EVOLUTION IN HYDROGEN SAFETY ACTIVITIES, REGULATIONS, AND STANDARDS IN CHINA OVER THE LAST DECADE

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Abstract

Hydrogen represents one effective solution for China to develop economy in a sustainable way, for its characteristics of unlimited supply, emissions reduction, and high energy efficiency. There has been an ever-increasing interest in the study of hydrogen safety in China over the last decade, driven by the development of hydrogen energy. First, activities related to hydrogen safety in China were reviewed, including the investigations of temperature rise during hydrogen fast filling, fire test for on-board hydrogen storage tank, consequence evaluation of hydrogen release and explosion, safety distance, and so on. Second, a systematic overview of Chinese regulations and standards for hydrogen technology was presented. The regulations and standards on hydrogen safety were described in detail. Some important on-going activities related to hydrogen safety were introduced subsequently. Finally, suggestions on further studies on hydrogen safety and development of relevant standards were proposed.

1.0 INTRODUCTION

Hydrogen is considered as a promising energy carrier for the characteristics of unlimited supply, zero emission, and high energy efficiency [1, 2]. Many countries have made specific roadmaps for the development of hydrogen energy [3-5]. China also attaches great importance to hydrogen energy to develop economy in a sustainable way. However, implementation of hydrogen economy demands a transition due to the challenges of technology and infrastructure development, and cost reduction. Demonstration projects continue to validate and disseminate hydrogen technology in China such as Beijing Olympic Games in 2008 and Shanghai Expo in 2010. Nevertheless, as in many other countries, extension and accessibility still need a continual improvement. Safety is one of the challenges on the way towards the popularization of the new technology [6, 7].

Hydrogen is flammable, colorless, and can cause fire and explosion if it is not used properly, thus it is difficult for hydrogen to achieve a wide social acceptance [8]. Great efforts are required to ensure the safety in hydrogen operation, handling and use. As one of the key challenges for deployment of hydrogen technologies in the consumer-oriented applications, hydrogen safety has been drawing many attentions in China. With support from national projects, such as the Key Project of National Programs for Fundamental Research and Development of China (973 program), the High-Technology Research and Development Program of China (863 program), and the National Natural Science Foundation of China [9], amounts of meaningful studies related to hydrogen safety have been conducted in China over the last decade. Besides, as a partner of International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), China has actively carried out international cooperation in hydrogen safety.

In this paper, activities of hydrogen safety in China were firstly reviewed, including investigations of temperature rise during hydrogen fast filling, fire test for on-board hydrogen storage tank, consequence evaluation of hydrogen release and explosion, safety distance of hydrogen fuelling station, and so on. Then, a systematic overview of regulations and standards for hydrogen technology was presented. The regulations and standards on hydrogen safety were described in detail. Besides, some important on-going activities with respect to hydrogen safety in China were introduced.

2.0 ACTIVITIES OF HYDROGEN SAFETY

2.1 Temperature rise during hydrogen fast filling

Temperature of on-board hydrogen storage tank can rise significantly during fast filling process due to two phenomena. One is compression of hydrogen inside the hydrogen storage tank when it is filled with higher-pressure hydrogen from the fuelling station. The other is Joule-Thomson heating of hydrogen as it is throttled through the orifices. However, the main contributor to the temperature rise is compression [10]. Excessive temperature rise can lead to failure of temperature-sensitive carbon fiber reinforced polymer. So it is required that the hydrogen fuelling should be conducted without exceeding the maximum gas temperature of 85℃ [11, 12]. It is essential to investigate the mechanism and control methods of temperature rise.

Liu et al. [13-15] conducted experimental studies together with numerical simulations of the temperature rise and its distribution in type III hydrogen storage tank (35 MPa, 150 L) during refuelling process. Influences of mass filling rate, ambient temperature, and initial pressure of the tank on maximum temperature rise were studied. The results showed that the maximum rise of temperature increased with increasing ambient temperature and mass filling rate, while it decreased with increasing initial pressure. Due to the requirements of higher gravimetric and volumetric capacity, and lower cost, 70 MPa on-board hydrogen storage tank is considered to be an economic option. Zheng et al. [16] conducted the fast filling experiment on type III on-board hydrogen storage tank (70 MPa, 74 L). Temperatures of gas inside and the outer surface were both measured at several different points during the refuelling process. The results indicated that the aft domes junction surface and the gas in caudal region attained the maximum temperature rise. Zhao et al. [12] developed a CFD model to predict the fast filling process of the 70 MPa, type III tank and analyzed the thermodynamic responses of fast filling under different filling times and pressure-rise patterns in detail. Further studies will focus on control methods of the maximum temperature rise during fast filling process to ensure safety.

