Submitted by the experts from Germany, Japan and USA

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REPORT ON THE DEVELOPMENT OF A GLOBAL TECHNICAL REGULATION FOR HYDROGEN VEHICLES

1. INTRODUCTION

During the 126th Session of WP.29 in March 2002, the Executive Committee of the 1998 Global Agreement adopted a Program of Work. Under the Program of Work, WP.29 has agreed to undertake work to begin exchanging information on fuel cell/hydrogen vehicles. In 2002, two proposals for draft regulations for vehicles powered by liquid and compressed gaseous hydrogen, developed under the European Integrated Hydrogen Project (EIHP), were submitted to WP.29. The Working Party/Group of Experts on Pollution and Energy formed an Informal Group on Hydrogen/Fuel Cell Vehicles (GRPE/IGH) to discuss and evaluate these draft proposals.

The IGH, under the chairmanship of Germany, met several times between 2002 and 2007 to discuss the two proposals. The Contracting Parties represented on the IGH, in addition to Germany, are the European Union, France, Japan, the Netherlands, and the United States of America. The European Association of Automotive Suppliers (CLEPA), the International Standards Organization (ISO), and the International Organization of Motor Vehicle Manufacturers (OICA) as well as individual vehicle manufacturers also participate.

2. REQUEST TO DEVELOP AN ACTION PLAN

At its 46th Session in May 2003, the GRPE considered the two draft regulations as potential ECE regulations under the 1958 Agreement: proposals - TRANS/WP.29/GRPE/2003/14 - for liquid hydrogen and informal document - GRPE-46-12(TRANS/WP.29/ GRPE/2004/3) - for compressed gaseous hydrogen. Following a discussion of the proposed regulations, the GRPE concluded that the draft regulations were not ready for adoption and postponed action on the proposals. Some delegations specifically expressed their concern that the proposals were not comprehensive enough, as they addressed only individual components, not the safety of the whole vehicle. The need for evaluation of the entire hydrogen fuel system, including conducting a fuel system crash test, which is not addressed by the current draft regulations, was also raised. In addition, a number of parties found the draft regulations to be very design specific with the potential of constraining future technological innovations. The US wanted to introduce the draft regulations not under the 1958 Agreement, but under 1998 Global Agreement.

The GRPE recommended that, given the global nature of the automotive industry, the group take a more global approach when considering the regulations for hydrogen vehicles and asked the delegations of the European Union, Japan and the United States to clarify their technical and political positions with respect to the development of regulations for hydrogen vehicles. The GRPE also directed the IGH to work with Japan, the United States, the European Union and other interested delegations to develop an Action Plan for the assessment of the hydrogen technologies for motor vehicles outlining any necessary research development and testing that would be needed for the development of the gtr. In 2006, Germany, Japan and the United States reaffirmed their commitment to serve as co-sponsors for the effort to develop the gtr. Japan and the US have served as co-chairs of the reorganized group into the Sub-Group on Hydrogen Safety (HFCV-SGS) and began plans to develop an 'Action Plan' for the gtr establishment. The proposal for a new Action Plan and restructured working group was adopted by WP.29 in June 2007. It was proposed that a gtr for hydrogen-powered vehicles based on a component level, subsystems, and whole vehicle crash test approach would be established by 2010 in phase 1 activity.

HISTORY OF GTR DEVELOPMENT

Gtr Development Tasks	**Dates**
Adoption of the Action Plan/ Establishment of the SGS	June 2007
1st HFCV-SGS meeting	September 2007
2nd HFCV-SGS meeting	January 2008
3rd HFCV-SGS meeting	May 2008
4th HFCV-SGS meeting	September 2008
5th HFCV-SGS meeting	January 2009
Drafting Task Force group meeting for fuel system	April 2009
6th HFCV-SGS meeting	May 2009
7th HFCV-SGS meeting	September 2009
8th HFCV-SGS meeting	January 2010
9th HFCV-SGS meeting	June 2010

10th HFCV-SGS meeting	September 2010
Task Force group meeting	November 2010
11th HFCV-SGS meeting	February 2011
12th HFCV-SGS meeting	June 2011
working document to 50th GRSP (ECE/TRANS/WP.29/GRSP/2011/33)	September 2011
Drafting Task Force group meeting	November 2011
50th GRSP	December 2011
working document to 51st GRSP (ECE/TRANS/WP.29/GRSP/2012/12)	March 2012
51st GRSP	May 2012
working document to 52nd GRSP (ECE/TRANS/WP.29/GRSP/2012/23)	September 2012
52nd GRSP	December 2012
final document adopted by WP.29 AC.3	March or June 2013

3. EVALUATION OF THE SAFETY PROBLEM

Safety of hydrogen vehicles has emerged in these years as an important motor vehicle safety issue. Ensuring that hydrogen fuel cell and internal combustion engine (ICE) vehicles provide consumers with a high level of safety requires extensive research efforts. Meanwhile, hydrogen vehicles have been deployed as part of demonstration fleets in several countries, including Germany, US, and Japan, yet very little data is available on safety performance of these vehicles.

