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PROPOSAL FOR A NEW DRAFT REGULATION:

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF:

1. SPECIFIC COMPONENTS OF MOTOR VEHICLES USING COMPRESSED GASEOUS HYDROGEN;
2. VEHICLES WITH REGARD TO THE INSTALLATION OF SPECIFIC COMPONENTS FOR THE USE OF COMPRESSED GASEOUS HYDROGEN;

Transmitted by the GRPE Informal Group "Hydrogen/Fuel Cell Vehicles" based on proposals developed by the Partners of the European Integrated Hydrogen Project – Phase II (EIHP2)

Notes: The document reproduced below was prepared by the experts of GRPE Informal Group "Hydrogen/Fuel Cell Vehicles" in order to set up new provisions for the type approval of vehicles using compressed gaseous hydrogen. The text is based on a document distributed without a symbol (informal document No. 12) during the forty-sixth session of GRPE (TRANS/WP.29/GRPE/46, para. 37), including some editorial modifications inserted by the informal group.

1. For editing purposes the **bold** characters identify references to standards or to other parts of this document.
2. A number of key words or phrases have been defined and are indicated in the text by *italic* characters. As these definitions are crucial to the correct interpretation of this document, it is strongly recommended that they remain highlighted in the final text of the new Regulation.

Note: This document is distributed to the Experts on Pollution and Energy only.

REGULATION ON UNIFORM PROVISIONS CONCERNING THE APPROVAL OF:
1. SPECIFIC COMPONENTS OF MOTOR VEHICLES USING COMPRESSED GASEOUS HYDROGEN;
2. VEHICLES WITH REGARD TO THE INSTALLATION OF SPECIFIC COMPONENTS FOR THE USE OF COMPRESSED GASEOUS HYDROGEN;

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ANNEXES

1. SCOPE

This Regulation applies to:

1.1. Compressed gaseous hydrogen systems for motor vehicles in which the hydrogen is stored in its gaseous phase under pressure and essentially at ambient temperature, including the complete *hydrogen system*, i.e. excluding the *propulsion system* (internal combustion engine or fuel cell system) or any auxiliary power unit.

1.2. *Specific components* of motor vehicles of categories M and N using compressed gaseous hydrogen (Part I of this Regulation). 1/

1.3. Vehicles of categories M and N with regard to the installation of s*pecific components* for the use of compressed gaseous hydrogen (Part II of this Regulation). 1/

2. DEFINITIONS, CONTAINER TYPES, PRESSURE CLASSIFICATIONS AND SERVICE CONDITIONS

2.1. DEFINITIONS

For the purpose of this Regulation and the accompanying annexes the following definitions shall apply and are indicated in the text by capitalised italic words, e.g. *valve*:

2.1.1. "*Approval of a vehicle type*": Approval of a type of vehicle with regard to its *hydrogen system* installed as original equipment.

2.1.2. "*Automatic valve*": A valve that is not operated manually. A *non-return valve* is not an *automatic valve*.

2.1.3. "*Auto-frettage*": A pressure application procedure used in manufacturing *composite containers* with metal *liners*, which strains the *liner* past its yield point sufficiently to cause permanent plastic deformation, which results in the *liner* having compressive stresses and the fibres having tensile stresses at zero internal pressure.

2.1.4. "*Auto-frettage pressure*": The pressure within the *over-wrapped container* at which the required distribution of stresses between the *liner* and the *over-wra*p is established.

2.1.5. "*Batch*": A production quantity of successively produced *finished containers* having the same nominal dimensions, design, specified materials of construction, process of manufacture, equipment for manufacture and, where appropriate, conditions of time, temperature and atmosphere during heat treatment.

1/ As defined in the Consolidated Resolution on the Construction of Vehicles (R.E.3) (document TRANS/WP.29/78/Rev.1/Amend.2).

2.1.6. "*Boundary of functional operation*": Defines the boundaries of the external physical limits within which a system is able to maintain control.

2.1.7. "*Burst pressure*": The *pressure* at which the *container* ruptures.

2.1.8. "*CGH_2*": Compressed gaseous hydrogen.

2.1.9. "*Complex electronic vehicle control systems*": Those *electronic control systems* which are subject to a hierarchy of control in which one electronically controlled function may be over-ridden by a higher level *electronic control system*/function. In this case, the function that is over-ridden becomes part of the complex system.

2.1.10. "*Composite container*": A *container* constructed of more than one material.

2.1.11. "*Container*": Any vessel used for the storage of compressed gaseous hydrogen within the temperature limits specified in this Regulation, excluding any other *hydrogen components* which may be attached to or fitted inside the *container*.

2.1.12. "*Container Assembly"*: Two or more *Containers* with integral interconnecting fuel lines protectively encased inside a housing shell.

