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Contains comments from the drafting task force – April 16, 2009

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 POWERED 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

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A. STATEMENT OF TECHNICAL RATIONALE AND JUSTIFICATION

1. INTRODUCTION

1. [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]

2. In the ongoing debates over the need to identify new sources of energy and to reduce the emissions of green house gases, countries around the world have explored the use of various alternative gases as fuels, including compressed natural gas, liquefied propane gas, and hydrogen. Hydrogen has emerged as one of the most promising alternatives due to its virtual zero emission. In the late 1990’s, the European Community allocated resources to study the issue under its European Integrated Hydrogen Project. A few years later, the United States outlined a vision for a global wide initiative, the International Partnership on the Hydrogen Economy, and invited Japan, European Union, China, Russia and many other countries to participate in this effort.

3. For decades scientists, researchers and economists have pointed to hydrogen, in both compressed gaseous and liquid forms, as a possible candidate as an alternative to gasoline and diesel as vehicle fuel. Ensuring the safe use of hydrogen as fuel is a critical ingredient in the world economies successfully transitioning to a hydrogen economy. By their nature, all fuels present an inherent degree of danger due to their energy content. The safe use of hydrogen, particularly in the compress gaseous form, lies in preventing catastrophic failures due to volatile combination of fuel, ambient air and ignition sources.

4. The governments have identified development of regulations and standards as one of the key requirements for a long-term promotion in commercialization of hydrogen-powered vehicles. Regulations and standards will help overcome technological barriers to commercialization, facilitate manufacturers’ investment in building hydrogen-powered vehicles and facilitate public acceptance by providing a systematic and accurate means of assessing and communicating risk associated with the use of hydrogen vehicles, be it to the general public, consumer, emergency response personnel and the insurance industry.

5. The 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.

2. GTR ACTION PLAN

6. 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.

7. 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).

8. 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 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.

9. 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.

10. 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.]

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3. DESCRIPTION OF COMPRESSED HYDROGEN FUEL CELL VEHICLES

11. Hydrogen fuel cell vehicles have an electric drive-train powered by a fuel cell that generates electricity electrochemically from hydrogen. The major subsystems as illustrated in Figure 1 are:

- Hydrogen fueling and fuel storage subsystem
- Hydrogen fuel delivery subsystem
- Fuel cell subsystem
- Electric propulsion and power management subsystem

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12. In addition to these primary subsystems, some FCVs are equipped with other advanced technologies to increase efficiency, such as regenerative braking systems that capture the energy lost during braking and store it in an upsized battery. Following is a description of each of these subsystems and their typical location within a hydrogen vehicle drivetrain. (Glenn will provide a simple diagram to address other technology such as battery/fuelcell vehicles)
ICE hydrogen powered vehicle write-up

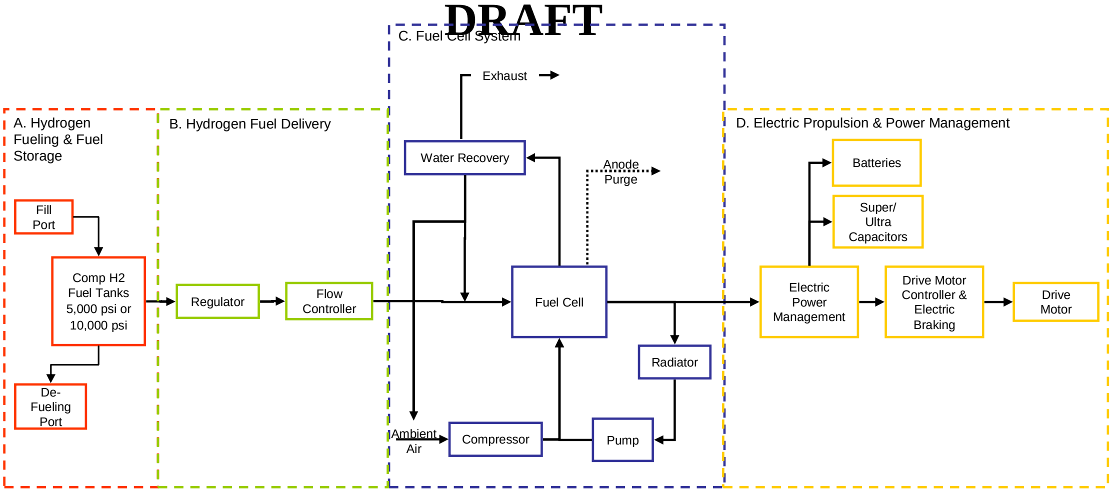

Figure 1. An example of a High Level Schematic of Compressed Hydrogen Fuel Cell Vehicle Subsystems (Glenn will provide another simplier schematic)

