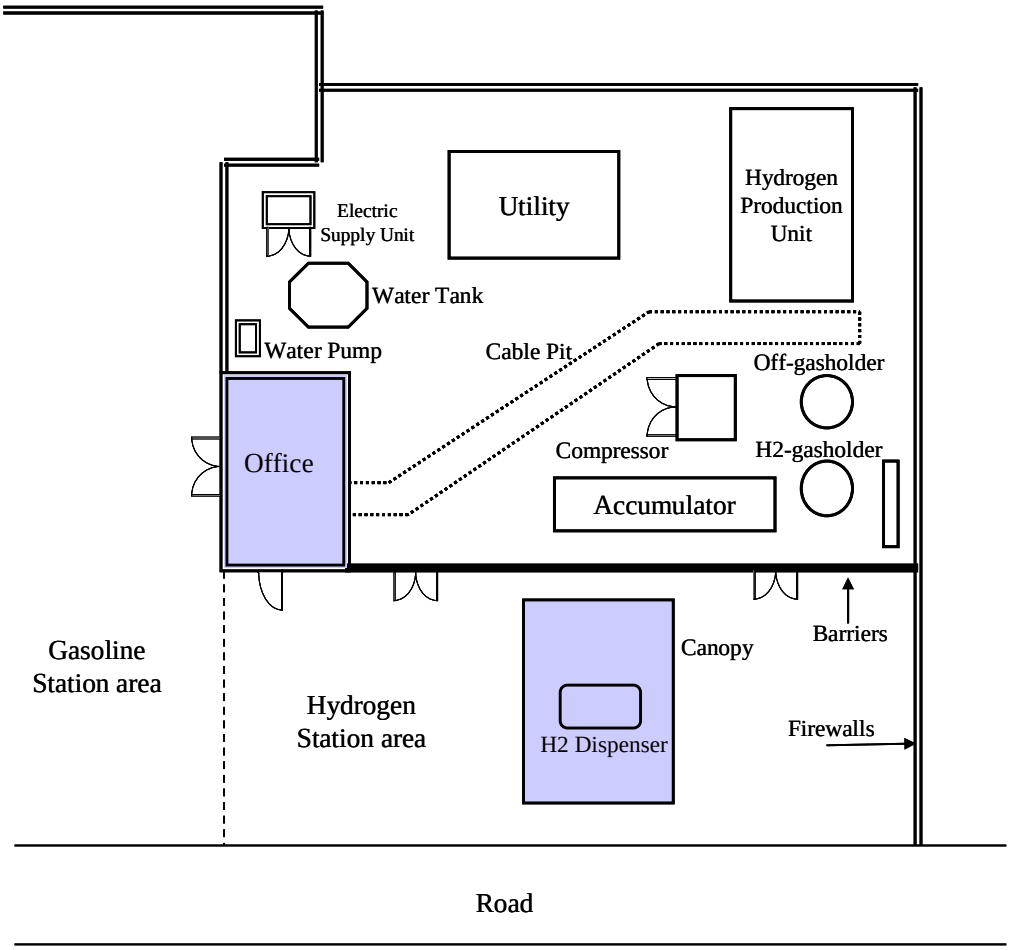

Figure 3. The Facility arrangement of the hydrogen supply station

Firewalls and barriers

In hydrogen stations, firewalls of 2m or higher are installed in the area surrounding it (excluding the area of the road where the vehicles enter and exit) as well as barriers within the site (Figure 3). Firewalls around the hydrogen station prevent any impact outside the station when a disaster occurs in the hydrogen supply station. At the same time, they prevent external forces, such as fires in adjacent areas, from having an impact on the hydrogen station. Furthermore, barriers are established within the station, separating the facility area where the compressor and the accumulator are located and the gas supply area where the hydrogen dispensers are located, thereby minimizing the impact on people within the hydrogen station in the event a hydrogen leakage occurs. It is also important to note that the difference between the firewalls and the barriers described here are purposes of installing and the strengthening.

Fire offset distance

It was determined that a distance of at least 6m should be maintained from the external area where flammable gas passes through the hydrogen station to facilities where open flames are handled (outside of the site, etc.). As a reference, we used previous investigations of compressed natural gas stations and LPG stations where an opening representative of pinholes that occur with a diameter of 0.2mm was made. Next, through experiments and simulations, it was determined that when 40MPa hydrogen leaked from the opening, the longitudinal distance at 1% concentration, which is the lower limit critical density (4%) for a hydrogen explosion multiplied by the safety ratio of ¼, was 5.3m [2]. Based on this finding, it was determined that if a 6m distance from facilities which handle open flames were secured, there would be no concern that the hydrogen would be ignited.

Site Boundary Distance

A distance of 6m or more from the outer surface of high pressure gas facilities to the site boundary of the hydrogen supply station was established. This was the distance where if hydrogen which leaked from a 1mm opening under 40MPa pressure were to ignite, the impact of the resulting outburst of flames and high temperature combustion gas stream would not reach the site boundary [3]. The opening diameter was then set at 1mm to take into account the safety ratio, which is five times wider in diameter and 25 times greater in hydrogen leakage volume than the typical diameter of the 0.2mm opening established in the previous paragraph.