2.1.13. "*Duty Cycle"*: One start up and shut down cycle of the *hydrogen conversion system(s).*

2.1.14. "*Electronic control system*": A combination of *units*, designed to co-operate in the production of the stated vehicle control function by electronic data processing. Such systems, often controlled by software, are built from discrete functional components such as sensors, electronic control units and actuators and connected by *transmission links*. They may include mechanical, electro-pneumatic or electro-hydraulic elements.

2.1.15. "*Excess flow system*": A system that shuts off the flow without manual intervention in the event of a pipe rupture or similar severe leakage.

2.1.16. "*Filling cycle*": A pressure increase of more than 25 per cent of the *working pressure* of the *container* due to an external source of hydrogen.

2.1.17. "*Finished container*": A *Container* that is typical of normal production, complete with identification marks and external coating including integral insulation specified by the *manufacturer*, but free from non-integral insulation or protection.

2.1.18. "*First pressure regulator*": The *Pressure Regulator* having the *Container* pressure as its inlet pressure.

2.1.19. "*Fitting*": A non-permanent connector used in a piping, tubing or hose system.

2.1.20. "*Flexible fuel line*": A flexible tubing or hose of any length through which hydrogen flows.

2.1.21. "*Fuel supply line*": The line that supplies the *hydrogen conversion system(s)* with hydrogen.

2.1.22. "*Fully wrap*": *Over-wrap* with the filaments wound around the *liner* both in the circumferential and longitudinal directions of the *container*.

2.1.23. "*Hoop wrap*": *Over-wrap* with the filaments wound in a substantially circumferential pattern over the cylindrical portion of the *liner,* so that the filaments do not carry any significant load in the longitudinal direction of the *container*.

2.1.24. "*Hydrogen component*": A component that is in direct contact with hydrogen or which forms part of a system installed because of the use of hydrogen. A *hydrogen component* can consist of a combination of metallic and non-metallic parts/subcomponents.

2.1.25. "*Hydrogen conversion system*": Any system designed for the conversion of hydrogen into electrical, mechanical or thermal energy, and includes, for example, the *propulsion system(s)* or auxiliary power unit(s).

2.1.26. "*Hydrogen filter*": A filter used to separate oil, water and dirt from hydrogen.

2.1.27. "*Hydrogen sensor*": A sensor used to detect hydrogen in air.

2.1.28. "*Hydrogen system*": An assembly of *hydrogen components* and connecting parts fitted on motor vehicles using hydrogen, excluding the *hydrogen conversion system(s)*. The boundary between the *hydrogen system* and the *hydrogen conversion system(s)* shall be defined by the vehicle manufacturer, but as a minimum requirement it shall be defined as the point(s) at which the *nominal working pressure* is higher than the:

a) Maximum operating *pressure* of fuel cell system(s),

b) The inlet *pressure* of the gas mixer (carburettor or injector(s)) for internal combustion engines or other combustion devices.

2.1.29. "*Leak test gas*": Hydrogen, helium or an inert gas mixture containing at least 5 per cent hydrogen or 10 per cent helium or a demonstrated detectable amount of helium or hydrogen gas.

2.1.30. "*Liner*": A *container* that is used as a gas tight, inner shell, on which reinforcing fibres are filament wound to reach the necessary strength. *Liners* may be designed to share the load with the reinforcement, or not to carry any part of the load.

2.1.31 "*Manual valve*": A manually operated valve.

2.1.32. "*Manufacturer*": The person or organization responsible for the design, manufacturing, testing and conformity of production of a *hydrogen component*.

2.1.33. "*Maximum allowable working pressure (MAWP)*": The maximum pressure to which a component downstream of a *pressure regulator* is subjected.

2.1.34. "*Multifunctional component*": *Specific components* combined or fitted together and which may include *hydrogen components*.

2.1.35. "*Nm^3*" or "*Ncm^3*" (normal cubic metre or centimetre): A volume of dry gas that occupies a volume of 1 m^3 or 1 cm^3 at a temperature of 273.15 K (0 °C) and an absolute pressure of 101.325 kPa (1 atm).

2.1.36. "*Nominal working pressure*": The pressure level at which a component typically operates. For *containers* it is the settled pressure at a uniform temperature of 288 K (15 °C) for a full *container*.

2.1.37. "*Non-return valve*": A valve that allows hydrogen to flow in only one direction.

2.1.38. "*Over-wrap*": Resin impregnated continuous filaments used as reinforcement around a *liner*.

2.1.39. "*Pressure*": Gauge pressure measured in MPa against atmospheric pressure, unless otherwise stated.

2.1.40. "*Pressure regulator*": A device used to control the delivery *pressure* of gaseous fuel to the *hydrogen conversion system*.

2.1.41. "*Pressure relief device*": A non-reclosing thermally activated device that prevents a *container* from bursting due to fire effects.