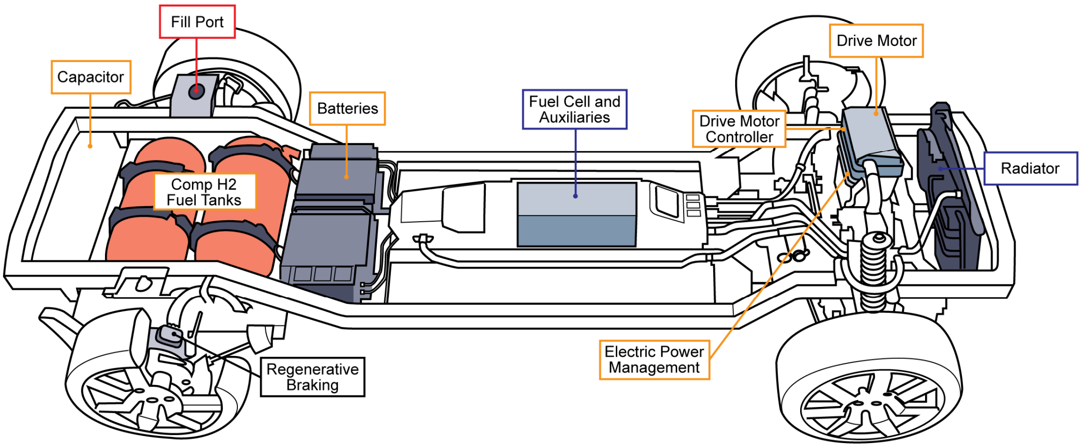

Figure 2. Schematic of a typical Compressed Hydrogen Fuel Cell Vehicle Component Locations and Mass Distribution

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3.1 HYDROGEN FUELING AND FUEL STORAGE SUBSYSTEM

Use metric as a primary unit and english units in brackets

13. At present, the most common method of storing and delivering hydrogen fuel onboard is in compressed gas form. Hydrogen is typically stored on current developmental vehicles at 5,000 psi (34.5 MPa)[1]. Compressed hydrogen systems operating at 10,000 psi (70 MPa) are also in development. The hydrogen fuel from the storage containers is supplied to the fuel cell by pressure piping with two or three stages of regulation that reduce the pressure to approximately 5 psi (.034 MPa) before entering the fuel cell stack.

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14. The primary components within the hydrogen fueling and fuel storage subsystem are the compressed hydrogen fuel containers. Because the hydrogen fuel has a low energy density per unit volume, storage containers must be designed to supply an adequate amount of hydrogen to achieve realistic vehicle driving ranges. Hydrogen fuel containers and fuel cell stacks also add weight and cost to the vehicle which compounds the challenge of achieving desirable driving ranges. To overcome these limitations, hydrogen fuel containers are being designed to take up as little space as possible using light weight composite materials. In addition, these fuel containers are specially designed to allow the storage of hydrogen at very high pressures to overcome the low energy density. These fuel containers are designed and tested to safety standards such as ANSI/CSA HGV2, Basic Requirements for Compressed Hydrogen Gas Vehicle (HGV) Fuel Containers, CSA B51, Part 2 Boiler, Pressure Vessel and Pressure Piping Code, SAE J2579, Recommended Practice for Fuel Systems in Fuel Cell and Other Hydrogen Vehicles, and ISO DIS 15869.2, Gaseous Hydrogen and Hydrogen blends – Land Vehicle Fuel Tanks. that intend to ensure they maintain high pressures and prevent leakage or rupture in the rigors of vehicle service.