Manufacturers have invested significant resources in producing and marketing these vehicles, and it is important they share their data, including crash test data, with governments to serve as a basis in support of their regulatory actions. Without positive results of basic and comprehensive research and testing, which would demonstrate safety of hydrogen vehicles, governments will not be in a position to develop regulations, or to instill confidence in hydrogen vehicles in prospective consumers.

With respect to the application of potential global technical regulation for hydrogen vehicle, the main focus of the scope of the gtr could be vehicles powered entirely by hydrogen. Furthermore, the regulation covers individual components and address the safety performance and integrity of the entire hydrogen fuel system. These requirements have been written, to the extent possible, in terms of performance, as design-specific requirements may potentially constrain future hydrogen-related technological innovations and methodologies.

4. REVIEW OF EXISTING INTERNATIONAL REGULATIONS

At present, Japan and the EC have national or international regulations or directives governing the manufacture of hydrogen vehicles in place, however, there have been several voluntary codes and standards developed by international standards-setting organizations, including the Society of Automotive Engineers (SAE), International Standards Organization (ISO), etc. These standards generally address a specific component of hydrogen vehicles, such as on-board storage tanks or pressure relief devices, but not the safety performance and integrity of the entire hydrogen fuel system or whole vehicles.

- Existing Regulations, Directives, and International Standards -

A. Vehicle fuel system integrity

(a) National regulations and directives

(a) European Union – Regulation 79/2009 – Type-approval of hydrogen-powered motor vehicles

(b) European Union – Regulation 406/2010 — implementing EC Regulation 79/2009

(c) Japan — Safety Regulation Article 17 and Attachment 17 – Technical Standard for Fuel Leakage in Collision

(d) Japan — Attachment 100 – Technical Standard For Fuel Systems Of Motor Vehicle Fueled By Compressed Hydrogen Gas

(e) Canada — Motor Vehicle Safety Standard (CMVSS) 301.1 – Fuel System Integrity

(f) Canada — Motor Vehicle Safety Standard (CMVSS) 301.2 – CNG Vehicles

(g) Korea — Motor Vehicle Safety Standard, Article 91 – Fuel System Integrity

(h) United States — Federal Motor Vehicle Safety Standard (FMVSS) No. 301 - Fuel System Integrity.

(i) United States — FMVSS No. 303 – CNG Vehicles

(j) China – GB/T 24548-2009 Fuel cell electric vehicles – terminology

(k) China -- GB/T 24549-2009 Fuel cell electric vehicles - safety requirements

(l) China -- GB/T 24554-2009 Fuel cell engine - performance - test methods

(b) National and International standards.

(a) ISO 17268 — Compressed hydrogen surface vehicle refuelling connection devices

(b) ISO 23273-1 — Fuel cell road vehicles — Safety specifications — Part 1: Vehicle functional safety

(c) ISO 23273-2 — Fuel cell road vehicles — Safety specifications — Part 2: Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen

(d) ISO 14687-2 — Hydrogen Fuel — Product Specification — Part 2: Proton exchange membrane (PEM) fuel cell applications for road vehicles

(e) SAE J2578 — General Fuel Cell Vehicle Safety

(f) SAE J2600 – Compressed Hydrogen Surface Vehicle Fueling Connection Devices

(g) SAE J2601 – Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles

(h) SAE J2799 – Hydrogen Quality Guideline for Fuel Cell Vehicles

B. Storage system

(a) National regulations and directives:

(a) China — Regulation on Safety Supervision for Special Equipment

(b) China — Regulation on Safety Supervision for Gas Cylinder

(c) Japan — JARI S001(2004) Technical Standard for Containers of Compressed Hydrogen Vehicle Fuel Devices

(d) Japan — JARI S002(2004) Technical Standard for Components of Compressed Hydrogen Vehicle Fuel Devices

(e) Japan — KHK 0128(2010) Technical Standard for Compressed Hydrogen Vehicle Fuel Containers with Maximum Filling Pressure up to 70MPa