2.2 Fire test of on-board hydrogen storage tank

Fire test, which is an important prototype test for on-board hydrogen storage tank, is designed to demonstrate the safety performance of tank under a specified fire condition [17]. At present, bonfire test methods have been proposed in CGH2R [18], JARI S 001 [19], SAE TIR J2579 [20], and ISO/TS 15869 [21]. But there are still some important test parameters that have not been unified. For example, fuel type and flow rate of the fire source, which can influence the temperature distribution and the activation time of the pressure relief device (PRD), are not specified [22, 23]. Zheng et al. [24-26] carried out experimental and numerical studies on the influences of these parameters in bonfire test. Temperatures of outer surface of a type III tank, which was filled with hydrogen up to 28.4 MPa, were monitored by fifteen thermocouples in the experiments. The internal pressure of the tank and temperatures of the thermocouples were recorded at an interval of 2 s. Numerical study of the test indicated that the influence of fuel type on temperature rising was significant, and the rate of temperature rising became faster with the increase of fuel flow. However, the filling medium (hydrogen or air) inside the tank has little effect on the rate of temperature rising. Thus, air can be used as the substitute of hydrogen in the fire test, and this conclusion has been adopted by HFCV-GTR [27].

Recent studies showed that vehicle fires usually caused on-board hydrogen storage tanks to experience localized fire [28]. Thus, localized fire test method has been proposed in HFCV-GTR to verify the safety performance of tank under such a fire condition. However, the validity and practicality of this test method still require to be further verified. Experiments together with numerical simulations of localized fire test were conducted on type III tanks filled with hydrogen and air respectively [29, 30]. The experimental results indicated that pressure and temperature of the internal gas changed little when the tanks were exposed to localized fire. Temperature rising of internal air or hydrogen also contributed little to the activation of thermally-activated pressure relief device (TPRD). In addition, difference between the pressure rises of internal hydrogen and air was small. Based on the temperature distribution and pressure rise measured in the experiment, a three-dimensional numerical model was developed to study the key factors that influenced the TPRD activation time. The results indicated that pressure of the tank and filling medium had weak influence on the TPRD activation time. However, the effect of resin decomposition in the composite layers caused by localized fire on heat transfer behavior of the tank was not considered in the model. The failure mechanism of composite tank wall subjected to localized fire still needs to be further investigated.

2.3 Consequence evaluation of hydrogen release and explosion

Release of hydrogen can be divided into instantaneous release and continuous release. Instantaneous release of hydrogen usually happens when a hydrogen storage system suddenly bursts. In this case, hydrogen will be depressurized in a very short time, which can be defined as physical explosion. Ignition of the dispersed hydrogen cloud will result in a flash fire. If the hydrogen accumulates in a confined area, an explosion of the confined vapor cloud may occur. For continuous release of hydrogen, direct ignition of the diffused hydrogen will result in a jet fire, while delayed ignition will produce a flash fire or an explosion [31, 32]. Li et al. [33] performed the calculation and analysis of these four typical consequences of hydrogen release, including physical explosion, flash fire, jet fire, and confined vapor cloud explosion. The results showed that the worst case of confined vapor cloud explosion and physical explosion produced the longest distances of harm effect for the continuous and instantaneous release of hydrogen, respectively. Harm effect distances of all the four typical consequences increased with release pressure for continuous release of hydrogen, but almost had no relation with the release inventory. While it was the opposite situation for instantaneous release, i.e. harm effect distances of all consequences increased with the release inventory, but almost had no relation with release pressure.

2.4 Safety distance of hydrogen fuelling station

More hydrogen fuelling stations are required to support fuel cell vehicle demonstration projects. Properly designated safety distance for hydrogen fuelling station is important to keep the risk to the public at an acceptable level. Both the safety of facilities and risk acceptance criteria should be considered in the calculation of safety distance. The safety distance of hydrogen fuelling station specified in Chinese standard, such as GB 50516-2010 [34], has large margin of safety to minimize risk, which hinder the development of hydrogen fuelling station because of the land cost [35]. For example, the safety distance between hydrogen storage tank and ignition source shall be larger than 30 m in GB 50516-2010, while that specialized in NFPA 55 [36] is not more than 15 m. Many safety distances between facilities in GB 50516-2010 are based on the successful experience in other related standards in China, such as GB 50177-2005 [37], which specifies the requirements for layout of facilities in industrial hydrogen station. For introduction of this new energy infrastructure in public, effective methods are required to calculate the safety distance reasonably without compromising safety.