15. Currently, containers constructed with composite materials are meeting the high pressure, lower container weight design challenges and are already in use in prototype hydrogen-powered vehicles. Most high pressure hydrogen fuel containers evaluated at the time of this study were constructed of multicomponent systems typically described as either a Type 3 or Type 4 container. Type 3 containers are typically constructed with an inner aluminum liner which serves as the gas containing membrane, wrapped with a load-bearing carbon fiber composite structural layer. The Type 4 container is similar in concept to the Type 3 container except that the inner liner is constructed of a thermoplastic liner.

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16. Fuel containers are typically located in the rear of the vehicle, mounted transversely, in front of or above the rear axle as shown in Figure 2. Hydrogen fuel containers are pressure vessels, whether or not the fuel is compressed or liquefied. Consequently, hydrogen fuel containers will be cylindrical vessels for the foreseeable future to reduce weight, particularly for the higher pressure vessels. Even so called “conformable containers” in development are based upon packaging of multiple cylindrical or near-cylindrical containers.

17. In addition to the fuel containers, the hydrogen fuel storage system consists of a number of auxiliary components needed for fueling/de-fueling and system safety such as pressure relief devices and container shut-off valves.

18. In the event of a fire, pressure relief devices (PRDs) vent (i.e., provide a controlled release at a remote site) the gas contained in compressed hydrogen fuel containers to prevent rupture. High temperatures in a fire will degrade the strength of metal, thermoplastic and

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[1] Some early developmental vehicles stored hydrogen at 3,600 psi (24.8 MPa), using natural gas vehicle fuel system components.

composite container materials and raise the internal pressure of the container, potentially causing rupture.

19. PRD venting of hydrogen vehicle fuel containers in the event of a fire is different from conventional boiler and pressure vessel applications, where pressure relief valves allow venting of temporary overpressures and the devices reseat and reseal after the pressure is returned to normal conditions. In conventional applications, overpressures typically arise from internal heating of the vessel contents and there is no damage to the vessel. PRDs for hydrogen vehicle fuel containers are intended solely to prevent container rupture in the event of an external fire. Containers and PRDs that have been subjected to such a fire should be removed from service and destroyed. Hence, these PRDs are designed to vent the entire contents of the container rapidly and do not reseat or allow repressurization of the container.

3.2 HYDROGEN FUEL DELIVERY SUBSYSTEM

20. Hydrogen is delivered from the storage containers to the fuel cell stack via a series of piping, pressure regulators, valving, filters and flow meters. The fundamental purpose of a hydrogen flow control system is to reliably deliver fuel to the fuel cell stack at a specified, stable pressure and temperature for proper fuel cell operation over the full range of vehicle operating conditions. Fuel must be delivered at a specified rate, even as the pressure in the fuel containers drop, or the ambient temperature changes. The fuel system delivery specifications are determined by the initial container storage pressure, the vehicle, and the vehicle duty cycle.

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21. Since sections of the piping system will see container pressures of up to 10,000 psig (70 MPa) standards intend to ensure they are designed and tested to maintain this pressure safely without leakage or rupture throughout their service life.

3.3 FUEL CELL SUBSYSTEM

22. The fuel cell provides the electricity needed to operate the drive motors and charge vehicle batteries and/or capacitors. There are several kinds of fuel cells, but Polymer Electrolyte Membrane (PEM) – also known as Proton Exchange Membranes - fuel cells are the type typically used in automobiles at this time. The PEM fuel cell consists of a “stack” of hundreds of cells in which hydrogen and oxygen combine electrochemically to generate electrical power. Fuel cells are capable of continuous electrical generation when supplied with pure hydrogen and oxygen, simultaneously generating electricity and water, with no carbon dioxide (CO_2) or other harmful emissions typical of gasoline-powered internal combustion engines (ICE).

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23. The “fuel cell subsystem” consists of a number of auxiliary components needed for the effective and efficient operation. These components include such items as an air pump for supply air to the stack and heat exchangers to recover waste heat and maximize efficiency. Figure 1 illustrates that, while this class of fuel cells are intended to operate on nearly pure hydrogen, the system includes some form of intermittent purge to remove diluents and contaminants to extend the life of the fuel cell.

24. Likely due to the inherently flat nature of the stack itself, most of the fuel cell and auxiliaries are packaged in a flat box located between the front and rear axles, under the passenger compartment. The same is true for hydrogen concept cars suggesting that fuel cell and vehicle manufacturers expect this to be the “typical” location for the fuel cell package.

