Submitted by TF-H2
78th GRSP, 1-4 December 2025, agenda item 19

**GRSP-78-15**

# Modifications to ECE/TRANS/WP.29/GRSP/2025/41*

The text reproduced below was prepared by TF-H2, aiming to provide a type-approval basis for hydrogen vehicles propelled with liquefied hydrogen as requested by the Working Party on General Safety Provisions. It is based on ECE/TRANS/WP.29/GRSP/2025/41. Modifications to this document are shown in track changes.

* Proposal for a new UN Regulation concerning the approval of motor vehicles and their components with regard to the safety-related performance of vehicles and systems fuelled with liquefied hydrogen

## Proposal

# Uniform provisions concerning the approval of motor vehicles and their components with regard to the safety-related performance of vehicles and systems fuelled with liquefied hydrogen

## Contents



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# 0. Introduction

0.1. Introduction for the original version

0.1.1. This is a transposition of paragraph 7. of UN Global Technical Regulation (GTR) No. 13, which has been adopted as optional for Contracting Parties, into a UN Regulation. Due to the introduction of hydrogen-propelled vehicles in UN Regulation No. 105 on the construction of vehicles for the transport of dangerous goods, the establishment of a UN Regulation incorporating the appropriate administrative provisions for type approval has been deemed advisable.

0.1.2. This UN Regulation does not intend to introduce new technical requirements deviating from those established in UN GTR No. 13, except for adjustment of deficiencies or clarifications considered as indispensable for facilitating the type approval of the related products.

0.1.3. It was decided to develop a new UN Regulation for vehicles and systems fuelled with liquefied hydrogen rather than incorporating them into UN Regulation No. 134 to allow Contracting Parties applying UN Regulation No. 134 not to apply the new UN Regulation until they have completed the necessary examinations to introduce this new technology into their respective national regulatory frameworks.

0.1.4. The test procedures for the verification of post-crash hydrogen leakage and concentration given in UN GTR No. 13 were deemed premature and not ready to use for type approval regulation.

0.1.5. On the other hand, applications of liquefied hydrogen are currently focused in the category of heavy duty vehicles (i.e. categories $M_2$, $M_3$, $N_2$ & $N_3$)[1], to which vehicle crash tests are not applied in most Contracting Parties. Therefore, the scope of this Regulation is limited to heavy duty vehicles and post-crash requirements are not adopted in this Regulation.

0.1.6. This Regulation uses the terms "liquified" and "liquid" hydrogen synonymously. It does not apply to cryo-compressed or compressed hydrogen storage systems.

0.1.7. It is expected that the next phase of UN GTR No. 13 will address the missing items such as post-crash requirements of vehicles with a liquefied hydrogen storage system.

0.1.8. The requirements of the fuelling receptacle of the liquified hydrogen gas vehicle will be included in a later amendment when ISO 25578 is published.

0.1.9. Due to the lack of experience with alternative material, the material for containers and vacuum jackets has been limited to metallic only. This limitation will be re-evaluated during phase 3 of the Informal Working Group GTR 13.

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# 1. Scope

This Regulation applies to[2]:

1.1. Part I - Liquefied hydrogen storage systems (LHSS) for hydrogen-fuelled vehicles on their safety-related performance.

[1] As defined in the Consolidated Resolution on the Construction of Vehicles (R.E.3.), document ECE/TRANS/WP.29/78/Rev.8, para. 2 - https://unece.org/transport/vehicle-regulations/wp29/resolutions

[2] This Regulation does not cover the electrical safety of the electric power train, the material compatibility and hydrogen embrittlement of the vehicle fuel system. This Regulation also does not cover containers or vacuum jackets made of materials other than metal until specific requirements for such materials have been defined.

1.2. Part II - Specific components for liquefied hydrogen storage systems (LHSS) for hydrogen-fuelled vehicles on their safety-related performance.

1.3. Part III - Hydrogen-fuelled vehicles of categories $M_2$, $M_3$, $N_2$ and $N_3$ incorporating its liquefied hydrogen storage system (LHSS) on their safety-related performance.

## 2. Definitions

For the purpose of this Regulation, the following definitions shall apply:

2.1. "*Boil-off control*" means a function to control the inner tank pressure to a value below the container's first PRD setting.

2.2. "*Boil-off converter*" means a system that converts boil-off hydrogen, e.g. to water and heat or other types of energy, to prevent hydrogen discharge and associated risks of generating flammable atmospheres around the vehicle.

2.3. "*Boil-off valve*" means a valve that vents the excess hydrogen gas pressure (boil-off gas) at a setting below the container's first pressure relief valve setting.

2.4. "*Burst disc*" means the non-reclosing operating part of a PRD which, when installed in the device, is designed to burst at a predetermined pressure to permit the discharge of hydrogen.

2.5. "*Check valve*" means a non-return valve that prevents reverse flow in the vehicle fuel line.

2.6. "*Container*" (for hydrogen storage) means the component within the hydrogen storage system, consisting of an inner container that stores the primary volume of hydrogen fuel surrounded by a vacuum jacket and the supporting structure between them.

2.7. "*Date of removal from service*" means the date (month and year) specified for removal from service.

2.8. "*Date of manufacture*" (of a liquefied hydrogen container) means the date (month and year) of the final inspection test carried out during manufacture.

2.9. "*Enclosed or semi-enclosed spaces*" means the special volumes within the vehicle (or the vehicle outline across openings) that are external to the hydrogen system (storage system, fuel cell system and fuel flow management system) and its housings (if any) where hydrogen may accumulate (and thereby pose a hazard), as it may occur in the passenger compartment, luggage compartment and space under the hood.

2.10. "*Exhaust point of discharge*" means the geometric centre of the area where fuel cell purged gas is discharged from the vehicle.

2.11. "*Fuel cell system*" means a system containing the fuel cell stack(s), air processing system, fuel flow control system, exhaust system, thermal management system and water management system.

2.12. "*Fuelling receptacle*" means the equipment to which a fuelling station nozzle attaches to the vehicle and through which fuel is transferred to the vehicle. The fuelling receptacle is used as an alternative to a fuelling port.

2.13. "*Hydrogen concentration*" means the percentage of the hydrogen moles (or molecules) within the mixture of hydrogen and air (equivalent to the partial volume of hydrogen gas).

2.14. "*Hydrogen-fuelled vehicle*" means any motor vehicle that uses compressed gaseous or liquefied hydrogen as a fuel to propel the vehicle, including fuel cell and internal combustion engine vehicles. Hydrogen fuel for passenger vehicles is specified in ISO 14687:2025 and SAE J2719_202003.

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2.15. "*Liquefied (or Liquid) Hydrogen Storage System (LHSS)*" means a container, PRDs, shut-off device(s), boil-off valve and the interconnection piping (if any) and fittings between the above components.

2.16. "*Luggage compartment*" means the space in the vehicle for luggage and/or goods accommodation, bounded by the roof, hood, floor, side walls, being separated from the passenger compartment by the front bulkhead or the rear bulkhead.

2.17. "*Manufacturer*" means the person or body responsible to the approval authority for all aspects of the type approval process and for ensuring conformity of production. It is not essential that the person or body is directly involved in all stages of the construction of the vehicle, system or component which is the subject of the approval process.

2.18. "*Maximum Allowable Working Pressure (MAWP)*" means the highest gauge pressure to which a LHSS is permitted to operate under normal operating conditions.

2.19. "*Maximum Fuelling Pressure (MFP)*" means the maximum dispensing system pressure expected during normal (fault-free) vehicle fuelling.

2.20. "*Periodic Technical Inspection (PTI)*" means the inspection of vehicles performed at specified intervals according to national regulations.

2.21 "*Pressure Relief Device (PRD)*" means a device that, when activated under specified performance conditions, is used to release hydrogen from a pressurized system and thereby prevent failure of the system. It can include first and second PRDs as a reclosing or non-reclosing type (e.g., safety relief valve and burst disc).

2.22. "*Rupture*" or "*burst*" both mean to come apart suddenly and violently, break open or fly into pieces due to the force of internal pressure.

2.23. "*Safety relief valve*" means a PRD that opens at a preset pressure level and can re-close.

2.24. "*Service life*" (of a liquefied hydrogen storage system) means the time frame during which service (usage) is authorized.

