GLOBAL REGISTRY

Created on 18 November 2004, pursuant to Article 6 of the
AGREEMENT CONCERNING THE ESTABLISHING OF GLOBAL TECHNICAL REGULATIONS FOR WHEELED VEHICLES, EQUIPMENT AND PARTS WHICH CAN BE FITTED AND/OR BE USED ON WHEELED VEHICLES

(ECE/TRANS/132 and Corr.1)

Done at Geneva on 25 June 1998

Addendum

Global technical regulation No. xx

HYDROGEN FUEL CELL VEHICLE
(Established in the Global Registry on [DATE])

Appendix

Proposal and report pursuant to Article 6, paragraph 6.3.7. of the Agreement

- Proposal to develop a global technical regulation concerning Hydrogen fuel cell vehicle (ECE/TRANS/WP.29/AC.3/17)
- Final progress report of the informal working group on Hydrogen fuel cell vehicle GTR .....

UNITED NATIONS

A. Justification and technical rationale

1. Introduction

[Introduction: [need to prepare a general statement about the need to reduce the dependence on oil, reduce green house gas emissions/protection of the environment and need to explore alternative fuels..hence focus on hydrogen – appeal/benefit of using hydrogen as on-board fuel, and at the same time, about the unique characteristics of hydrogen which when stored on-board, under high pressure pose additional risks – need for "hydrogen-specific" regulation that would take into account the additional concerns. As part of this intro, we can also briefly discuss the major differences between the conventional ICE and hydrogen FCV systems, including the distinction in the electric power of the HFC battery vs. the conventional car/14.4 V battery]

Purpose: goals of this global regulation (gtr) are to develop and establish a gtr for Hydrogen Fuel Cell Vehicles (HFCV) that: (1) Attains equivalent levels of safety as those for conventional gasoline powered vehicles and (2) Is performance-based and does not restrict future technologies.

Given that hydrogen-powered vehicle technology is still emerging, WP.29/AC.3 agreed that input from researchers is a vital component of this effort. Based on a comparison of existing regulations and standards of HFCV with conventional vehicles, it is important to investigate and consider: (1) The main differences in safety and environmental aspects and (2) What items need to be regulated based on justification.

In June 2005, WP.29/AC.3 agreed to a proposal from Germany, Japan and United States of America regarding how best to manage the development process for a gtr on hydrogen-powered vehicles (ECE/TRANS/WP.29/AC.3/17). Under the agreed process, once AC.3 develops and approves an action plan for the development of a gtr, two subgroups will be formed to address the safety and the environment aspects of the gtr. The subgroup safety (HFCV-SGS) will report to GRSP. The chair for the group will be discussed and designated by summer of 2007. The environmental subgroup (HFCV-SGE) is chaired by European Commission and reports to GRPE. In order to ensure communication between the subgroups and continuous engagement with WP.29 and AC.3, the project manager (Germany) will coordinate and manage the various aspects of the work ensuring that the agreed action plan is implemented properly and that milestones and timelines are set and met throughout the development of the gtr. The gtr will cover fuel cell (FC) and internal combustion engine (ICE), compressed gaseous hydrogen (CGH2) and liquid hydrogen (LH2) in the phase 1 gtr. At the (X) WP.29, the gtr action plan was submitted and approved by AC.3 (ECE/TRANS/WP.29/2007/41).

In order to develop the gtr in the context of an evolving hydrogen technology, the trilateral group proposes to develop the gtr in two phases:

(a) Phase 1 (gtr for hydrogen-powered vehicles):
Establish a gtr by 2010 – 2012 for hydrogen-powered vehicles based on a component level, subsystems, and whole vehicle crash test approach. For the crash testing, the gtr would specify that each contracting party will use its existing national crash tests but develop and agree on maximum allowable level of

hydrogen leakage. The new Japanese regulation, and any available research and test data will be used as a basis for the development of this first phase of the gtr.

(b) Phase 2 (Assess future technologies and harmonize crash tests):
Amend the gtr to maintain its relevance with new findings based on new research and the state of the technology beyond phase 1. Discuss how to harmonize crash test requirements for HFCV regarding whole vehicle crash testing for fuel system integrity.