Quantitative risk assessments were performed on two gaseous hydrogen fuelling stations in Shanghai. Risks to station personnel, refuelling customers and third parties were evaluated respectively. Both individual risk measure and societal risk measure were used in the risk assessments. Safety distances of facilities in the stations were calculated by model described in the paper [35]. Different mitigation measures to reduce risks were also discussed [38, 39], which provided guidance for the design of hydrogen fuelling station. However, some accidental data used in the assessments were based on generic database because a comprehensive accidental database for hydrogen fuelling station was not available. The limitations of experimental data and experience about hydrogen fuelling station led to the uncertainties in the assessments. More demonstration projects and experiments are required to build up the accident database. Further studies are needed to develop an applicable method to calculate the safety distance of hydrogen fuelling station, and then promote the progress of related standards.

2.5 Other activities

Mechanical tests using specimens pre-charged with hydrogen were conducted by Bai and Pan et al. to measure the effects of hydrogen on the properties of some metallic materials [40, 41]. Hydrogen induced martensite transformation [42] and hydrogen-enhanced dislocation emission [43] were also investigated. In Zhejiang University, a test apparatus with high pressure (140 MPa) gaseous hydrogen is being developed. This apparatus will be used to study the compatibility of metallic material contact with high-pressure hydrogen. Tensile test by slow strain rate technique, fracture toughness test and fatigue crack growth test can be performed with this apparatus.

Experimental and numerical studies on crash test of on-board hydrogen supply system for fuel cell vehicle were performed by Jiang et al. to verify the safety performance of components under crash condition [44]. In addition, fatigue test system for hydrogen cycling has been developed by An et al. to test the expected service performance of hydrogen storage system [45].

3.0 REGULATIONS AND STANDARDS

There are both regulations and standards for the safety of hydrogen. Regulations are issued by regulatory agencies, such as the General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (AQSIQ). Standards in China are classified into four categories, namely national standards, industrial standards, local standards, and enterprise standards. National standards are usually developed by national standardization committees, which are supervised by Standardization Administration of the People's Republic of China (SAC) [46]. National standards may be either mandatory or recommendatory, which have the prefix code of “GB” and “GB/T” respectively.

3.1 Regulations related to hydrogen technology

AQSIQ is responsible for many activities in the areas of regulations, standards, quality, metrology, and conformity assessment. AQSIQ has issued a series of regulations on safety supervision for special equipment (boilers, pressure vessels, pressure pipes, etc.), which have the prefix code of “TSG”. Some of these regulations are related to hydrogen technology, including TSG R0002-2005—Super-high pressure vessel safety and technical supervision regulation, TSG R0004-2009—Supervision regulation on safety technology for stationary pressure vessel, and TSG R0009-2009—Gas cylinders safety and technical supervision regulation for vehicles. The regulations specify the requirements for production (including material, design, fabrication, erection, maintenance, reconstruction), use, inspection, and supervision of relevant equipment.

3.2 Standardization committees related to hydrogen technology

Standardization of hydrogen technology is mainly promoted by the National Standardization Technical Committee of Hydrogen (SAC/TC 309) in China. SAC/TC 309 was founded in 2008 by the approval of SAC [47]. As shown in Table 1, in addition to SAC/TC 309, some other national standardization committees also undertake the standardization work in specific areas related to hydrogen technology. Cooperation and coordination between these committees effectively promote the development of hydrogen technology standard system.

Table 1. National standardization committees related to hydrogen technology

Name	Related standardization work
National Standardization Technical Committee of Hydrogen (SAC/TC 309)	Production, storage, transportation, and utilization of hydrogen, as well as the contact with ISO/TC 197
National Standardization Technical Committee of fuel cell (SAC/TC 342)	Glossary, performance, general requirement and test method of fuel cell
National Standardization Technical Committee of Boilers & Pressure Vessels (SAC/TC 262)	Design, fabrication, maintenance, inspection, and supervision of hydrogen storage vessels
National Standardization Technical Committee of Gas Cylinders (SAC/TC 31)	Glossary, design, fabrication, maintenance, inspection, and supervision of gas cylinders used for hydrogen storage and transportation. Subcommittee 8 of National Standardization Technical Committee 31 (SAC/TC 31/SC8) is specifically for high pressure vehicle fuel tank.
National Standardization Technical Committee of Automotive (SAC/TC 114)	Glossary, classification, technical requirement and test method of hydrogen powered vehicle