2.25. "*Shut-off device*" means a device between the storage container and the vehicle fuel system that must default to the "closed" position when not connected to a power source.

2.26. "*Single failure*" means a failure caused by a single event, including any consequential failures resulting from this failure.

2.27. "*Steady-state conditions*" means a test phase during which temperature, pressure and flowrate remain constant.

2.28. "*Type of hydrogen storage system*" means an assembly of components which do not differ significantly in such essential aspects as:

(a) the manufacturer's trade name or mark;

(b) the MAWP;

(c) the structure, materials, capacity and physical dimensions of the container; and

(d) the structure, materials and essential characteristics of PRDs and shut-off device, if any.

2.29. "*Type of specific components of hydrogen storage system*" means a component or an assembly of components which do not differ significantly in such essential aspects as:

(a) the manufacturer's trade name or mark;

(b) the sort of component: PRD (safety relief valve or burst disc) or shut-off device, and

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(c) the structure, materials and essential characteristics.

2.30. "*Vehicle type*" with regard to hydrogen safety means vehicles which do not differ in such essential aspects as:

(a) the manufacturer's trade name or mark; and

(b) the basic configuration and main characteristics of the vehicle fuel system.

2.31. "*Vehicle fuel system*" means an assembly of components used to store or supply hydrogen fuel to a Fuel Cell (FC) or Internal Combustion Engine (ICE).

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## 3. Application for approval

3.1. The application for approval of a type of vehicle, system or component with regard to the safety-related performance of vehicles and systems fuelled with liquefied hydrogen shall be submitted by the manufacturer or by his authorized representative.

3.2. It shall be accompanied by the documents mentioned below and include the following particulars:

3.2.1. Detailed description of the type of vehicle, system or component in accordance with the applicable model of information document given in Annex 1, Part I.

3.3. A sufficient number of vehicles and/or components representatives of the type to be approved shall be submitted to the Technical Service conducting the approval tests.

## 4. Approval

4.1. If the type of vehicle, system or component submitted for approval pursuant to this Regulation meets the requirements of the relevant part of this Regulation, approval of that vehicle, system or component shall be granted.

4.2. An approval number shall be assigned to each type approved in accordance with Schedule 4 of the Agreement (E/ECE/TRANS/505/Rev.3).

4.3. Notice of approval or of extension, refusal or withdrawal of approval pursuant to this Regulation shall be communicated to the Contracting Parties to the Agreement which apply this Regulation by means of a form conforming to the model in Annex 1, Part 2.

4.4. There shall be affixed, conspicuously and in a readily accessible place specified on the approval form, to every vehicle, system or component conforming to a type approved under this Regulation, an international approval mark conforming to the models described in Annex 2, consisting of:

4.4.1. A circle surrounding the letter "E" followed by the distinguishing number of the country which has granted approval[3];

4.4.2. The number of this Regulation, followed by the letter "R", a dash and the six digit number, of which the first two digits indicate the series of amendments to this Regulation to which the approval is granted and the subsequent four digits indicates section 3 of the type approval number granted, to the right of the circle prescribed in paragraph 4.4.1.

4.5. If the vehicle conforms to a vehicle type approved under one or more other Regulations, annexed to the Agreement, in the country which has granted approval under this Regulation, the symbol prescribed in paragraph 4.4.1. needs not be repeated; in such a case, the Regulation and approval numbers

[3] As defined in Annex 3 to the Consolidated Resolution on the Construction of Vehicles (R.E.3), document ECE/TRANS/WP.29/78/Rev. 8 (https://unece.org/transport/vehicle-regulations/wp29/resolutions)

and the additional symbols shall be placed in vertical columns to the right of the symbol prescribed in paragraph 4.4.1. above.

4.6. The approval mark shall be clearly legible and be indelible.

4.6.1. In the case of a vehicle, the approval mark shall be placed close to or on the vehicle data plate.

4.6.2. In the case of an LHSS, the approval mark shall be placed close to or on the container.

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# 5. Part I – Specifications of the Liquefied Hydrogen Storage System (LHSS)

This part specifies the requirements for the LHSS.

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The boundaries of the LHSS are defined by the interfaces which can isolate the stored liquefied (and/or gaseous) hydrogen from the remainder of the fuel system and the environment. All components located within this boundary are subject to the requirements defined in this paragraph. - Figure 1 shows a typical LHSS. The closure devices shall include, at a minimum, the following functions, which may be combined:

(a) Shut-off function;

(b) Boil-off control;

(c) Pressure relief function.

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Figure 1

**Typical Liquefied Hydrogen Storage System (LHSS)**

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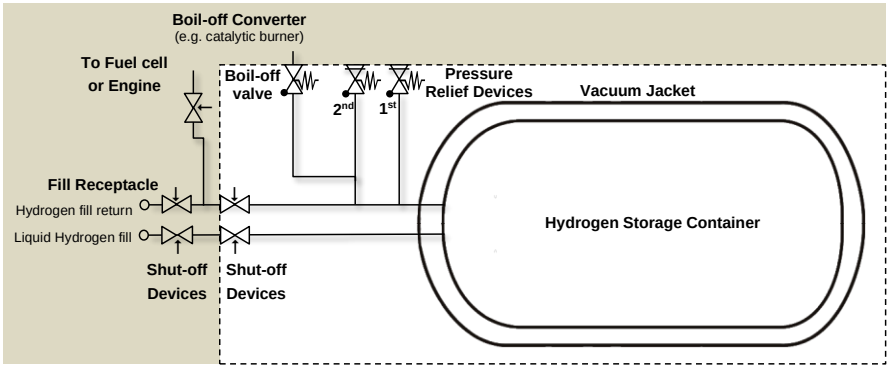


The LHSS shall qualify for the performance test requirements specified in this paragraph. The manufacturer shall specify a MAWP.

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The test elements within these performance requirements are summarized in Table 1.

Table 1
**Overview of performance requirements**

| |
|---|
| **Paragraph 5.1. Verification of baseline metrics** |
| 5.1.1. Proof pressure |
| 5.1.2. Baseline initial burst pressure, performed on the inner container |
| 5.1.3. Baseline Pressure cycle life |
| **Paragraph 5.2. Verification of expected on-road performance** |
| 5.2.1. Boil-off |
| 5.2.2. Boil-off discharge rate |
| 5.2.3. Vacuum loss |
| **Paragraph 5.3. Verification for service-terminating conditions:** Bonfire test |
| **Paragraph 5.4. Requirements for PRD and shut-off device** |

5.1. Verification of baseline metrics

5.1.1. Proof pressure

The inner container and the pipe work situated between the inner container and the vacuum jacket is pressurized to a pressure $p_{test} \geq$ 130 per cent (MAWP + 0.1 MPa) in accordance with the test procedure in Annex 3, paragraph 1.1. without visible deformation, degradation of container pressure, or detectable leakage.

5.1.2. Baseline initial burst pressure

The burst test is performed in accordance with the test procedure in Annex 3, paragraph 1.2. on one sample of the inner container that is not integrated in the vacuum jacket and not insulated.

The burst pressure shall be at least equal to the burst pressure used for the mechanical calculations. For inner containers that is either:

(a) MAWP (in MPa) plus 0.1 MPa multiplied by 3.25;

or

(b) MAWP (in MPa) plus 0.1 MPa multiplied by 1.5 and multiplied by $R_m/R_p$, where $R_m$ is the minimum ultimate tensile strength of the container material and $R_p$ is the minimum yield strength where $R_{p1.0}$ shall be used for austenitic steels and $R_{p0.2}$ for other metals.

5.1.3. Baseline pressure cycle life

The manufacturer shall either provide a calculation in order to demonstrate that the container is designed according to current regional legislation or accepted standards (e.g. the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, EN 1251-1:2000 and EN 1251-2:2000 or other applicable regulations for the design of metallic pressure containers), or define and perform suitable tests (including Annex 3, paragraph 1.3.) that prove the same level of safety compared to a design supported by calculation according to accepted standards.

5.2. Verification for expected on-road performance

5.2.1. Boil-off

The boil-off test is performed on an LHSS equipped with all components as described in paragraph 5. (Figure 1). The test is performed on a system filled with liquid hydrogen in accordance with the test procedure in Annex 3, paragraph 2.1. and shall demonstrate that the boil-off valve limits the pressure in the inner storage container to below the MAWP.