The gtr will consist of the following key areas:

(a) Component and subsystem level requirements (non-crash test based):
Evaluate the non-crash requirements by reviewing analyses and evaluations conducted to justify the requirements. Add and subtract requirements or amend test procedures as necessary based on existing evaluations or on quick evaluations that could be conducted by Contracting Parties and participants. Avoid design specific requirements to the extent possible and do not include provisions that are not justified. The main areas of focus are as follows:

(i) Performance requirements for fuel containers, pressure relieve devices, fuel cells, fuel lines, etc.
(ii) Electrical isolation; safety and protection against electric shock (in-use).
(iii) Performance and other requirements for sub-systems integration in the vehicle.

(b) Whole vehicle requirements (crash test based):
Examine the risks posed by the different types of fuel systems in different crash modes, using as a starting point the attached tables. Review and evaluate analyses and crash tests conducted to examine the risks and identify countermeasures for hydrogen-powered vehicles. The main areas of focus are as follows:

(i) Existing crash tests (front, side and rear) already applied in all jurisdictions.
(ii) Electrical isolation; safety and protection against electric shock (post crash).
(iii) Maximum allowable hydrogen leakage.

Application: the CPs decided at this to set requirements for passenger FC vehicles only with the understanding that in the coming years, it will appropriate to extend the application of the regulation and/or establish new requirements for additional classes of vehicles, specifically, motor coaches, trucks, and two-/three-wheel motorcycles.]

Provide background information on hydrogen technologies

Discuss the GTR action plan;

Describe the Japanese regulation;

Other government regulations

Industry standards

2. Procedural background

3. Existing regulations, directives, and international voluntary standards

3.1. Vehicle fuel system integrity

National regulations:

Japanese Safety Regulation article 17 and Attachment 17 – Technical Standard for Fuel Leakage in Collision, etc.

Japanese Attachment 100 – Technical Standard For Fuel Systems Of Motor Vehicle Fueld By Compressed Hydrogen Gas

ECE

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

Canadian Motor Vehicle Safety Standards (CMVSS) 301.2 – Fuel System Integrity

Industry standards:

ISO
SAE J2578 - Recommened Practice For General Fuel Cell Vehicle Safety

3.2 Storage-system

National regulations:

Japanese

ECE

FMVSS 304 - Compressed Natural Gas fuel Container Integrity.

Industry standards:

ISO

SAE J2579 - Technical Information Report for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles

3.3. Electric safety

National regulations:

Japanese Attachment 101 – Technical Standard for Protection of Occupants against High Voltage in Fuel Cell Vehicle.

ECE Regulation 100 - Uniform Provisions Concerning The Approval Of Battery Electric Vehicles With Regard To Specific Requirements for The Construction AND Functional Safety

FMVSS 305 - Electric-Powered Vehicles: Electrolyte Spillage and Electrical Shock Protection.

CMVSS 305—Electric Powered Vehicles: Electrolyte Spillage And Electrical Shock Protection

Industry standards:

ISO

SAE J1766—Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing

4. Technical rationale, economic impacts, and anticipated benefits

4.1. Vehicle fuel system integrity

Need explanations and justifications including test reports, analysis, studies for:

- 4% lower flammability limit (LFL)
- Description of the exhaust system's operation, figures…
- Need explanation for "moving 3 seconds time interval" in the exhaust system requirement.
- Post crash - H_2 maximum leakage :

The maximum post crash hydrogen leakage is based on the heat energy equivalent to maximum post crash leakages from gasoline vehicles. Calculations? Testing? Explanation the difference between Japanese and OICA's proposed leakage amount.

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4.2 Storage-systems

4.3. Electric safety

5. Markings

B. Text of the regulation

1. Purpose

2. Application / Scope

3. Definitions

Need definitions for the followings:

Pressure relief device: A device that, when activated under specified performance conditions, is used to release fluid from a pressurized system and thereby prevent failure of the system. Thermally activated PRDs are designated TPRDs.

Pressure relief valve: A pressure relief device that opens at a preset pressure level and can re-close.