22. The electricity generated by the fuel cell is used to drive electric motors that ultimately propel the vehicle. Because fuel cells within vehicles operate at high voltage and, in some cases are equipped with auxiliary propulsion batteries, they are designed to standards that intend to avoid the risk of electrical shock, loss of isolation, and potential ignition of surrounding materials.

3.4 ELECTRIC PROPULSION AND POWER MANAGEMENT SUBSYSTEM

23. Hydrogen fuel cell vehicles are powered by electric motors in which the electrical energy provided by the fuel cell is converted to the mechanical energy necessary to drive the wheels of the vehicle. The electric drive system has similarities to electric vehicles. It may also utilize batteries and ultracapacitors similar to those used in hybrid vehicles.

24. Many hydrogen fuel cell vehicles are front wheel drive, typically, with the electric drive motor and drivetrain located in the "engine" compartment mounted transversely over the front axle. This pattern is consistent for small fuel cell automobiles which are similar in size to existing economy cars. Some larger SUV type fuel cell vehicles are all wheel drive with two electric motors, one each over the front and rear axle while other design use four compact motors one at each wheel.

25. Generally the electrical power generated by the fuel cell may go directly to the end use and/or may be stored in a capacitor or battery when needed for acceleration. Since fuel cell voltage varies with load, a key aspect of power management is voltage control for the fuel cells and voltage conversion to the desired output. In automotive applications, the power will be primarily used by the propulsion system with auxiliary power units powering components such as valves, sensors, fans, and compressors.

26. Some fuel cell propulsion system designs have batteries and/or ultracapacitors to buffer the power delivery from the cell. These are also used to recapture energy during stopping through regenerative braking. However, as fuel cell technologies advance they are increasingly able to scale their electric output to meet the propulsion needs of the vehicle, eliminating the need for a battery buffer on many vehicles. It is expected that manufacturers will try to minimize the use of batteries to reduce both cost and weight from the vehicle. It is unclear whether batteries will be needed for regenerative braking energy storage in future fuel cell vehicles. If the fuel cell efficiency is sufficient, this may not be required.

Glenn – will provide write-up on liquid H2 vehicles; could be part of the ICE write-up.

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4. EXISTING REGULATIONS, DIRECTIVES, AND INTERNATIONAL VOLUNTARY STANDARDS

4.1 VEHICLE FUEL SYSTEM INTEGRITY

National regulations:

EC regulation 79-2009

- 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 Fuel 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 - Recommended Practice For General Fuel Cell Vehicle Safety

4.2 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

4.3 ELECTRIC SAFETY

National regulations:
Include Korea regs;

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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 to provide info. On ISO stds

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

5. TECHNICAL RATIONALE

5.1. VEHICLE FUEL SYSTEM

5.1.1 IN-USE

Below are the requirements from the TUV proposal that were recommended for Part A; rewrite the language for part A:

- The hydrogen system of a vehicle shall function in a safe and proper manner. It shall reliably withstand the chemical, electrical, mechanical and thermal service conditions

- The materials used in the hydrogen system shall be compatible with gaseous or liquid hydrogen.

- A hydrogen system shall fulfill at least the following functions:
  − refuelling
  − protection against overpressure;
  − excess flow protection
  − automatic shut-off (automatic isolation of the fuel storage system)
  − safety management
  − boil-off management for LH2

- No component of the hydrogen system, including any protective materials that form part of such components, shall project beyond the outline of the vehicle or protective structure. *Need to explain why this is not required in the part B of the GTR. Or how it would be covered by the system safety requirements.*

- The hydrogen system shall be installed such that it is protected against damage under normal operating conditions.

- An excess flow system for the fuel line and the filling line shall be part of the hydrogen system

- A pressure relief device shall be provided and installed into the opening of a container or at least one container in a container assembly, or into an opening in a valve assembled into the container. *This issue is being addressed by the storage system's bonfire test. Provide explanation in Part A.*

Japan will provide a risk assessment to justify all three following components for each container: main shut off valve, a container check valve (=container non-return valve) and a container safety valve (= pressure relief device).