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5.2.2. Boil-off discharge rate

After the boil-off test in paragraph 2.1. of Annex 3, the LHSS is kept at boil-off pressure and the total discharge rate due to boil-off shall be measured in accordance with the test procedure in Annex 3, paragraph 2.2.

The boil-off converter recommended by the LHSS manufacturer may be installed for this test if requested by the manufacturer.

The maximum allowable discharge from the hydrogen storage system is R: 150 Nml/min, where:

$R = (V_{width} + 1) \cdot (V_{height} + 0.5) \cdot (V_{length} + 1)/30.4$ and

$V_{width}$, $V_{height}$, $V_{length}$ are the vehicle width, height, length (m), respectively.

***NOTE:*** *The equation is based on the assumption that the vehicle is equipped with only one LHSS, which consists of only one container.*

5.2.3. Vacuum loss

The vacuum loss test is performed on an LHSS equipped with all components as described in paragraph 5. (Figure 1). The test is performed on a system filled with liquid hydrogen in accordance with the test procedure in Annex 3, paragraph 2.3. and shall demonstrate that both first and second PRDs limit the pressure to the values specified in Annex 3, paragraph 2.3. if vacuum pressure is lost.

5.3. Verification of service-terminating conditions: Bonfire test

The function of the PRDs and the absence of rupture under the following service terminating conditions shall be demonstrated in accordance with the test procedures provided in Annex 3, paragraph 3.

An LHSS is filled to half-full liquid level and exposed to fire in accordance with the test procedure of Annex 3, paragraph 3. The PRD(s) shall release the contained gas in a controlled manner without rupture.

The test is successfully completed when the requirements on the pressure limits for the PRDs as described in Annex 3, paragraph 3. are fulfilled.

5.4. Requirements for PRD and shut-off device

The PRDs and shut-off devices shall be tested and type-approved in accordance with Part II of this Regulation and produced in conformity with the approved type**.**

Retesting of the LHSS is not required if alternative closure devices are provided having comparable function, fittings, materials, strength and dimensions, and satisfy the condition above.

5.5. Labelling

A label shall be permanently affixed on each container with at least the following information: name of the manufacturer, serial number, date of manufacture, MAWP, fuel type (i.e. "$LH_2$" for liquid hydrogen).

5.6. Periodic technical inspection

The LHSS or vehicle manufacturer shall provide guidelines, e.g. in the owner's manual, by means of a QR code, a web-link, etc., for the periodic technical inspection, and identify any special conditions that would require immediate inspection such as LHSS reinstallation, vehicle collision, fire, etc., during its service life. Upon request, these guidelines shall be made available to the type-approval authorities and the competent authorities in the Contracting Parties responsible for the periodic inspection of vehicles.

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## 6. Part II – Specifications of the specific components for liquefied hydrogen storage system (LHSS)

6.1. Pressure relief device qualification requirements

The PRD shall meet the following performance qualification requirements:

(a) Pressure test (Annex 4, paragraph 1. test procedure);

(b) External leakage test (Annex 4, paragraph 2. test procedure);

(c) Operational test (Annex 4, paragraph 4. test procedure);

(d) Corrosion resistance test (Annex 4, paragraph 5. test procedure); and

(e) Temperature cycle test (Annex 4, paragraph 8. test procedure).

6.2. Shut-off device qualification requirements

The shut-off device shall meet the following performance qualification requirements:

(a) Pressure test (Annex 4, paragraph 1. test procedure);

(b) External leakage Test (Annex 4, paragraph 2. test procedure);

(c) Endurance test (Annex 4, paragraph 3. test procedure);

(d) Corrosion resistance test (Annex 4, paragraph 5. test procedure);

(e) Resistance to dry-heat test (Annex 4, paragraph 6. test procedure);

(f) Ozone ageing test (Annex 4, paragraph 7. test procedure);

(g) Temperature cycle test (Annex 4, paragraph 8. test procedure); and

(h) Flex line cycle test (Annex 4, paragraph 9. test procedure), if applicable.

## 7. Part III – Specifications of vehicle fuel system incorporating LHSS

This part specifies requirements for the integrity of the hydrogen fuel delivery system, which includes the LHSS, piping, joints, and components in which hydrogen is present. Test procedures are given in Annex 5.

7.1. In-use fuel system integrity

7.1.1. Fuelling receptacle requirements

7.1.1.1. A label shall be affixed close to the fuelling receptacle; for instance, inside a refilling hatch, showing the following information: fuel type (e.g. "$LH_2$" for liquefied hydrogen), MFP, date of removal from service of containers.

7.1.1.2. The fuelling receptacle shall be mounted on the vehicle to ensure positive locking of the fuelling nozzle. The receptacle shall be protected from tampering and the ingress of dirt and water (e.g. installed in a compartment which can be locked). Test procedure is by visual inspection.

7.1.1.3. The fuelling receptacle shall not be mounted within the external energy absorbing elements of the vehicle (e.g. bumper) and shall be installed in such a way that access for refilling shall not be required in the passenger compartment, luggage compartment, or in any other unventilated compartment.

7.1.2. LHSS installation

The LHSS shall be installed in accordance with the instructions provided by the manufacturer of the LHSS, and in conformity with the description provided in Annex 1, Part 2 to this Regulation.

7.2. In-use fuel system integrity

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7.2.1. Over-pressure protection for the low-pressure system

The hydrogen system downstream of a pressure regulator shall be protected against overpressure due to the possible failure of the pressure regulator. The set pressure of the overpressure protection device shall be lower than or equal to the MAWP for the appropriate section of the hydrogen system. The over-pressure protection shall comply with the installation verification referred to in Annex 5, paragraph 4.

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7.2.2. Hydrogen discharge systems

7.2.2.1. Pressure relief systems

The hydrogen gas discharge from pressure relief systems shall be directed such that the hydrogen exhaust does not impinge upon:

(a) enclosed or semi-enclosed spaces;

(b) any vehicle wheel housing;

(c) hydrogen containers;

(d) the vehicle's REESS

7.2.2.2. Vehicle exhaust system

7.2.2.2.1. The vehicle exhaust system shall comply with the test for the vehicle exhaust system referred to in Annex 5, paragraph 2.

7.2.2.2.2. At the vehicle exhaust system's point of discharge, the hydrogen concentration level shall:

(a) Not exceed 4.0 per cent average by volume during any moving three-second time interval during normal operation including start-up and shutdown; and

(b) Not exceed 8.0 per cent at any time.

7.2.3. Protection against flammable conditions: single failure conditions

7.2.3.1. Hydrogen gas discharge, leakage and/or permeation from the vehicle fuel system shall not directly vent into the passenger compartment, luggage compartment, or to any enclosed or semi-enclosed spaces within the vehicle that contains unprotected ignition sources.

7.2.3.2. Any single failure downstream of the main hydrogen shut-off device shall not result in accumulations in levels of a hydrogen concentration in the passenger compartment according to test procedure in Annex 5, paragraph 1.2.

7.2.3.3. If, during operation, a single failure results in a hydrogen concentration exceeding 3.0 per cent by volume in air in the enclosed or semi-enclosed spaces of the vehicle, then a warning shall be provided (paragraph 7.2.3.5.). If the hydrogen concentration exceeds 4.0 per cent by volume in the air in the enclosed or semi-enclosed spaces of the vehicle, the main shut-off device shall be closed to isolate the storage system. (Annex 5, paragraph 1. test procedure).

7.2.3.4. Fuel system leakage

The hydrogen fuelling line (e.g. piping, joint, etc.) downstream of the main shut-off device(s) to the fuel cell system or the engine shall not leak. Compliance shall be verified at the MAWP for the hydrogen fuelling line (Annex 5, paragraph 3. test procedure).

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7.2.3.5. Tell-tale signal warning to driver

The warning shall be given by a visual signal or display text with the following properties:

(a) Visible to the driver while in the driver's designated seating position with the driver's seat belt fastened;

(b) Yellow in colour if the detection system malfunctions (e.g. circuit disconnection, short-circuit, sensor fault). It shall be red in compliance with paragraph 7.2.3.3.

(c) When illuminated, shall be visible to the driver under both daylight and nighttime driving conditions; and

(d) Remains illuminated when 3.0 per cent concentration or detection system malfunction exists and the master control is in the 'on' position or the propulsion system is otherwise activated.