Metal materials for use with hydrogen

Hydrogen is known to have adverse effects on the mechanical properties of metal materials due to hydrogen embrittlement. The metal materials which can be used at hydrogen stations have been established on the basis of results of material assessments under a high-pressure hydrogen environment and investigations [4]. Therefore a decision was made to use SUS316L for the piping of high pressure gas and SUS316L or SCM435 for the accumulator, which holds a huge quantity of hydrogen. These measures prevent the leakage of large quantities of hydrogen from pipe breakage or ruptures in accumulators due to hydrogen embrittlement and corrosion.

While the metal materials that can be used are limited to two types at present, this is not to say that other metal materials cannot be used; the problem is that there is not enough convincing data to permit their use at present. As soon as the necessary data regarding existing materials and new materials is collected, investigation of their viability will be conducted.

4.2 Compressor-related Measures

There is a compressor which pressurizes the hydrogen to 40MPa at the hydrogen station. Although the amount of hydrogen inside the compressor is not a significant amount, the compressor contains many machine parts with reciprocating motions and rotations at high speed, so measures are taken to prevent explosions and breakages.

Figure 4. The compressor in the casing

Measures to prevent dispersed materials

A compressor is placed inside a steel-plated casing on the assumption that movable parts have the potential to disperse in the event of a breakdown in the compressor (Figure 4). It was decided that the wall between the compressor and the accumulator

should be a sturdy barrier, particularly to prevent a secondary disaster from dispersed material from the compressor hitting the accumulator and causing damage by opening holes.

Measures to prevent hydrogen from remaining in the casing

A ventilator is installed to prevent hydrogen from remaining inside the compressor casing. An interlock is installed to automatically shut down the compressor in the event the ventilator stops. A hydrogen leakage detector is also installed inside the casing.

Temperature monitoring at the outlet of the compressor

When hydrogen is compressed under high pressure, the hydrogen itself rises to a high temperature. After the hydrogen is cooled using a gas coolant, it then flows to the accumulator which is filled with hydrogen. However, if there is an abnormality in the gas coolant, the hydrogen, still at a high temperature, will flow into the accumulator and, in the worst event, the structural design temperature can be expected to be exceeded. To avoid such accidents, the temperature at the outlet of the compressor is monitored and an interlock is installed to shut down the compressor if the set value is exceeded.

4.3 Accumulator-related Measures

In the hydrogen station, a large amount of hydrogen is stored in the accumulator which consists of a number of high-pressure cylinders. As a matter of course, many safety measures for the accumulator are taken to prevent hydrogen from leaking. However, if a leakage occurs in the worst event, measures are taken to prevent significant leakage of hydrogen through early detection using a hydrogen sensor and a flame detector to close the shut-off valve immediately (Figure 5).

Figure 5. The accumulator

Two or more interrupting devices

To prevent hydrogen leaking from the accumulator, two or more shut-off valves are fitted at the outlet of the accumulator. One is a conventional shut-off valve which stops the leakage using a detection system. The other is an excess flow valve which stops independently under the pressure caused by a hydrogen leak. Safety is increased by establishing two different types of shut-off valves with different activation systems.

Preventive measures against temperature increases

A water sprinkler system is installed to prevent an increase in internal pressure from increases in temperature in the accumulator due to fire, direct sunlight, or other heat source. A certain reduction in the degree of the impact of fire in adjacent areas can be anticipated through the use of firewalls. A sprinkling system is also activated when the temperature reaches a certain level through the constant monitoring of the surface temperature of the accumulator. An adequate supply of water is also stored in the hydrogen supply station.

Safety measures for earthquakes

In Japan, safety measures for earthquakes are issues that cannot be ignored. First of all, the accumulator is installed on a solid ground surface after exploration is undertaken on the ground of the planned site. A vibration sensor is installed so that operation of the hydrogen supply station is automatically shut off when an earthquake occurs. Furthermore, the accumulator and the above-mentioned shut-off valves are installed within the same structural framework, so that the hydrogen can be shut off without fail even if the accumulator tilts to one side or is toppled by earthquakes.

4.4 Dispenser-related Measures

In view of the presence of the drivers of fuel cell vehicles and employees of the hydrogen stations, a high degree of safety in the vicinity of the dispensers is necessary (Figure 6).

Figure 6. The dispenser

Distance between the road and the dispenser

A distance of six meters from the road to the dispenser is required for as a fire offset distance for safety reasons.

Hydrogen leakage detector

The filling coupler section that connects with the fuel cell vehicle has a tendency to leak due to its structural function in attaching to and detaching from vehicles. Furthermore, hydrogen leaked from the internal piping is apt to accumulate inside the dispenser. Therefore, hydrogen leakage detectors are installed in these two places and filling is immediately brought to a halt when a leakage is detected.