(f) Korea — High Pressure Gas Safety Control Law

(g) United States — FMVSS 304 - Compressed Natural Gas fuel Container Integrity

(h) European Union — Regulation 406/2010 implementing EC Regulation 79/2009

(i) China — QC/T 816-2209 Hydrogen supplying and refueling vehicles -specifications

(b) National and International standards:

(a) CSA B51 Part 2 — High-pressure cylinders for the on-board storage of natural gas and hydrogen as fuels for automotive vehicles

(b) CSA NGV2-2000 – Basic Requirements for Compressed Natural Gas Vehicle (NGV) Fuel Containers

(c) CSA TPRD-1-2009 – Pressure Relief Devices For Compressed Hydrogen Vehicle Fuel Containers

(d) CSA HGV 3.1-2011 – Fuel System Component for Hydrogen Gas Power Vehicles (Draft)

(e) ISO 13985:2006 — Liquid Hydrogen – Land Vehicle Fuel Tanks

(f) ISO 15869:2009 — Gaseous Hydrogen and Hydrogen Blends – Land Vehicle Fuel Tanks (Technical Specification)

(g) SAE J2579 — Fuel Systems in Fuel Cell and Other Hydrogen Vehicles

C. Electric safety

(a) National regulations and directives:

(a) Canada — CMVSS 305—Electric Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection

(b) ECE — Regulation 100 - Uniform Provisions Concerning the Approval of Battery Electric Vehicles with Regard to Specific Requirements for the Construction and Functional Safety

(c) Japan — Attachment 101 – Technical Standard for Protection of Occupants against High Voltage in Fuel Cell Vehicles

(d) Japan — Attachment 110 – Technical Standard for Protection of Occupants against High Voltage in Electric Vehicles and Hybrid Electric Vehicles

(e) Japan — Attachment 111 – Technical Standard for Protection of Occupants against High Voltage after Collision in Electric Vehicles and Hybrid Electric Vehicles

(f) Korea — Motor Vehicle Safety Standard, Article 18-2 – High Voltage System

(g) Korea — Motor Vehicle Safety Standard, Article 91-4 – Electrolyte Spillage and Electric Shock Protection

(h) United States — FMVSS 305 - Electric-Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection

(b) National and International Industry standards:

(a) ISO 23273-3 — Fuel cell road vehicles — Safety specifications — Part 3: Protection of persons against electric shock

(b) SAE J1766 — Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing

(c) SAE J2578 — General Fuel Cell Vehicle Safety

5. SPECIFIC SAFETY ISSUES TO BE ADDRESSED

Current existing regulations concerning the fuel system do not address the unique properties of hydrogen, hydrogen on-board storage, or fuel cells as a high voltage electrical component in vehicles. For example, hydrogen is colorless, odorless, with a wide range of flammability, and high propensity to leak.

A. Unique Safety Challenges Presented by Hydrogen and Hydrogen Vehicles

Even though the existing regulations address, for example, the storage of CNG, the on-board storage of hydrogen needs to be examined because of the high pressure that is projected. Also, hydrogen may be stored as a cryogenic liquid, requiring complex venting and cooling, as metal hydrides or as chemical hydrides, with both methods requiring specific safety and environmental considerations. Regulations also exist for electric vehicles, but these may not be properly address the unique properties of the fuel cell as a high voltage component since, among other reasons, fuel cell does not discharge like a conventional battery. The following issues have been identified to be examined and addressed by the gtr:

a. Characteristics of hydrogen as a fuel differ from conventional vehicle fuels
b. Characteristics of hydrogen storage differ from storage of other fuels
    i. high pressure (up to 70Mpa)
    ii. cryogenic liquid (complexity of cooling and venting)
    iii. metal and chemical hydrides (thermal management for charging and discharging H, high pH waste)
    iv. aging
c. Characteristics of fuel cells as high voltage electrical devices differ from conventional auto batteries
    i. high voltage operation (up to 400V)
    ii. electrical isolation

B. Research and Testing

The objective of the research is to provide the technical basis for developing the gtr for hydrogen vehicles. At the <u>component level</u>, stakeholders conducted and evaluated bonfire, burst, and pressure recycling tests to determine adequacy of proposed requirements for hydrogen on-board containers. Along with these tests, additional testing has been conducted to evaluate safety performance of thermal and pressure activated pressure relief devices and thermal and electrical management systems for tanks, fuel cells, and batteries, purging of fuel cell lines, etc. Still, more testing should be done to understand better ignitability and flammability through controlled releases of hydrogen and electrical arc at various severed locations in tubing between on-board storage tanks and fuel cell stack. Extensive testing is also merited to examine if external debris or matter can cause ignition of venting hydrogen. Additional work should be also performed to evaluate onboard refuelling performance and for potential leakage from vehicle or fuelling system interface.