7.2.4. Vehicle identification

On vehicles equipped with an LHSS, labels as specified in Annex 6 shall be installed.

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These labels shall be placed on the front of the vehicle and on the left side as well as on the right side of the vehicle; for the side in vicinity of a front door, if available. If there is no front door available, the label must be placed on the first third of the vehicle length.

In addition, for vehicles of category $M_2$ and $M_3$, a label shall be placed on the rear of the vehicle.

7.3. LHSS retention

The LHSS shall be subject to the relevant accelerations in compliance with the acceleration corridors which are specified in Tables 2 to 3 in both positive and negative directions.

The LHSS shall remain attached to the vehicle at a minimum of one attachment point

The accelerations shall be measured at the location where the LHSS is installed. The LHSS shall be mounted and fixed on the representative part of the vehicle. The mass used shall be representative for a fully equipped and filled LHSS.

The test pulse shall be within the minimum and maximum value as specified in Tables 2 to 3. A higher shock level and /or longer duration as described in the maximum value in Tables 2 to 3 may be applied to the LHSS if recommended by the manufacturer.

Figure 2
**Generic description of test pulses**

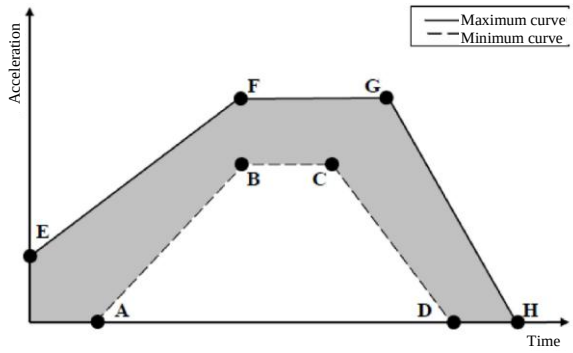

Table 2
**For $M_2$ and $N_2$ Vehicles:**

| *Point* | *Time (ms)* | *Longitudinal acceleration (g)* | *Transverse acceleration (g)* |
|---|---|---|---|
| A | 20 | 0 | 0 |
| B | 50 | 10 | 5 |
| C | 65 | 10 | 5 |
| D | 100 | 0 | 0 |
| E | 0 | 5 | 2.5 |
| F | 50 | 17 | 10 |
| G | 80 | 17 | 10 |
| H | 120 | 0 | 0 |

Table 3
**For $M_3$ and $N_3$ Vehicles:**

| *Point* | *Time (ms)* | *Longitudinal acceleration (g)* | *Transverse acceleration (g)* |
|---|---|---|---|
| A | 20 | 0 | 0 |
| B | 50 | 6.6 | 5 |
| C | 65 | 6.6 | 5 |
| D | 100 | 0 | 0 |
| E | 0 | 4 | 2.5 |
| F | 50 | 12 | 10 |
| G | 80 | 12 | 10 |
| H | 120 | 0 | 0 |

A calculation method may be used instead of practical acceleration testing if its equivalence can be demonstrated by the manufacturer to the satisfaction of the Technical Service and in agreement with the Type Approval Authority.

7.4. Flammable materials used in the vehicle shall be protected from liquefied air that may condense on elements of the fuel system.

7.5. The insulation of the components shall prevent liquefaction of the air in contact with the outer surfaces, unless a system is provided for collecting and vaporizing the liquefied air. The materials of the components nearby shall be compatible with an atmosphere enriched with oxygen.

## 8. Modification of type and extension of approval

8.1. Every modification to an existing type of vehicle or hydrogen storage system or specific component for hydrogen storage system shall be notified to the Type Approval Authority which approved that type. The Authority shall then either:

(a) Decide, in consultation with the manufacturer, that a new type-approval is to be granted; or

(b) Apply the procedure contained in paragraph 8.1.1. (Revision) and, if applicable, the procedure contained in paragraph 8.1.2. (Extension).

8.1.1. Revision

When particulars recorded in the information documents of Annex 1 have changed and the Type Approval Authority considers that the modifications made are unlikely to have an appreciable adverse effect and that in any case the vehicle/component still meets the requirements, the modification shall be designated a "revision".

In such a case, the Type Approval Authority shall issue the revised pages of the information documents of Annex 1 as necessary, marking each revised page to show clearly the nature of the modification and the date of re-issue. A consolidated, updated version of the information documents of Annex 1, accompanied by a detailed description of the modification, shall be deemed to meet this requirement.

8.1.2. Extension

The modification shall be designated an "extension" if, in addition to the change of the particulars recorded in the information folder,

(a) Further inspections or tests are required; or

(b) Any information on the communication document (with the exception of its attachments) has changed; or

(c) Approval to a later series of amendments is requested after its entry into force.

8.2. Confirmation or refusal of approval, specifying the alterations, shall be communicated by the procedure specified in paragraph 4.3. above to the Contracting Parties to the Agreement which apply this Regulation. In addition, the index to the information documents and to the test reports, attached to the communication document of Annex 1, shall be amended accordingly to show the date of the most recent revision or extension.

8.3. The Type Approval Authority issuing the extension of approval shall assign a serial number to each communication form drawn up for such an extension.

## 9. Conformity of production

9.1 Procedures concerning conformity of production shall conform to the general provisions defined in Schedule 1 to the Agreement (E/ECE/324-E/ECE/TRANS/505/Rev.3).

9.2. A vehicle, system or component approved pursuant to this Regulation shall be so manufactured as to conform to the type approved by meeting the respective requirements of paragraphs 5. to 7. above.

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9.3. The Type Approval Authority which has granted approval may at any time verify the conformity of control methods applicable to each production unit. The minimum frequency of such inspections shall be once every three years.

## 10. Penalties for non-conformity of production

Deleted: [9.4. Every inner container and the pipe work situated between the inner container and the outer jacket shall be pressure tested according to Annex 3 paragraph 1.1.]¶

10.1. The approval granted in respect of a vehicle, system or component type pursuant to this Regulation may be withdrawn if the requirements laid down in paragraph 9. above are not complied with.

10.2. If a Contracting Party withdraws an approval, it had previously granted, it shall forthwith so notify the other Contracting Parties applying this Regulation by sending them a communication form conforming to the model set out in Part 2 of Annex 1 to this Regulation.

## 11. Production definitively discontinued

If the holder of the approval completely ceases to manufacture a type of vehicle, system or component approved in accordance with this Regulation, he shall so inform the Type Approval Authority which granted the approval, which in turn shall forthwith inform the other Contracting Parties to the Agreement applying this Regulation by means of a communication form conforming to the model set out in Part 2 of Annex 1 to this Regulation.

## 12. Names and addresses of the Technical Services responsible for conducting approval tests and of the Type Approval Authorities

The Contracting Parties to the Agreement applying this Regulation shall communicate to the United Nations secretariat the names and addresses of the Technical Services responsible for conducting approval tests and of the Type Approval Authorities which grant approval and to which forms certifying approval or extension or refusal or withdrawal of approval are to be sent.

# Annex 1 - Part 1

## Information documents

### Model – I: Information document No … on the type-approval of liquefied hydrogen storage systems (LHSS) for hydrogen-fuelled vehicles on their safety-related performance

The following information, if applicable, shall include a list of contents. Any drawings shall be supplied in appropriate scale and in sufficient detail on size A4 or on a folder of A4 format. Photographs, if any, shall show sufficient details.