3.3 Standard system

The standard system is defined as a scientific organic whole which is formed according to the internal relations of standards in a certain scope [48]. The standard system of hydrogen technology presents a general view of all the standards that are necessary for the development of hydrogen energy. SAC/TC 309 has begun to perform the investigation of standard system since it was founded. Chinese standard system of hydrogen technology is divided into eight parts based on the characteristic of hydrogen energy, as shown in Fig. 1 [49]. The specific information of each part is given in Table 2. Furthermore, these parts can be subdivided according to their characters.

Scientific and practical standard system could provide the foundation for the modification, supplement and promotion of related standards. The standard system of hydrogen technology is a dynamic system. It can be predicted that new technologies and problems will occur gradually in the future. The influence of these new things on standard system should be taken into consideration in time. It’s necessary to update the standard system regularly to catch the pace of hydrogen technology.

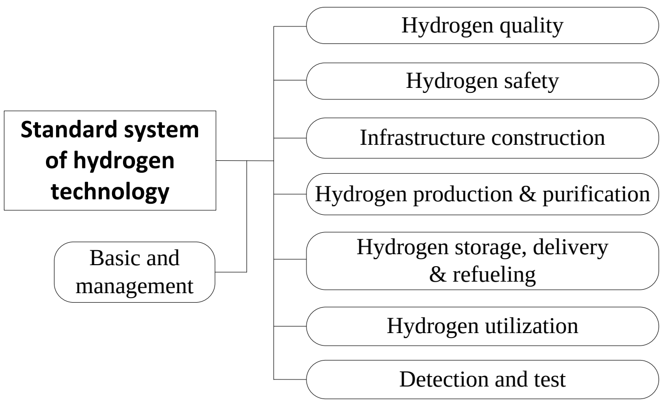

Figure 1. General framework of hydrogen technology standard system

Table 2. Details of hydrogen technology standard system

Category	Details
Basic and management	Glossary, symbol, classification, type designation and management of products related with hydrogen
Hydrogen quality	Purity, impurity content, and assessment criteria of gaseous or liquid hydrogen
Hydrogen safety	Safety regarding hydrogen production, purification, storage, delivery, refuelling and utilization
Infrastructure construction	Design, technical requirement, installation, maintenance, and inspection during infrastructure construction
Hydrogen production & purification	Technical requirement, equipment and accessory with respect to hydrogen production and purification
Hydrogen storage, delivery & refuelling	Technical requirement, equipment and accessory regarding hydrogen storage, delivery and refuelling
Hydrogen utilization	Technical requirement of fuel cell, combustion engine, and other applications of hydrogen
Detection and test	Test method and relevant test equipment

3.4 Standards published, approved and under development

GB 4962, 'Technical safety regulation for gaseous hydrogen use', the first standard on hydrogen technology in China, was published in 1985. More standards related to hydrogen technology have been published since then with the development of hydrogen energy. The active standards on hydrogen technology at the end of 2012 are shown in Table 3.

Table 3. Standards published

Number	Name
GB/T 3098.17-2000	Mechanical properties of fasteners-Preloading test for the detection of hydrogen embrittlement-Parallel bearing surface method
GB/T 3634.1-2006	Hydrogen-Part 1:Industrial hydrogen
GB/T 3634.2-2011	Hydrogen-Part 2:Pure hydrogen, high purity hydrogen and ultra pure hydrogen
GB/T 3965-1995	Methods for determination of diffusible hydrogen in deposited metal
GB 4962-2008	Technical safety regulation for gaseous hydrogen use
GB/T 8650-2006	Evaluation of pipeline and pressure vessel steels for resistance to hydrogen-induced cracking
GB/T 16942-2009	Gas for electronic industry-Hydrogen
GB/T 19773-2005	Specification of hydrogen purification system on pressure swing adsorption
GB/T 19774-2005	Specification of water electrolyte system for producing hydrogen
GB/T 20042	Proton exchange membrane fuel cell
GB/Z 21742-2008	Portable proton exchange membrane fuel cellpower systems
GB/Z 21743-2008	Stationary proton exchange membrane fuel cell power system (separate)-Tests methods for the performance
GB/T 23606-2009	Copper-hydrogen embrittlement test method
GB/T 23645-2009	Test methods of fuel cell power system for passenger cars
GB/T 23646-2009	Fuel cell power system for electric bicycles-Technical specification
GB/T 24499-2009	Technology glossary for gaseous hydrogen, hydrogen energy and hydrogen energy system
GB/T 24549-2009	Fuel cell electric vehicles-Safety requirements