Single failure mode

Fuel cell module

Vehicle exhaust system

Flammability limits:LFL: Lowest concentration of fuel at which a gas mixture is flammable. National and international standard bodies (such as NFPA and IEC) recognize 4% hydrogen in air as the LFL.UFL: Highest concentration of fuel at which there is sufficient oxidant in the gas mixture for the mixture to be flammable. The UFL of hydrogen is 74% in air and 95% in pure oxygen as in each case 5% oxygen is required in the mixture.

The exhaust's point of discharge

High voltage: As used in this gtr, high voltage is defined as greater than or equal to 60 VDC and 30 VAC.

4. General requirements: Each hydrogen fuel cell vehicle and hydrogen powered vehicle shall meet the requirements of section 5.1 and 5.2. Each vehicle using high voltage shall meet the requirement of section 5.3.

5. Performance requirements

5.1 Vehicle fuel system integrity

5.1.1 Purpose: This section specifies requirements for the integrity of the hydrogen storage fuel system. The purpose of this section is to reduce deaths and injuries occurring from fires or explosions that result from uncontrolled fuel spillage during use and after vehicle crashes.

5.1.2 Requirements – in use

5.1.2.1 Pressure Relief System Installation: The hydrogen gas discharge from pressure relief devices at the gas container or upstream of the first pressure regulator located downstream of the gas container of compressed gas hydrogen systems shall not be directed:

a) into or towards the vehicle passenger or luggage compartments
b) into or towards any vehicle wheel housing
c) towards hydrogen gas containers
d) forward from the vehicle, or horizontally from the back or sides of the vehicle

The hydrogen gas discharge from **other pressure relief systems** shall not be directed:

a) towards exposed electrical terminals, exposed electrical switches or other ignition sources
b) into or towards the vehicle passenger or luggage compartments
c) into or towards any vehicle wheel housing
d) towards hydrogen gas containers

5.1.2.2 Single failure conditions:

5.1.2.2.1 Any single failure downstream of the main hydrogen shut off valve shall not result in a hydrogen concentration in air greater than 4% by volume within the passenger compartment.

5.1.2.2.2 If a single failure downstream of the main hydrogen shut off valve results in a hydrogen concentration in air greater than 4% by volume within an enclosed or semi enclosed space in the vehicle, the main hydrogen shutoff valve shall be immediately closed.

5.1.2.2.3 A malfunction of the hydrogen leakage detection system shall be indicated to the driver by means of visual and/or audible warning.

5.1.2.3 Vehicle exhaust system: The vehicle exhaust system's point of discharge shall not exceed 4% average concentration of hydrogen in air by volume during any moving three-second time interval during normal operation including start-up and shutdown.

5.1.3 Requirements - post crash

Each contracting party under the UNECE 1998 Agreement will maintain its existing national crash tests and use the following requirements and limit values for compliance.

5.1.3.1 Fuel leakage: After the crash test, the rate of uncontrolled hydrogen gas leakage measured and calculated by the following procedure shall not exceed an average of 120 NL per minute within 60 minutes after the crash.

5.2 Storage system provisions

5.2.1. Purpose: This section specifies the requirements for the integrity of the fuel container of hydrogen powered motor vehicle. The purpose of this section is to reduce deaths and injuries occurring from fires and explosion of fuel container(s) during normal use and after a vehicle crash

5.2.3 Performance Requirements

5.2.4 Markings

5.3 Electric safety

5.3.1 Purpose: This section specifies the requirements for high voltage. The purpose of this section is to reduce death and injuries during use and after a crash which occur because of electrical shock.

5.3.2 Requirements and test procedures - in-use

5.3.2.1 Performance requirements

5.3.3 Requirements and test procedures - post crash

5.3.3.1 Performance requirements

5.3.4 Markings

6.2. Test conditions and procedures

Need test validation

6.2.1 [Demonstration of fuel system integrity crash test compliance

The crash tests used to evaluate post-crash hydrogen leakage are those already applied in the respective jurisdictions.