If the systems or components have electronic controls, information concerning their performance shall be supplied.

| | |
|---|---|
| 0. | General |
| 0.1. | Make (trade name of manufacturer): ..... |
| 0.2. | Type:..... |
| 0.2.1. | Commercial name(s) (if available): ..... |
| 0.5. | Name and address of manufacturer: ..... |
| 0.8. | Name(s) and address(es) of assembly plant(s):..... |
| 0.9. | Name and address of the manufacturer's representative (if any):..... |
| 3. | Power plant |
| 3.9. | Hydrogen storage system |
| 3.9.1. | Hydrogen storage system designed to use liquid / compressed (gaseous) hydrogen[1] |
| 3.9.1.1. | Description and drawing of the hydrogen storage system: ..... |
| 3.9.1.2. | Make(s):..... |
| 3.9.1.3. | Type(s):..... |
| 3.9.2. | Container(s) |
| 3.9.2.1. | Make(s):..... |
| 3.9.2.2. | Type(s):..... |
| 3.9.2.3. | Maximum allowable working pressure (MAWP):..... MPa |
| 3.9.2.4. | Number of filling cycles: ..... |
| 3.9.2.5. | Capacity:..... litres (water) |
| 3.9.2.6. | Material:..... |
| 3.9.2.7. | Description and drawing:..... |
| 3.9.3 | Pressure relief device(s) |
| 3.9.3.1. | Make(s):..... |
| 3.9.3.2. | Type(s):..... |
| 3.9.3.3. | MAWP:..... MPa |
| 3.9.3.4. | Set pressure:..... |
| 3.9.3.5. | Set temperature:..... |
| 3.9.3.6. | Blow off capacity:..... |
| 3.9.3.7. | Normal maximum operating temperature:.....°C |
| 3.9.3.8. | Material:..... |
| 3.9.3.9. | Description and drawing:..... |
| 3.9.3.10. | Approval number:..... |
| 3.9.5. | Shut-off device(s) |
| 3.9.5.1. | Make(s):..... |
| 3.9.5.2. | Type(s):..... |

[1] Delete where not applicable (there are cases where nothing needs to be deleted when more than one entry is applicable).

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3.9.5.3. MAWP: ..... MPa

3.9.5.4. Material:.....

3.9.5.5. Description and drawing:.....

3.9.5.6. Approval number:.....

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**Deleted:** 3.9.5.4. Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s): MPa:¶

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**Model – II: Information document No … on the type-approval of specific component for liquefied hydrogen storage systems (LHSS) for hydrogen-fuelled vehicles on their safety-related performance**

The following information, if applicable, shall include a list of contents. Any drawings shall be supplied in appropriate scale and in sufficient detail on size A4 or on a folder of A4 format. Photographs, if any, shall show sufficient details.

If the components have electronic controls, information concerning their performance shall be supplied.

| | |
|---|---|
| 0. | General |
| 0.1. | Make (trade name of manufacturer): ..... |
| 0.2. | Type:..... |
| 0.2.1. | Commercial name(s) (if available): ..... |
| 0.5. | Name and address of manufacturer: ..... |
| 0.8. | Name(s) and address(es) of assembly plant(s):..... |
| 0.9. | Name and address of the manufacturer's representative (if any):..... |
| 3. | Power plant |
| 3.9.3. | Pressure relief device(s) |
| 3.9.3.1. | Make(s):..... |
| 3.9.3.2. | Type(s):..... |
| 3.9.3.3. | Maximum allowable working pressure (MAWP):..... MPa |
| 3.9.3.4. | Set pressure:..... |
| 3.9.3.5. | Set temperature:..... |
| 3.9.3.6. | Blow off capacity:..... |
| 3.9.3.7. | Normal maximum operating temperature:.....°C |
| 3.9.3.8. | Material:..... |
| 3.9.3.9. | Description and drawing:..... |
| 3.9.5. | Shut-off device(s) |
| 3.9.5.1. | Make(s):..... |
| 3.9.5.2. | Type(s):..... |
| 3.9.5.3. | MAWP:..... MPa |
| 3.9.5.4. | Material:..... |
| 3.9.5.5. | Description and drawing:..... |

**Deleted:** Maximum Allowable Working Pressure (

**Deleted:** )

**Deleted:** 3.9.5.4. Nominal working pressure(s) and if downstream of the first pressure regulator, maximum allowable working pressure(s): MPa:¶

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## Model – III: Information document No … on the type-approval of hydrogen-fuelled vehicles of incorporating liquefied hydrogen storage system (LHSS) on its safety-related performance

The following information, if applicable, shall include a list of contents. Any drawings shall be supplied in appropriate scale and in sufficient detail on size A4 or on a folder of A4 format. Photographs, if any, shall show sufficient details.

If the systems or components have electronic controls, information concerning their performance shall be supplied.

| | |
|---|---|
| 0. | General |
| 0.1. | Make (trade name of manufacturer): ..... |
| 0.2. | Type:..... |
| 0.2.1. | Commercial name(s) (if available): ..... |
| 0.3. | Means of identification of type, if marked on the vehicle[2]: ..... |
| 0.3.1. | Location of that marking: ..... |
| 0.4. | Category of vehicle[3]: ..... |
| 0.5. | Name and address of manufacturer: ..... |
| 0.8. | Name(s) and address(es) of assembly plant(s):..... |
| 0.9. | Name and address of the manufacturer's representative (if any):..... |
| 1. | General construction characteristics of the vehicle |
| 1.1. | Photographs and/or drawings of a representative vehicle:..... |
| 1.3.3. | Powered axles (number, position, interconnection):..... |
| 1.4. | Chassis (if any) (overall drawing): ..... |
| 2. | MASSES AND DIMENSIONS (in kg and mm) (Refer to drawing where applicable) |
| 2.4. | Range of vehicle dimensions (overall) |
| 2.4.1. | For chassis without bodywork |
| 2.4.1.1.2. | Minimum permissible length: ..... |
| 2.4.1.2.2. | Minimum permissible width: ..... |
| 2.4.1.3. | Height (in running order) (for suspensions adjustable for height, indicate normal running position): ..... |
| 2.4.1.3.1. | Maximum permissible height: ..... |
| 2.4.2. | For chassis with bodywork |
| 2.4.2.1. | Length: ..... |
| 2.4.2.2. | Width: ..... |
| 2.4.2.3. | Height (in running order) (for suspensions adjustable for height, indicate normal running position): ..... |
| 3. | Power plant |
| 3.9. | Hydrogen storage system |
| 3.9.1. | Hydrogen storage system designed to use liquid / compressed (gaseous) hydrogen[1] |
| 3.9.1.1. | Description and drawing of the hydrogen storage system: ..... |
| 3.9.1.2. | Make(s):..... |
| 3.9.1.3. | Type(s):..... |
| 3.9.1.4. | Approval Number:..... |

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[2] If means of identification of type contains characters not relevant to describe the vehicle type covered by this information document, such characters shall be represented in the documentation by the symbol "[..]" (e.g. […]).

[3] As defined in the Consolidated Resolution on the Construction of Vehicles (R.E.3.), document ECE/TRANS/WP.29/78/Rev.8, para. 2. - https://unece.org/transport/vehicle-regulations/wp29/resolutions

[1] Delete where not applicable (there are cases where nothing needs to be deleted when more than one entry is applicable).

| | | |
|---|---|---|
| 3.9.6. | Hydrogen leakage detection sensors: | ..... |
| 3.9.6.1. | Make(s): | ..... |
| 3.9.6.2. | Type(s): | ..... |
| 3.9.7. | Refuelling connection or receptacle | |
| 3.9.7.1. | Make(s): | ..... |
| 3.9.7.2. | Type(s): | ..... |
| 3.9.8. | Drawings showing requirements for installation and operation: | ..... |

## Annex 1 - Part 2

### Communication

(Maximum format: A4 (210 x 297 mm)


[4]

issued by: Name of administration:
.....
.....
.....

concerning [4]: Approval granted
Approval extended
Approval refused
Approval withdrawn
Production definitively discontinued

of a type of vehicle/system/component with regard to the safety-related performance of vehicles and systems fuelled with liquefied hydrogen pursuant to Regulation No. XYZ

Approval No.: ..... Extension No.: .....

1. Trademark:.....
2. Type and trade names: .....
3. Name and address of manufacturer:.....
4. If applicable, name and address of manufacturer's representative:.....
5. Brief description of vehicle/component:[5].....
6. Installation restrictions applicable to the LHSS as described in paragraph 7.1.2.: .....
   .....
7. Date of submission of vehicle/component for approval:[5] .....
8. Technical Service performing the approval tests: .....
9. Date of report issued by that Service: .....
10. Number of report issued by that Service:.....

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[4] Distinguishing number of the country which has granted/extended/refused/withdrawn an approval (see approval provisions in the Regulation).
[4] Delete what does not apply.

11. Approval with regard to the safety-related performance of hydrogen-fuelled vehicles is granted/refused: [5].....

12. Place:.....

13. Date:.....

14. Signature:.....

15. The information document annexed to this communication:.....

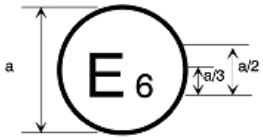
16. Any remarks:.....