Number	Name
GB/T 25319-2010	Fuel cell power system used for motor vehicles-Technical specification
GB/T 25447-2010	Proton exchange membrane fuel cell test system and activation system
GB/T 26466-2011	Stationary flat steel ribbon wound vessels for storage of high pressure hydrogen
GB/T 26779-2011	Fuel cell electric vehicles-Refuelling receptacle
GB/T 26915-2011	Determination of energy conversion efficiency and quantum yield for hydrogen production in the solar photocatalytic water splitting system
GB/T 26916-2011	Methods for performance evaluation of small-size integrative hydrogen energy system
GB/T 26990-2011	Fuel cell electric vehicles - On-board hydrogen system-Specifications
GB/Z 27753-2011	Test method for adaptability to operating conditions of membrane electrode assembly used in PEM fuel cells
GB/T 28183-2011	Test methods of fuel cell power system for bus
GB/T 29126-2012	Fuel cell electric vehicles - On-board hydrogen system-Test methods
GB 50177-2005	Design code for hydrogen station
GB 50516-2010	Technical code for hydrogen fuelling station

The vacant fields of standardization and the relations between existing standards could be found by comparing the standard system shown in Table 2 and the standards in Table 3. It can be seen that Chinese standards related to hydrogen technology have developed very fast in recent years. However, there are still a lot of standards required to be set compared with that of other developed countries. For example, as one of the most important bases for wide use of hydrogen, standards on safety requirements for hydrogen storage are rarely at present. Meanwhile, more investigations should be conducted on the standardization of hydrogen utilization, which is one of the key points to promote the development of the standard system of hydrogen technology.

Standards which have been approved are shown in Table 4, and these standards will be published in the near future. It can be observed that the standards under development, which are shown in Table 5, are mainly on hydrogen storage, delivery, fuelling, and hydrogen safety. This trend can exactly cover the shortages of the existing standards and push the commercialization of hydrogen energy in China [47].

Table 4. Standards approved

No.	Name
1	Essential safety requirements for hydrogen systems
2	Absorber for pressure swing absorption hydrogen purification
3	Water electrolyte oxygen-hydrogen generator
4	Liquid hydrogen fuelling system interface for land vehicle

Table 5. Standards under development

No.	Name
1	Fully-wrapped carbon fiber reinforced cylinders with an aluminum liner for the on-board storage of compressed hydrogen as a fuel for land vehicles
2	Compressed hydrogen refuelling connection devices for surface vehicle
3	Specification on compression hydrogen dispenser for surface vehicle
4	Test method for the safety of low pressure hydrogen storage device for small fuel cell vehicle
5	The minimum allowable values of energy efficiency and energy efficiency grades of water electrolyte system for hydrogen production

No.	Name
6	Method of determining reversible hydrogenation-dehydrogenation PCT of hydride materials
7	Metal hydride hydrogen storage system for fuel cells backup power
8	H_2—Specification for proton exchange membrane fuel cell vehicles
9	Safety technical regulation for hydrogen fuelling station
10	Safety requirements on hydrogen-oxygen generator
11	Safety technical regulation for mobile hydrogen refuelling facility
12	Safety instructions for management and operation of hydrogen fuelling station
13	Safety technical requirements for hydrogen storage devices used in hydrogen fuelling station
14	Quality of hydrogen and natural gas mixed gas

3.5 Standards on hydrogen safety

Standards on safety requirements for hydrogen production, storage, and application play an important role in improving the acceptance of hydrogen in market and society. The representative standards on hydrogen safety are introduced, including the basic safety requirements for use of gaseous hydrogen and hydrogen systems, and requirements for hydrogen fuelling station, type III on-board hydrogen storage tank, as well as fuel cell.