Container assembly = Storage system

- Rigid fuel lines shall be secured such that they shall not be subjected to critical vibration or other stresses, e.g. they shall be supported at an interval of 1 m or less.. *Justification for not accepting the Japanese requirement shall be provided in part A.*

Also, recommended practices can be mentioned as part of the write-up.

- During the refilling process the hydrogen system shall have the means to provide electrical coninuity with the refilling facilities before hydrogen transfer is permitted. *Japan will provide test data for justification in part A.*

- The receptacle shall be secured against maladjustment and rotation. The receptacle shall also be protected from unauthorized interference, and the ingress of dirt and water so far as is reasonably practicable, e.g. a locked hatch. It shall be safe against reasonably foreseeable handling errors. *provide a write-up on for part A. Encourage industry to standardize filling receptacle.*

- The gas filling port (or receptacle make sure it's consistent thru out the document)- shall not be installed in the passenger compartment, luggage compartment and other places where ventilation is not sufficient. *provide write up for part A.*

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

- 4% lower flammability limit (LFL)

Lower Flammability Limit (LFL): Lowest concentration of fuel in which a gas mixture is flammable. National and international standard bodies (such as NFPA and IEC) recognize 4% hydrogen in air as the LFL. See the US Department of Interior, Bureau of Mines Report 503 for further information. Flammability limits (LFL, UFL) depend on mixture temperature, pressure and the presence of dilution gases, and are assessed using specific test methods (e.g., ASTM E681-04). While the LFL value in Note a is appropriate for evaluating flammability in general surroundings of vehicles or inside passenger compartments, this criteria may be overly restrictive for flowing gas situations where ignition requires more than 4% hydrogen in many cases. Whether an ignition source at a given location can ignite the leaking gas plume depends on the flow conditions and the type of ignition. At 4% hydrogen in a stagnant, room temperature mixture, combustion can only propagate in the upward direction. At approximately 8 to 10% hydrogen in the mixture, combustion can also be propagated in the downward and horizontal directions and the mixture is readily combustible regardless of location of ignition source.

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- Description of the exhaust system's operation, figures…
- Need explanation for "moving 3 seconds time interval" in the exhaust system requirement.
- Post crash - H2 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.

5.1.3

5.2 STORAGE-SYSTEM

5.3. ELECTRIC SAFETY

Describe the Japanese regulation;

Other government regulations

Industry standards

B. Text of the regulation

1. Purpose: This regulation specifies performance requirements for hydrogen powered vehicles. The purpose of this regulation is to minimize human harms that may occur as a result of fires or explosions related to the vehicle fuel system and/or from electric shock caused by the vehicle's high voltage system.

Deleted: the number of deaths and injuries

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2. Application / Scope: This regulation applies to all vehicles of Category 1-1 and 1-2, with a gross vehicle mass (GVM) of 4,536 kilograms or less.

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Passenger vehicle – Use SR-1 definitions¶

3. Definitions

For the purpose of this regulation, the following definitions shall apply:Hydrogen powered vehicle: any motor vehicle that uses hydrogen as fuel to propel the vehicle including fuel cell and internal combustion engine vehicle.

3.1 Vehicle fuel system: all components used to store or supply hydrogen fuel to the storage system or to the fuel cell module or internal combustion engine (ICE).

3.2 Storage system: The Hydrogen Storage System consists of the pressurized container(s), Pressure Relief Devices (PRDs), shut off device(s), and all components, fittings and fuel lines between the container(s) and these shut off device(s) that isolate the stored hydrogen from the remainder of the fuel system and the environment.

3.3 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.

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

3.5 Single failure: a failure caused by a single event, including any consequential failures resulting from this failure.

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3.6 Fuel cell module: Fuel cell modules are comprised of one or more fuel cell stacks; connections for conducting fuels, oxidants, and exhausts; electrical connections for the power delivered by the stacks; and means for monitoring and/or control. Additionally, fuel cell modules may incorporate means for conducting additional fluids (e.g., cooling media, inert gas), means for detecting normal and/or abnormal operating conditions, enclosures or pressure vessels, and ventilation systems.