[5] Delete what does not apply.

## Annex 2

### Arrangements of the approval marks

Model A (See paragraphs 4.4. to 4.4.2. of this Regulation)



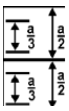

XYZR - 001185 


a = 8 mm min

The above approval mark affixed to a vehicle/component shows that the vehicle/system type concerned has been approved in Belgium (E6) for its safety-related performance of vehicles and systems fuelled with liquefied hydrogen pursuant to Regulation No. XYZ. The first two digits of the approval number indicate that the approval was granted in accordance with the requirements of Regulation No. XYZ in its original form.

Model B (see paragraph 4.5. of this Regulation)


| | |
|---|---|
| 100 | 05 2492 |
| XYZ | 00 1628 |



a = 8 mm min.

The above approval mark affixed to a vehicle shows that the road vehicle concerned has been approved in the Netherlands (E4) pursuant to Regulations Nos. XYZ and 100. The first two digits of the latter number[1] indicate that, at the dates when the respective approvals were granted, Regulation No. 100 was amended by the 05 series of amendments and Regulation No. XYZ was still in its original form.

[1] The latter number is given only as an example.

# Annex 3

## Test procedures for LHSS design qualification

1. Verification tests for Baseline metrics

1.1. Proof pressure test

The inner container and the pipe work situated between the inner container and the vacuum jacket shall withstand an inner pressure test at room temperature according to the following requirements.

1.1.1. The test pressure $p_{test}$ is defined by the manufacturer and shall fulfil the following requirements:

$p_{test} \geq 130$ per cent (MAWP + 0.1 MPa)

For containers, either $p_{test}$ is equal to or greater than the maximum pressure of the inner container during [vacuum loss test] (as determined in Annex 3, paragraph 2.3.) or the manufacturer proves by calculation that at the maximum pressure of the inner container during fault management no yield occurs;

1.1.2. The test is conducted according to the following procedure:

(a) The test is conducted on the inner storage container and the pipe work between inner storage container and vacuum jacket before the vacuum jacket is mounted;

(b) The test is either conducted hydraulically with water or a glycol/water mixture, or alternatively with gas. The container is pressurized to test pressure $p_{test}$ at an even rate and kept at that pressure for at least 10 minutes;

(c) The test is done at ambient temperature. In the case of using gas to pressurize the container, the pressurization is done in a way that the container temperature stays at or around ambient temperature.

The test is passed successfully if, during the first 10 minutes after applying the proof pressure, no visible permanent deformation, no visible degradation in the container pressure and no visible leakage are detectable.

1.2. Baseline initial burst pressure

The test is conducted according to the following procedure:

(a) The test is conducted on the inner container at ambient temperature;

(b) The test is conducted hydraulically with water or a water/glycol mixture;

(c) The pressure is increased at a constant rate, not exceeding 0.5 MPa/min until burst or leakage of the inner container occurs;

(d) When the MAWP is reached there is a wait period of at least ten minutes at constant pressure, during which time the deformation of the inner container can be checked;

(e) The pressure is recorded or written during the entire test.

The test is passed successfully if the passing criteria described in paragraph 5.1.2. of this Regulation is fulfilled.

1.3. Baseline pressure cycle life

The container pressure cycled with a number of cycles at least three times the number of possible full pressure cycles (from the lowest to highest operating pressure) for an expected on-road performance. The number of pressure cycles is defined by the manufacturer under consideration of operating pressure range, size of the storage and, respectively, maximum number of refuellings and maximum number of pressure cycles under extreme usage and storage

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**Formatted:** Normal, Justified, Indent: Before: 2 cm, Hanging: 2 cm, After: 2 cm, Space After: 0.5 line

**Deleted:** [(b) For non-metallic containers, $p_{test}$ is equal to or greater than the maximum pressure of the inner container during [vacuum loss test] (as determined in Annex 3, paragraph 2.3.).]¶

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**Deleted:** For inner containers made out of an aluminium alloy or other [metallic] material, a passing criterion shall be defined which guarantees at least the same level of safety compared to steel inner containers.

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conditions. Pressure cycling is conducted between atmospheric pressure and MAWP at liquid nitrogen temperatures, e.g. by filling the container with liquid nitrogen to certain level and alternately pressurizing and depressurizing it with (pre-cooled) gaseous nitrogen or helium.

2. Verification for expected on-road performance

2.1. Boil-off test

2.1.1. The test is conducted according to the following procedure:

(a) For pre-conditioning, the LHSS is fuelled with liquid hydrogen to the specified maximum filling level. Hydrogen is subsequently extracted until it meets half filling level, and the system is allowed to completely cool down for at least 24 hours and a maximum of 48 hours;

(b) The LHSS is filled to the specified maximum filling level;

(c) The LHSS is pressurized until boil-off pressure is reached;

(d) The test lasts for at least another 48 hours after boil-off started and is not terminated before the pressure stabilizes. Pressure stabilization has occurred when the average pressure does not increase over a two hour period.

2.1.2. The pressure of the inner container shall be recorded during the entire test. The test is passed when the following requirements are fulfilled:

(a) The pressure shall stabilize and stay below MAWP during the whole test;

(b) The PRDs are not allowed to open during the whole test.

2.2. Boil-off discharge rate

2.2.1 The boil-off discharge rate test shall be performed directly after the boil-off test in paragraph 2.1 under the same conditions. In case a boil-off converter is used it shall be preconditioned until the nominal operating conditions as per the manufacturer's specifications or steady-state conditions are reached before conducting the measurement. The inner container pressure is kept at boil-off pressure during the entire test. The hydrogen boil-off discharge rate shall be measured by an appropriate method (e.g., suitable hydrogen detector and mass flow meter) at the outlet of the boil-off valve, the boil-off vent line or the boil-off converter (if used) as applicable. The test shall at least last for 1 hour after stabilisation.

2.2.2 The boil-off discharge rate shall be recorded during the entire test.

2.3. Vacuum loss test

2.3.1. The first part of the test is conducted according to the following procedure:

(a) The vacuum loss test is conducted with a completely cooled-down LHSS (according to the procedure in Annex 3, paragraph 2.1.);

(b) The LHSS is filled with liquid hydrogen to the specified maximum filling level;

(c) The vacuum enclosure is flooded with air at an even rate to atmospheric pressure;

(d) The test is terminated when the first PRD does not open any more.

2.3.2. The pressure of the inner container and the vacuum jacket is recorded or written during the entire test. The opening pressure of the first safety device is recorded or written. The first part of test is passed if the following requirements are fulfilled:

(a) The first PRD opens ≤ MAWP and limits the pressure to not more than 110 per cent of the MAWP;

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(b) The second PRD does not open during the entire test.

2.3.3. After passing the first part, the test shall be repeated subsequently to re-generation of the vacuum and cool-down of the LHSS as described above.

(a) The vacuum is re-generated to a value specified by the manufacturer. The vacuum shall be maintained at least 24 hours. The vacuum pump may stay connected until the time directly before the start of the vacuum loss;

(b) The second part of the vacuum loss test is conducted with a completely cooled-down LHSS (according to the procedure in Annex 3, paragraph 2.1.);

(c) The LHSS is filled with liquid hydrogen to the specified maximum filling level;

(d) The line downstream the first PRD is blocked and the vacuum enclosure is flooded with air at an even rate to atmospheric pressure;

2.3.4. The pressure of the inner container and the vacuum jacket is recorded during the entire test. The second part of the test is passed if the second PRD does not open below 110 per cent of the set pressure of the first PRD and limits the pressure in the container to a maximum 136 per cent of the MAWP if a safety valve is used, or, 150 per cent of the MAWP if a burst disc is used as the second PRD.

3. Verification test for service-terminating conditions - Bonfire test

The bonfire test shall be conducted on the LHSS.