GB 4962 [50], 'Technical safety regulation for gaseous hydrogen use', was published in 1985 and revised in 2008. GB 4962 specifies the safety requirements for utilization, purging, storage, compression, filling and discharge of gaseous hydrogen, as well as fire fighting system, principles and operations of emergency. GB 4962 is applicable to all the aboveground applications of gaseous hydrogen. However, on-board hydrogen storage systems and aeronautic hydrogen systems are excluded from this standard. 'Essential safety requirements for hydrogen systems', which was approved in 2011, is the first standard specialized for safety of hydrogen systems in China. Classification of hydrogen systems, basic properties of hydrogen, risk of hydrogen system, and essential requirements for risk control are specified in the standard. This standard is applicable to hydrogen production, storage and delivery systems. In particular, safety requirements for slush hydrogen systems, guidelines for solid-state hydrogen storage systems and special introductions for hydrogen production by renewable energy are included in this standard [51].

GB 50177-2005 [37], 'Design code for hydrogen station', specifies the requirements for layout, equipment selection, architectural structure and other aspects on safety design of industrial hydrogen station. GB 50516-2010 [34], 'Technical code for hydrogen fuelling station', covers the safety requirements for design, construction, operation and management of hydrogen fuelling station. Requirements for safety distance, operation and management of hydrogen storage, transportation and compression equipments are also included in GB 50516-2010. The standard for type III on-board hydrogen storage tank, 'Fully-wrapped carbon fiber reinforced cylinders with an aluminum liner for the on-board storage of compressed hydrogen as a fuel for land vehicles', which specifies its type and parameters, safety technical requirements and test methods, is under development at present. GB/T 24549-2009 [52], 'Fuel cell electric vehicles-Safety requirements', specifies the safety requirements for on-board hydrogen supply system, fuel cell system, power system and electrical system. Safety requirements for emergency protection of fuel cell power system are also given in this standard. GB/T 24549-2009 is applicable to the fuel cell electric vehicles using gaseous hydrogen.

As shown in Table 5, many standards on safety requirements for hydrogen fueling station are being developed, including management and operation of hydrogen fueling station, and technical requirements for relevant hydrogen storage devices. Many issues related to hydrogen safety will be formulated into standards in the future, driven by the development of hydrogen energy.

4.0 ON-GOING ACTIVITIES

R&D of hydrogen safety and international cooperation are being actively conducted in China. Some important on-going activities on hydrogen safety are introduced.

4.1 ISO standard for pressure swing adsorption system

Pressure swing adsorption is one of the effective methods for hydrogen separation and purification. Some progress has been made on pressure swing adsorption system in China after years of studies [53, 54]. In July of 2012, an international standard proposal about pressure swing adsorption system submitted by SAC was approved by ISO/TC 197. The title of the standard is 'Pressure swing adsorption system for hydrogen separation and purification' (ISO 17971). ISO/TC 197 has set up WG 17 to formulate ISO 17971which will be finished in three years [47].

4.2 IPHE round robin test for composite pressure vessels

A multi-phase Round Robin testing program for composite pressure vessels is launched by IPHE to yield a harmonized test measurement protocol that will yield consistent results independent of test facility. Zhejiang University participates actively in the hydraulic cycling test, which is part of the program. The hydraulic cycling tests are carried out on type IV tanks from Lincoln Composites. Temperatures of the metal end boss and tank skin are monitored and maintained at a specific level during the test.

4.3 WHTC 2013, session of hydrogen safety

The 5th World Hydrogen Technologies Convention (WHTC 2013) and the 14th China Hydrogen Energy Conference (CHEC 2013) will be held together in Shanghai, China, in 25-28 September 2013. WHTC is organized by International Association for Hydrogen Energy (IAHE) to develop the technologies required for the promotion of hydrogen energy. A special session for hydrogen safety will be set up in the conference to promote international cooperation in this area. This session will mainly focus on the following three themes: 1) Regulations, codes & standards; 2) Global collaboration; 3) Latest advances in hydrogen safety R&D.

5.0 FUTURE DIRECTIONS AND CONCLUDING REMARKS

Studies on many issues related to hydrogen safety have been conducted in China over the last decade. Meanwhile, amounts of relevant standards have been formulated based on the basic studies, and the standard system of hydrogen technology is being continually developed and improved. However, more investigations on hydrogen safety are still required to accelerate the commercialization of hydrogen energy. Further work should be made on the following aspects:

(1) Demonstration projects for hydrogen energy to promote the study of hydrogen safety and accumulate practical experiences.

(2) Studies on critical safety issues which hinder the commercialization of hydrogen energy, such as compatibility of material with high pressure hydrogen, safety distance, and development of advanced test facilities to support relevant studies.

(3) Improvement of the standard system of hydrogen technology and strengthening of management of the standards.

(4) International communication and cooperation in the studies on hydrogen safety, and harmonization of relevant standards.

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