Deleted: <#>Vehicle exhaust system ¶
¶

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Deleted: National and international standard bodies (such as NFPA and IEC) recognize 4% hydrogen in air as the LFL. (need explanation in part A)¶

3.7 Lower Flammability limit (LFL): Lowest concentration of fuel at which a gaseous fuel mixture is flammable at normal temperature and pressure.

3.8 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.

Remove if not used in section 5.

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3.9 The exhaust's point of discharge: geometric center of the area where fuel cell purged gas is discharged from the vehicle.

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3.10 High voltage: Classification of an electric component or circuit, if its maximum working voltage is > 60 V and ≤ [1500] V of direct current (DC) or > 30 V and ≤ [1000] V of alternate current AC.

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high voltage is defined as greater than or equal to 60 VDC and 30 VAC. Refer to ELSA document

3.11 Enclosed and semi-enclosed space: Volume surrounded by vehicle components or structure in such a manner that hydrogen may accumulate within the volume. These volumes include but not limited, to spaces such as passenger compartment, luggage compartment, fuel storage compartment, and space under the hood.(and spaces under the vehicle)

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4. General requirements:

4.1 Each hydrogen powered vehicle shall meet the requirements of section 5.1 and 5.2. In addition, vehicles using high voltage shall meet the requirement of section 5.3.

4.2 Each contracting party under the UNECE 1998 Agreement will maintain its existing national crash tests and use the limit values of section 5.1.3.1 for compliance.

5. Performance requirements

5.1 Storage system: This section specifies the requirements for the integrity of the fuel container of hydrogen powered motor vehicle.

Deleted: *Requirements for: Detection system (Set requirements for self monitoring, warning, fail-safe and functional); and Refuelling system*¶
¶

See OICA proposal

[A storage system shall be capable of preventing reverse flow on the fill line.]
[Shut-off valve – closes when it's unpowered]

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5.1.2 Performance Requirements

5.1.3 Markings

Proposal for label

5.2 Vehicle fuel system: This section specifies requirements for the integrity of the hydrogen fuel system.

Deleted: **integrity**

Re-number

5.2.1 Requirements – in use:

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5.2.2 Gas fueling port: Gas fueling port shall prevent reverse flow.

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5.2.1.1 Hydrogen discharge system:

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5.2.1.1.1 *The vent line, if present, for hydrogen gas discharge from TPRD(s) of the storage system shall be covered, e.g. by a cap. (visual inspection)*

Deleted: *[The hydrogen discharge outlet shall be protected against*

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Deleted: *blockage, e.g. by cap]*

5.2.1.1.2 The hydrogen gas discharge from TPRD(s) of the storage system 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

5.2.1.2 Single failure of hydrogen system:

Deleted: conditions

[If a single failure of the hydrogen system results in a hydrogen concentration in air greater than 4% by volume within the passenger compartment, luggage compartment, and spaces within the vehicle that contain unprotected ignition sources, the main hydrogen shutoff valve(s) shall close and provide warning.

The enclosed spaces that contain the storage system shall not contain unprotected ignition sources. All spaces containing the hydrogen storage system shall vent to the outside of the vehicle]

Need definitions for "unprotected ignition source"

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

5.2.1.2.2 If a single failure downstream of the main hydrogen shut off valve results in a hydrogen concentration of 4% by volume in air in the enclosed or semi-enclosed spaces within the vehicle that are not suitable for flammable gases then the main hydrogen shutoff valve shall be closed and a warning to the driver shall be provided per 5.2.1.2.3. The vehicle manufacturers shall provide a list of spaces that are suitable for flammable gases which are exempted from this requirement.

Test procedure stays in brackets; OICA will validate and revise the test procedure.

Add a requirement for failure in upstream (i.e. the storage system)

5.2.1.2.3 Driver warning: The vehicle shall be equipped with a visual indicator (e.g. tell-tale) that provides a warning to the driver in the event of 5.2.1.2.2 or in the event of a malfunction of the hydrogen leakage detection system.

5.2.2.3 Fuel cell / vehicle discharge system: At vehicle exhaust system's point of discharge, the hydrogen concentration level shall not exceed 4% average by volume during any moving three-second time interval during normal operation including start-up and shutdown.