Flame detector

Because a hydrogen flame is not visible to the eye, a flame detector is installed near the dispensers and automatically stops the filling process when a flame is detected. An ultraviolet ray-type flame detector is considered to be the most effective form of technology at this stage. However, it is susceptible to malfunctions due to exposure to sunlight and reflected light; therefore, it is necessary to consider factors such as the installation of a hood, the position of its installation, and the direction the device is facing.

Protection of the filling hose

To prevent bending, twisting, wearing from touching the ground, and damage to the filling hose, a spiral guard is installed on the hose. Regulations require the periodic replacement of the hose.

Upper limit control of the flow rate for filling

When hydrogen is being filled into the fuel tank of a fuel cell vehicle and a period equivalent to the time it takes to fill a gasoline vehicle is estimated (about five minutes) to be an appropriate filling time, it is necessary to fill the cylinder at a reasonable flow rate. On the other hand, because the pressure of the fuel cylinder of a fuel cell vehicle has a high pressure of 35MPa, the temperature will increase if the flow rate at the time of filling the hydrogen is high, due to the effect of compression expansion. Therefore, it is assumed that at this rate, it will exceed the allowable temperature of the cylinder. The Japan Automobile Research Institute recognizes this aspect and has initiated vigorous data collection procedures regarding the high-speed filling of hydrogen cylinders and the level of

temperature increases [5]. This investigation and the safety ratio were taken into consideration and the upper limit of the flow rate was set for filling hydrogen fuel cell vehicles.

Prevention of collisions by out of control vehicles

To prevent out of control vehicles or drivers mistakenly stepping on the accelerator instead of the brakes from crashing into or colliding with dispensers, a collision-proof fence is installed around the dispensers. The strength of the protective barriers is set to withstand the force of a normal vehicle (2 tons) colliding at 20km/h. Furthermore, the island surrounding the dispensers is raised and the piping is buried inside a trench. A vibration sensor is installed inside the dispensers to automatically halt the filling process by closing the shut-off valve not only when there is an earthquake but also when a vehicle collides with the dispensers.

Prevention of fuel cell vehicles from moving by mistake

If a vehicle starts moving by mistake while it is being filled with hydrogen, a dispenser hose may be wrenched off and this will lead to a significant leakage of hydrogen. Even if the hose is not wrenched away from the dispenser, the dispenser itself may be pulled down and damage to the internal piping can be expected. Because such accidents actually occur at gas stations [6], the installation of a break-away device is required by gas stations under the Fire Service Law. Under the High Pressure Gas Safety Law, the hydrogen supply station is similarly required to install a break-away device to prevent damage to the hose by a moving vehicle that has been mistakenly started.

5. FUTURE ISSUES

As explained thus far, conditions to enable the widespread development of hydrogen stations are being established. However, aside from the issue of the distribution rate of fuel cell vehicles, there are some outstanding issues that stand in the way of widespread use of hydrogen supply stations.

To resolve these issues, the first challenge is to reduce the cost of setting up hydrogen stations. Needless to say, to reduce the cost of the equipment such as compressors, accumulators, dispensers, and hydrogen production equipment, it is also necessary to reduce the manufacturing costs of all of the peripheral parts and necessary devices such as piping, joints, valves and sensors as well. It is hoped that this can be achieved through further developments in technology and cost reduction through mass production accompanying the widespread permeation of hydrogen supply stations.

Second, there is a need for a further review of the regulations concerning the site area of hydrogen supply stations. For example, in setting up a combined gasoline/hydrogen station, a 6m site boundary distance is required following the installation of compressors, accumulators, and hydrogen production equipment. The Fire Service Law also requires the installation of hydrogen dispensers outside the filling area for gasoline vehicles. Therefore, to establish a combined hydrogen/gasoline station, twice the size of a regular gasoline station site will be required. In short, under present conditions, only a gasoline station with a large site will be able to be converted to a combined station. To resolve this situation, it may be necessary to review the regulations to facilitate the installation of compressors and accumulators underground or to install accumulators on a second storey above an office, for example.

In addition, to reduce the site area and increase safety, reduction of the volume of stored hydrogen must be considered as an option. If less hydrogen is stored, the impact in the event of leakage will be significantly less. Therefore, an on-demand hydrogen supply system where only the necessary amount of hydrogen is produced as needed and is pressurized at the time the fuel cell vehicle is filled should be considered.

6. CONCLUSION

The new regulations concerning hydrogen stations came into force in April 2005. The new combined gasoline/hydrogen supply station model was established to conform to these regulations. Safety measures will be investigated further using this station model. To promote the widespread use of fuel cell vehicles and hydrogen stations in the future, further cost reductions and improvements in safety are essential. For the genuinely safe use of hydrogen energy, the development of new materials and new technologies will also become increasingly important, and ongoing initiatives to review the regulations in line with such developments are vital.

7. ACKNOWLEDGEMENT

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