On the full vehicle level, tests have been conducted to determine overall crashworthiness and integrity. During operation and while parked, hydrogen leakage and concentrations inside and outside the vehicle should be measured over time, as well as testing of the passive and active ventilation systems, with a specific emphasis on the performance of the recovery or conversion systems to remove hydrogen. Research and testing have been done to evaluate electrical isolation of the fuel cell, cooling system and auxiliary batteries to determine electrical isolation of the entire high voltage system in pre-crash and post-crash scenarios. Supplementary evaluation of post-crash, especially for emergency medical services, is recommended to determine any special post-crash handling requirements for occupants, rescue personnel, towing service or disposal.

C. Outline of gtr

Finally, it is concluded through dedicated discussion that the gtr covers fuel cell (FC) and internal combustion engine (ICE), compressed gaseous hydrogen (CGH_2) and liquid hydrogen (LH_2) in Phase 1. The application of the GTR is for passenger vehicles and three main areas outlined in the Action Plan have been discussed and included in gtr text, these are fuel system integrity, electrical safety, and hydrogen storage system.

- Discussion of HFCV-SGS and Task Force meetings -

1st meeting took place in September 2007 in Bonn
At the initial meeting, the group developed and agreed on the Terms of Reference for the gtr development.

2nd meeting took place in January 2008 in Geneva

SGS began to discuss the overall features of the gtr and its scope. SGS also discussed the high pressure containers and container - storage assembly, hydrogen leakage and its detection.

3rd meeting took place in May 2008 in Washington D.C.
At the 3rd meeting, SGS discussed in general the structure, scope and application of the gtr. Some delegates proposed including 2- and 3- wheeled vehicles, but requirements for those vehicles will be developed in Phase 2. Also discussed were vehicle fuel system integrity and the integrity of hydrogen containers, mainly for the compressed gaseous hydrogen. The Group heard a presentation by BMW on proposed requirements for liquefied hydrogen vehicles.

4th meeting took place in September 2008 in Tokyo
Discussions and presentation on container bonfire test, FC bus and passenger vehicles, container development, and the overall storage system, vehicle fuel system integrity and electric safety.

5th meeting took place in January 2009 in Budapest
Discussions on definitions, vehicle fuel system integrity, pressure relief devices and their discharge direction, leakage limit for enclosed areas within the vehicle; leakage limits for the exhaust outlet. SGS held an extensive discussion on the need and requirements for telltale. Also discussed, were post crash, electric safety,

Drafting Task Force meeting took place in April 2009 in Frankfurt
The TF made a significant progress in identifying critical issues that need to be included in the gtr and proposed draft language, which was later adopted by SGS.

6th meeting took place in May 2009 in Beijing
SGS discussed hydrogen permeation, comparison of integrity of different hydrogen containers for gaseous compressed gas, and demonstration/testing protocols of container integrity.

7th meeting took place in September 2009 in Ottawa
At the meeting SGS discussed the changes discussed and proposed by the Task Force. SGS also focused on resolving several key issues, namely, the number of cycles, initial burst pressure and of the storage system. Also discussed by the group were the differences between the hydraulic and pneumatic testing and leak permeation concerns.

8th meeting took place in January 2010 in Geneva

The two main topics of the discussions in Geneva were overpressurization of the downstream, which some delegation felt strongly about as deemed critical in order to ensure integrity of the system. SGS resolved this by developing a performance-based requirement; and the airtightness test for fuel lines. This issue, on which SGS was unable to reach a consensus, was resolved by agreeing in principle on a requirement describing an objective and reasonable test. Also resolved were the four types of containers that can be used for on-board storage of hydrogen.

9thth meeting took place in June 2010 in Seoul

SGS discussed the issue of testing hydrogen containers' integrity; specifically, the number of cycles representative of the life span of containers given the difference in vehicles and their uses. SGS also discussed the issue of including in the gtr the requirements for individual components that are deemed safety-critical, such as PRDs, maximum fueling pressure, and testing that is needed to validate several of the requirements.