3.1. The first part of the test is conducted according to the following procedure:

(a) The bonfire test is conducted with a completely cooled-down LHSS (according to the procedure in Annex 3, paragraph 2.1.);

(b) The LHSS contained during the previous 24 hours a volume of liquid hydrogen at least equal to half of the water volume of the inner container;

(c) The LHSS is filled with liquid hydrogen so that the quantity of liquid hydrogen measured by the mass measurement system is half of the maximum allowed quantity that may be contained in the inner container;

(d) A fire burns 0.1 m underneath the vacuum jacket. The length and the width of the fire exceed the plan dimensions of the vacuum jacket by 0.1 m. The temperature of the fire is at least 590 ºC. The fire shall continue to burn for the duration of the test;

(e) The pressure of the inner container at the beginning of the test is between 0.00 MPa and 0.01 MPa at the boiling point of hydrogen in the inner container;

(f) The test shall continue until the storage pressure decreases to or below the pressure at the beginning of the test, or alternatively in case the first PRD is a re-closing type, the test shall continue until the safety device has opened for a second time;

(g) The test conditions and the maximum pressure reached within the inner container during the test are recorded by the Technical Service.

3.2. The test is passed if the following requirements are fulfilled:

(a) The second PRD is not operated below 110 per cent of the set pressure of the first PRD;

(b) The container shall not burst and the pressure inside the inner container shall not exceed the permissible fault range of the inner container.

3.3. The permissible fault range for steel containers is as follows:

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**Deleted:** For steel containers the

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**Deleted:** pressure relief device

**Deleted:** pressure relief device

**Deleted:** [

**Deleted:** For other container materials, an equivalent level of safety shall be demonstrated.]

**Deleted:** [The tested liquefied hydrogen storage system shall be representative of the design and the manufacturing of the type to be homologated. Its manufacturing shall be completely finished and it shall be mounted with all its equipment.]

**Deleted:** container

**Deleted:** container

**Deleted:** container

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(a) If a safety valve is used as second PRD, the pressure inside the container does not exceed 136 per cent of the MAWP of the inner container;

(b) If a burst disc with a relief external to the vacuum space is used as a second PRD, the pressure inside the container is limited to 150 per cent of the MAWP of the inner container;

(c) If a burst disc with a relief internal to the vacuum space is used as second PRD, the pressure inside the container is limited to 150 per cent of the MAWP + 0.1 MPa of the inner container.

For other materials, an equivalent level of safety shall be demonstrated.

**Deleted:** pressure relief device

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# Annex 4

## Test procedures for specific components for LHSS

The test procedures for PRDs (paragraph 6.1. of this Regulation) and shut-off devices (paragraph 6.2. of this Regulation) are described below,

Table 1
**Applicability of the test procedures for specific components**

| | | *Test object* | | | |
|---|---|---|---|---|---|
| *No.* | *Test procedure* | *Reclosing PRD* | *Non-reclosing PRD* | *Shut-off device* | *Remark* |
| 1 | Pressure test | X | X | X | |
| 2 | External leakage test | X | X | X | |
| 3 | Endurance test | | | X | Followed by test No.2 |
| 4 | Operational test | X | | | |
| 5 | Corrosion resistance test | X | X | X | Followed by test No.2 |
| 6 | Resistance to dry-heat test | | | X | |
| 7 | Ozone ageing test | | | X | |
| 8 | Temperature cycle test | X | X | X | Followed by test No.2 |
| 9 | Flex line cycle test, if applicable | | | X | Followed by test No.2 |

Testing shall be performed with hydrogen gas having gas quality compliant with ISO 14687:2025/SAE J2719_202003 unless otherwise specified. All tests shall be performed at ambient temperature 20 (±5) °C unless otherwise specified.

1. Pressure test

PRDs and shut-off devices shall withstand without any visible evidence of leak or deformation a test pressure of 150 per cent MAWP with the outlets of the high-pressure part plugged. The pressure shall subsequently be increased from 150 per cent to 300 per cent MAWP. The component shall not show any visible evidence of rupture or cracks.

The pressure supply system shall be equipped with a positive shut-off valve and a pressure gauge having a pressure range of not less than 150 per cent and no more than 200 per cent of the test pressure; the accuracy of the gauge shall be 1 per cent of the pressure range.

For components requiring a leakage test, this test shall be performed prior to the pressure test.

2. External leakage test

PRDs, shut-off devices and flex fuel lines, if applicable, shall be free from leakage through stem or body seals or other joints and shall not show evidence of porosity in casting when tested as described in Annex 4, paragraph 3 at any gas pressure between zero and its MAWP.

The test shall be performed on the same equipment at the following conditions:

(a) At ambient temperature;

(b) At the minimum operating temperature or at liquid nitrogen temperature after sufficient conditioning time at this temperature to ensure thermal stability;

(c) At the maximum operating temperature after sufficient conditioning time at this temperature to ensure thermal stability.

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During this test, the equipment under test shall be connected to a source of gas pressure. If a component has a pressure relieving function, that function shall be disabled during the test. A positive shut-off device and a pressure gauge having a pressure range of not less than 150 per cent and not more than 200 per cent of the test pressure shall be installed in the pressure supply piping; the accuracy of the gauge shall be 1 per cent of the pressure range. The pressure gauge shall be installed between the positive shut-off device and the sample under test.

Throughout the test, the sample shall be tested for leakage, with a surface-active agent without formation of bubbles or measured with a leakage rate less than 216 Nml/hr.

3. Endurance test

3.1. Shut-off devices shall be capable of conforming to the leakage test requirements of Annex 4, paragraph 2., after being subjected to 20,000 operation cycles.

3.2. The external leakage test, as described in Annex 4, paragraph 2. shall be carried out immediately following the endurance test.

3.3. The shut-off device shall be securely connected to a pressurized source of dry air or nitrogen and subjected to 20,000 operation cycles. A cycle shall consist of one opening and one closing of the component within a period of not less than 10 ± 2 seconds.

3.4. The shut-off device shall be operated through 96 per cent of the number of specified cycles at ambient temperature and at the MAWP of the shut-off device. During the off cycle the downstream pressure of the test fixture shall be allowed to decay to 50 per cent of the MAWP of the shut-off device.

3.5. The shut-off device shall be operated through 2 per cent of the total cycles at the maximum material temperature (-40 °C to +85 °C) after sufficient conditioning time at this temperature to ensure thermal stability and at MAWP. The shut-off device shall comply with Annex 4, paragraph 2. at the appropriate maximum material temperature (-40 °C to +85 °C) at the completion of the high temperature cycles.

3.6. The shut-off device shall be operated through 2 per cent of the total cycles at the minimum material temperature (-40 °C to +85 °C) but not less than the temperature of liquid nitrogen after sufficient conditioning time at this temperature to ensure thermal stability and at the MAWP of the shut-off device. The shut-off device shall comply with Annex 4, paragraph 2. at the appropriate minimum material temperature (-40 °C to +85 °C) at the completion of the low temperature cycles.

4. Operational test

The operational test shall be carried out in accordance with EN 13648-1:2009 or EN 13648-2:2002. The specific requirements of the standard are applicable.

5. Corrosion resistance test

Metallic hydrogen components shall comply with the leakage tests referred to in Annex 4, paragraph 2. after being submitted to 144 hours salt spray test according to ISO 9227:2022 with all connections closed.

A copper or brass hydrogen containing component shall comply with the leakage tests referred to in Annex 4, paragraph 2. and after being submitted to 24 hours immersion in ammonia according to ISO 6957:1988 with all connections closed.

6. Resistance to dry-heat test

The test shall be carried out in compliance with ISO 188:2023. The test piece shall be exposed to air at a temperature equal to the maximum operating temperature for 168 hours. The change in tensile strength shall not exceed ±25

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per cent. The change in ultimate elongation shall not exceed the following values:

(a) maximum increase 10 per cent;

(b) maximum decrease 30 per cent.

7. Ozone ageing Test

The test shall be in compliance with ISO 1431-1:2024. The test piece, which shall be stressed to 20 per cent elongation, shall be exposed to air at +40 °C with an ozone concentration of 50 parts per hundred million during 120 hours.

No cracking of the test piece is allowed.

8. Temperature cycle test

A non-metallic part containing hydrogen shall comply with the leakage tests referred to in Annex 4, paragraph 2. after having been submitted to a 96-hour temperature cycle from the minimum operating temperature up to the maximum operating temperature with a cycle time of 120 minutes, under MAWP.

9. Flex line cycle test

If applicable, a flexible fuel line shall be capable of conforming to the leakage test requirements referred to in Annex 4, paragraph 2., after being subjected to 6,000 pressure cycles.