To evaluate possible hydrogen discharge following the vehicle crash tests, the following procedure should be used.

a) Compressed Gaseous Hydrogen Storage:

The gas container shall be filled with helium to minimum 90% of the nominal working pressure. The main stop valve and shut-off valves, etc. for hydrogen gas, located in the downstream hydrogen gas piping, shall be kept open immediately prior to the impact.

The pressure and temperature of the gas shall be measured immediately before the impact and 60 minutes after the impact either inside the gas container or upstream of the first pressure-reducing valve downstream of the gas container.

The rate of hydrogen gas leakage shall be measured by the following procedure.
The helium gas pressure immediately before the impact and 60 minutes after the impact, upstream of the first pressure-reducing valve either within the gas container or the one located downstream of the gas container shall be converted to the pressure at 0°C using equation1.

Equation 1: $P_0' = P_0 \times \{273 / (273 + T_0)\}$
where:
P_0' : Helium gas pressure converted to pressure at 0 °C before impact (MPa abs)
P_0 : Measured helium gas pressure before impact (MPa abs)
T_0 : Measured helium gas temperature before impact (°C)

$P_{60}' = P_{60} \times \{273 / (273 + T_{60})\}$
where:
P_{60}' : Helium gas pressure converted to pressure at 0 °C 60 minutes after impact (MPa abs)
P_{60} : Measured helium gas pressure 60 minutes after impact (MPa abs)
T_{60} : Measured helium gas temperature 60 minutes after impact (°C)

The gas density calculated from equation 2 before the impact and 60 minutes after the impact shall be calculated using the pressure at 0°C converted from the helium gas pressure upstream of the first pressure-reducing valve within the gas container or the one located downstream of the gas container obtained from equation 1.

Equation 2: $\rho_0 = -0.0052 \times (P_0')^2 + 1.6613 \times P_0' + 0.5789$
where:
ρ_0 : Helium gas density before impact (kg/m^3)
$\rho_{60} = -0.0052 \times (P_{60}')^2 + 1.6613 \times P_{60}' + 0.5789$
where:
ρ_{60} : Helium gas density 60 minutes after impact (kg/m^3)

The helium gas volume before the impact and 60 minutes after impact shall be calculated from equation 3 using the gas density obtained from equation 2. However, the internal volume shall be the internal volume of the gas container in cases where the helium gas pressure has been measured inside the gas container; and the internal volume of the container down to the first pressure-reducing valve located downstream of the gas container in cases where the helium gas pressure has been measured upstream of the first pressure-reducing valve located downstream of the gas container.

Equation 3: $Q_0 = \rho_0 \times V \times (22.4 / 4.00) * 10^{-3}$
where:
Q_0 : Helium gas volume before impact (m^3)
V : Internal volume (L)

$Q_{60} = \rho_{60} \times V \times (22.4 / 4.00) * 10^{-3}$
where:
Q_{60} : Helium gas volume 60 minutes after impact (m^3)
V : Internal volume (L)

The rate of helium gas leakage shall be calculated.
$\Delta Q = (Q_0 - Q_{60}) \times 10^3$
$RHe = \Delta Q / 60$
where:
ΔQ : Volume of helium gas leakage 60 minutes after impact (NL)
RHe : Rate of helium gas leakage (NL/min)

The rate of helium gas leakage shall be converted to the rate of hydrogen gas leakage.
$RH = 1.33 \times RHe$
where:
RH : Rate of hydrogen gas leakage (NL/min)

b) Liquid Hydrogen Storage:

The fuel storage container shall be filled with liquid nitrogen (LN2) to minimum the mass equivalent of the maximum quantity of LH2 that may be contained in the inner vessel and then the system shall be pressurized with a gaseous N2 up to typical operating pressure.

The main stop valve and shut-off valves, etc. for hydrogen, located in the downstream hydrogen gas piping, shall be kept open immediately prior to the impact.

After the collision, the liquid hydrogen storage system must be tight, i.e. bubble free* if using detecting spray. No uncontrolled release of the test fluid is allowed.

** With bubble detection spray, any leakage in the range above 0,1Pa l/s can be detected. In case of N2 used as test fluid, the corresponding detectable hydrogen leakage would be about 0,5 Pa l/s (that is far below 1 NL per minute!).*]

7. Annexes