10th meeting took place in September 2010 in San Francisco

SGS discussed need for validation tests for material compatibility of containers and requirements for individual components. The group continued to discuss the liquid hydrogen requirements, specifically, the storage and refueling. Most contracting parties felt that they were not ready for adoption of the liquid hydrogen portion of the gtr, but there is a general agreement that the issue will be addressed in further discussion and perhaps also in Phase2.

Drafting Task Force meeting took place in November 2010 in Berlin

SGS discussed the BMW proposal for liquid hydrogen vehicles, electric safety, container composition, and TPRD performance.

11th meeting took place in February 2011 in Brussels

Main issues discussed were the engulfing fire duration. US wanted to extend the time to 10 minutes, based on data presented earlier by Japan and SAE; the group however did not agree. Germany proposed to adopt a shorter time but discuss this issue in Phase 2. OICA proposed a component test for environment exposure. Drop and vibration tests were also discussed. SGS also discussed developing fuelling receptacle requirements. Another topic was the reduction of the allowable concentration from 4% to 2%. US argued that an additional margin of safety is needed to address the potential that random spot concentration of hydrogen could be higher than 4%. Next topic was the liquid hydrogen container and post crash requirements.

Many of the contracting parties are not prepared to adopt the LH2 section, but will not object to the inclusion of this section in Phase 1. The container material compatibility was also discussed but in the absence of consensus, deferred to Phase 2. Regarding the Electrical safety, SGS discussed issues, such as electric shock protection.

12th meeting took place in June 2011 in Paris
These main issues were: material compatibility, liquefied hydrogen system, electric safety and the engulfing, bonfire and localized fire tests. Another important issue is timing of the completion of the gtr. Based on the feedback from several contracting parties that are in the process of validating additional test procedures, the submission of the draft gtr as informal document to GRSP may be delayed until– WP.29, June 2012. The co-sponsors, Germany, Japan and the US, will continue their discussions with other contracting parties and participants to accelerate the work to complete it in a timely manner but an agreement has been made in SGS that we will not rush to the completion at the expense of submitting a robust gtr.

Task Force meeting took place in November 2011 in Mainz
SGS concluded the Phase 1 with agreeing to present a draft gtr to the GRSP for discussion.

All documents related to HFCV-SGS informal meetings are available on following UN web-site.
https://www2.unece.org/wiki/pages/viewpage.action?pageId=3178603

6. BNEFITS AND COSTS

At this time, the gtr does not attempt to quantify costs and benefits for this first stage. While the goal of the gtr is to enable increased market penetration of HFCVs, the resulting rates and degrees of penetration are not currently known or estimatable. Therefore, a quantitative cost-benefit analysis was not possible.
Some costs are anticipated from greater market penetration of HFCVs. For example, building the infrastructure required to make HFCVs a viable alternative to conventional vehicles will entail significant investment costs for the private and public sectors, depending on the country. Especially in the early years of HFCV sales, individual purchasers of HFCVs are also likely to face greater costs than purchasers of conventional gasoline or diesel vehicles, the same goes for manufacturers of new HFCVs (However, costs incurred by HFCV purchasers and manufacturers would essentially be voluntary, as market choice would not be affected).
While some costs are expected, the contracting parties believe that the benefits of gtr are likely to greatly outweigh costs. Widespread use of HFCVs, with the establishment of the necessary infrastructure for fuelling, is anticipated to reduce the number of gasoline and diesel vehicles on the road, which should reduce worldwide consumption of fossil fuels. Perhaps most notably, the reduction in greenhouse gas and criteria pollutant emissions (such as NO_2, SO_2, and particulate

matter) associated with the widespread use of HFCVs is anticipated to result in significant societal benefits over time by alleviating climate change and health impact costs. The gtr may also lead to decreases in fuelling costs for the operators of HFCVs, as hydrogen production is potentially unlimited and expected to become more cost-effective than petroleum production for conventional vehicles. Furthermore, decreased demand for petroleum is likely to lead to energy and national security benefits for those countries with widespread HFCV use, as reliance on foreign oil supplies decreases. Additionally, although not attributable to this gtr, the gtr may create benefits in terms of facilitating OEM compliance with applicable fuel economy and greenhouse gas emission standards by promoting a wider production and use of HFCVs.

The contracting parties have also not been able to estimate net employment impacts of the gtr. The new market for innovative design and technologies associated with HFCVs may create significant employment benefits for those countries with ties to HFCV production. On the other hand, employment losses associated with the lower production of conventional vehicles could offset those gains. The building and retrofitting of infrastructure needed to support hydrogen production and storage is likely to generate net additions to the job market in the foreseeable future.