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Deleted: OICA will look at other vehicle discharge systems (ICE, liquid H2…) to include in this requirement.¶
¶
Japan's requirement does not allow average reading for 3 second interval. Japan will provide test procedure and data. ¶

OICA will provide justification for the 3-second interval

5.2.2 Requirements - post crash

5.2.2.1 Fuel leakage limit: the rate of uncontrolled hydrogen gas leakage measured and calculated by 6.1 shall not exceed an average of 120 NL per minute within 60 minutes after the crash.

Use Japan's informal paper for justification in part A

5.3 Electric safety

5.3.1 Purpose: This section specifies the requirements for vehicle's high voltage system.

5.3.2 Requirements and test procedures - in-use

See OICA proposal

5.3.2.1 Performance requirements

5.3.3 Requirements and test procedures - post crash

See OICA proposal

5.3.3.1 Performance requirements

5.3.4 Markings

[A label shall be provided close to the receptacle, for example, inside a refilling hatch, showing the following information: gas type (GH2 or LH2) "xx" MPa for GH2-storage systems where "xx" = nominal working pressure of the container(s).]

6 Test conditions and procedures

Need test validation

6.1 [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: $P_0' = P_0 \text{ x } \{273 / (273 + T_0)\}$
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)

$P_{60}' = P_{60} \text{ x } \{273 / (273 + T_{60})\}$
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: $\rho_0 = -0.0052 \text{ x } (P_0')^2 + 1.6613 \text{ x } P_0' + 0.5789$
where:
ρ_0 : Helium gas density before impact (kg/m^3)
$\rho_{60} = -0.0052 \text{ x } (P_{60}')^2 + 1.6613 \text{ x } P_{60}' + 0.5789$
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: $Q_0 = \rho_0 \text{ x } V \text{ x } (22.4 / 4.00) * 10^{-3}$
where:
Q_0 : Helium gas volume before impact (m^3)
V : Internal volume (L)

$Q_{60} = \rho_{60} \text{ x } V \text{ x } (22.4 / 4.00) * 10^{-3}$
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.
$\Delta Q = (Q_0 - Q_{60}) \text{ x } 10^3$
$RHe = \Delta Q / 60$
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 x 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!).*]

[6.2 Demonstration of compliance for single failure condition

[Preparation:
The test shall be conducted without any influence of wind.
Special attention shall be paid to the test environment as during the test flammable mixtures of hydrogen and air may occur.
Prior to the test the vehicle has to be prepared to allow remotely controllable hydrogen releases from the hydrogen system. The number and location of the release points downstream of the main hydrogen shutoff valve shall be defined by the vehicle manufacturer taking worst case leakage scenarios into account.
Only for the purpose of the test hydrogen concentration detectors have to be installed in enclosed or semi enclosed volumes on the vehicle.
If there is structure taken to prevent hydrogen from intruding into passenger compartments, it is not necessary to have H2 concentration measurement points in the passenger compartments.

Example hydrogen concentration measurement locations can be found in the document “Examples of hydrogen concentration measurement points for testing”.

Procedure:
i) Vehicle doors, windows and other covers shall be closed.
ii) Start the propulsion system, allow it to warm up to its normal operating temperature and leave it operating at idle for the test duration.
iii) A leak shall be simulated using the remote controllable function.
iv) The hydrogen concentration shall be measured continuously until the concentration does not rise anymore for 3 minutes or until the main hydrogen shutoff valve is closed.

v) If during the test the hydrogen concentration at one of the measurement locations exceeds 4% significantly, the test shall be terminated.]*

[ ] this part of the proposal still needs to be confirmed]*

[6.3 Demonstration of compliance for fuel cell vehicle exhaust system

i) The fuel cell system of the test vehicle shall be warmed up. (is this the worst case scenario? Should this be removed to include all vehicle's stages)
ii) The measuring device shall be warmed up before use.
iii) Place the measuring section of the measuring device on the centre line of the exhaust gas flow within 100 mm from the exhaust gas outlet.
iv) Perform the test procedure below while continuously measuring the hydrogen concentration:
With the vehicle in a stationary state, start the fuel cell system. After a lapse of at least one minute turn off the system and continue the measurement until the fuel cell system shut down procedure is completed.]

OICA- provides the response time for the measuring device

Japan will submit its test procedure for consideration.

7. Annexes