A flexible fuel line shall be securely connected to a pressurized source of pneumatic or hydraulic test media. The pressure shall change from atmospheric pressure to the MAWP of the container within less than five seconds, and after a time of at least five seconds, shall decrease to atmospheric pressure within less than five seconds.

The appropriate test for external leakage, as referred to in Annex 4, paragraph 2., shall be carried out immediately following the endurance test.

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## Annex 5

### Test procedures for a vehicle fuel system incorporating LHSS

1. Compliance test for single failure conditions

Either test procedure of paragraph 1.1. or paragraph 1.2. shall be executed:

1.1. Test procedure for vehicle equipped with hydrogen gas leakage detectors

1.1.1. Test condition

1.1.1.1. Test vehicle: The propulsion system of the test vehicle is started, warmed up to its normal operating temperature, and left operating for the test duration. If the vehicle is not a fuel cell vehicle, it is warmed up and kept idling. If the test vehicle has a system to stop idling automatically, measures are taken so as to prevent the engine from stopping.

1.1.1.2. Test gas: Two mixtures of air and hydrogen gas: > 3.0 per cent concentration of hydrogen in the air to verify function of the warning, and > 4.0 per cent concentration of hydrogen in the air to verify function of the shut-down. The proper concentrations are selected based on the recommendation (or the detector specification) by the manufacturer.

***NOTE:*** *The storage of pre-mixed gases of greater than 2 per cent hydrogen in the air in compressed gas cylinders may be restricted or prohibited in various jurisdictions where test laboratories are located. As an alternative, gas mixtures up to 4 per cent hydrogen in situ may be used within the test area by a mixing station that injects the required amount of hydrogen into a flowing stream of air. The hydrogen/air mixture can then be delivered to the point of release within the vehicle by a flexible hose.*

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1.1.2. Test method

1.1.2.1. Preparation for the test: The test is conducted without any influence of wind by appropriate means such as;

(a) A test gas induction hose is attached to the hydrogen gas leakage detector;

(b) The hydrogen leak detector is enclosed with a cover to make gas stay around hydrogen leak detector.

1.1.2.2. Execution of the test

(a) Test gas is blown to the hydrogen gas leakage detector;

(b) Proper function of the warning system is confirmed within 10 seconds when tested with the gas to verify function of the warning;

(c) The main shut-off device is confirmed within 10 seconds to be closed when tested with the gas to verify function of the shut-down. For example, the monitoring of the electric power to the shut-off device or of the sound of the shut-off device activation may be used to confirm the operation of the main shut-off device of the hydrogen supply.

1.2. Test procedure for integrity of enclosed spaces and detection systems.

1.2.1. Preparation:

1,2.1.1. The test is conducted without any influence of wind.

1.2.1.2. Special attention is paid to the test environment as during the test flammable mixtures of hydrogen and air may occur.

1.2.1.3. Prior to the test, the vehicle is prepared to simulate remotely controllable hydrogen releases from the hydrogen system. Hydrogen releases may be demonstrated by using external fuel supply without modification of the test vehicle fuel lines. The number, location and flow capacity of the release points

downstream of the main hydrogen shut-off device are defined by the vehicle manufacturer taking worst case leakage scenarios under single failure condition into account. As a minimum, the total flow of all remotely controlled releases shall be adequate to trigger demonstration of the automatic "warning" and hydrogen shut-off functions.

1.2.1.4. For the purpose of the test, a hydrogen concentration detector is installed where hydrogen gas may accumulate most in the passenger compartment (e.g. near the headliner) when testing for compliance with paragraph 7.2.3.2. of this Regulation and hydrogen concentration detectors are installed in enclosed or semi enclosed volumes on the vehicle where hydrogen may accumulate from the simulated hydrogen releases when testing for compliance with paragraph 7.2.3.1. of this Regulation.

1.2.2. Procedure:

1.2.2.1. Vehicle doors, windows and other covers are closed.

1.2.2.2. The propulsion system is started, allowed to warm up to its normal operating temperature and left operating at idle for the test duration.

1.2.2.3. A leak is simulated using the remote controllable function.

1.2.2.4. The hydrogen concentration is measured continuously until the concentration does not rise for 3 minutes. When testing for compliance with paragraph 7.2.3.3. of this Regulation, the simulated leak is then increased using the remote controllable function until the main hydrogen shut-off device is closed and the tell-tale warning signal is activated. The monitoring of the electric power to the shut-off device or of the sound of the shut-off device activation may be used to confirm the operation of the main shut-off device of the hydrogen supply.

1.2.2.5. When testing for compliance with paragraph 7.2.3.2. of this Regulation, the test is successfully completed if the hydrogen concentration in the passenger compartment does not exceed 1.0 per cent. When testing for compliance with paragraph 7.2.3.3. of this Regulation, the test is successfully completed if the tell-tale warning and shut-off function are executed at (or below) the levels specified in paragraph 7.2.3.3. of this Regulation; otherwise, the test is failed and the system is not qualified for vehicle service.

2. Compliance test for the vehicle exhaust system

2.1. The power system of the test vehicle (e.g. fuel cell stack or engine) is warmed up to its normal operating temperature.

2.2. The measuring device is warmed up before use to its normal operating temperature.

2.3. The measuring section of the measuring device is placed on the centre line of the exhaust gas flow within 100 mm from the exhaust point of discharge external to the vehicle.

2.4. The exhaust hydrogen concentration is continuously measured during the following steps:

(a) The power system is shut-down;

(b) Upon completion of the shut-down process, the power system is immediately started; and

(c) After completion of the start-up process as defined by the manufacturer, the power system is turned off and measurement continues until the power system shut-down procedure is completed.

2.5. The measurement device shall:

(a) Have a measurement response-time ($t_0$ - $t_{90}$) of less than two seconds, where $t_0$ is the moment of hydrogen concentration switching, and $t_{90}$ is the time when 90 per cent of the final indication is reached.

(b) Have a resolution time of less than 300 milliseconds (sampling rate of > 3.33 Hz).

3. Compliance test for fuel line leakage

3.1. The power system of the test vehicle (e.g. fuel cell stack or engine) is warmed up and operating at its normal operating temperature with the operating pressure applied to fuel lines.

3.2. Hydrogen leakage is evaluated at accessible sections of the fuel lines from the high-pressure section to the fuel cell stack (or the engine), using a gas leak detector or a leak detecting liquid, such as soap solution.

3.3. Hydrogen leak detection is performed primarily at joints.

3.4. When a gas leak detector is used, detection is performed by operating the leak detector for at least 10 seconds at locations as close to fuel lines as possible.

3.5. When a leak detecting liquid is used, hydrogen gas leak detection is performed immediately after applying the liquid. In addition, visual checks are performed a few minutes after the application of liquid to check for bubbles caused by trace leaks.

4. Installation verification

The system is visually inspected for compliance.

# Annex 6

## Provisions for a label for liquefied hydrogen vehicles


(Paragraph 7.2.4. of this Regulation)

The label consists of a sticker which shall be weather resistant.

The centre zone indicates the first energy source.

The upper zone indicates the second energy source.

The left zone indicates the gas behaviour due to density.

The right zone indicates the state of aggregation of stored liquefied fuel.

Layout and symbols shall be in accordance with ISO 17840-4:2018.

The colour and dimensions of the sticker shall fulfil the following requirements:

Colours:

Background: white or white reflecting

Border: Light-blue, RGB code 0, 176, 240 or similar

Letters: Light-blue, RGB code 0, 176, 240 or similar

Dimensions:

Sticker width: ≥ 110 mm

Sticker height: ≥ 80 mm

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**[Annex 7** ¶

**Periodic technical inspection**¶

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1. Periodic technical inspection means the inspection of vehicles performed at specified intervals according to national regulations. Guidelines for the visual inspection of each hydrogen system [during its service life] shall be provided by the hydrogen system manufacturer on the basis of use under service conditions specified herein.¶
2. Each hydrogen system shall be visually inspected at least every 48 months after the date of its entry into service on the vehicle (vehicle registration), and at the time of any reinstallation, for external damage and deterioration. ¶
3. The visual inspection shall be performed in accordance with the manufacturer's specifications: hydrogen system without a label containing mandatory information or with labels containing mandatory information that are illegible in any way shall be removed from service. ¶
4. If the hydrogen system can be positively identified by the manufacturer and serial number, a replacement label may be applied, allowing the hydrogen system to remain in service.]¶