2.1.42. "*Pressure relief valve*" A reclosing pressure activated device that prevents a *hydrogen component* from bursting due to excessive pressure.

2.1.43. "*Propulsion system*": The internal combustion engine or fuel cell system used to propel the vehicle

2.1.44. "*Range of control*": Refers to an output variable and defines the range over which the system is likely to exercise control.

2.1.45. "*Receptacle*": A device fitted in the vehicle used to permit refilling of the *container(s)*, i.e. a filling unit.

2.1.46. "*Removable storage system*": A removable system within a vehicle that houses and protects one or more *containers* or a *container assembly* and includes all Class 0 *hydrogen components* used in the *hydrogen system.*

2.1.47. "*Removable storage system connector*": The hydrogen connection device between a *removable storage system* and the section of the *hydrogen system* permanently installed in the vehicle. A *removable storage system connector* consists of parts mounted on the *removable storage system* and on the vehicle.

2.1.48. "*Rigid fuel line*": Tubing that has not been designed to flex in normal operation and through which hydrogen flows.

2.1.49. "*Safety concept*": Measures designed into the system to ensure safe operation even in the event of a failure or random faults.

2.1.50. "*Safety device*": A device intended to ensure safe operation.

2.1.51. "*Safety instrumented systems*": Process control systems that prevent an impermissible fault range from being reached by an automatic intervention in the process.

2.1.52. "*Service life*": The life in years during which the *containers* may safely be used in accordance with the service conditions.

2.1.53. "*Specific component*": A *hydrogen component* that is subjected to type approval in accordance with this Regulation.

2.1.54. "*Transmission links*": The means used for interconnecting distributed *units* for the purpose of conveying signals, operating data or an energy supply. This equipment is generally electrical but can be mechanical, pneumatic or hydraulic.

2.1.55. "*Units*": The smallest divisions of system components that will be considered, as these combinations of components will be treated as single entities for purposes of identification, analysis or replacement.

2.1.56. "*Usage monitoring and control system*": A system that counts the *filling cycles* and prevents further use of the vehicle when a predetermined number of *filling cycles* is exceeded.

2.1.57. "*Vehicle type*": A vehicle fitted with *specific components* for the use of hydrogen that does not differ with respect to the following conditions:

a) The *manufacturer(s)*,
b) The installation of the *hydrogen components*,
c) Type(s) of *specific components*.

2.2. CONTAINER TYPES

A *container* shall be classified into the following types according to the type of construction:

Type 1 Seamless metallic *container*.
Type 2 *Hoop wrapped container* with a seamless metallic *liner*.
Type 3 *Fully wrapped container* with a seamless or welded metallic *liner*.
Type 4 *Fully wrapped container* with a non-metallic *liner*.

2.3. PRESSURE CLASSIFICATIONS

Hydrogen components shall be classified with regard to their *nominal working pressure* and function as defined below:

Class 0 High-pressure components/systems including fuel lines and *fittings* containing hydrogen at a *nominal working pressure* greater than 3.0 MPa.
Class 1 Medium-pressure components/systems including fuel lines and *fittings* containing hydrogen at a *nominal working pressure* greater than 0.45 MPa and up to and including 3.0 MPa.
Class 2 Low-pressure components/systems including fuel lines and *fittings* containing hydrogen at a *nominal working pressure* up to and including 0.45 MPa.

2.4. SERVICE CONDITIONS

Unless indicated otherwise the following service conditions shall apply throughout this Regulation and its annexes:

2.4.1. *Service life*

The *service life* of *hydrogen components* shall be specified by the vehicle manufacturer and may vary with different applications, however, it shall not exceed 20 years.

2.4.2. *Working pressure*

The vehicle manufacturer shall specify the *nominal working pressure(s)* of the *hydrogen system*. For the components downstream of the *first pressure regulator*, the MAWP(s) shall also be specified.

The MAWP(s) shall be equal to or shall exceed the set pressure of the overpressure protection specified in **paragraph 14.1.18.** of this Regulation.

2.4.3. External surfaces

The effects on external surfaces of the *hydrogen components* in their installed position shall be considered in relation to the following:

a) Water, either by intermittent immersion or road spray,
b) Salt, due to the operation of the vehicle near the ocean or where ice-melting salt is used,
c) Ultra-violet radiation from sunlight,
d) Impact of gravel,
e) Solvents, acids and alkalis, fertilisers,
f) Automotive fluids, including gasoline, hydraulic fluids, battery acid, glycol and oils,
g) Exhaust gases.

2.4.4. Gas Composition

Compressed hydrogen gas shall comply with, or be of greater purity than, the Type 1, Grade A gas composition specified in **ISO 14687:1999/Cor1: 2001 Hydrogen Fuel – Product Specification.**

2.4.5. Temperatures

2.4.5.1. Material temperatures

The normal operating temperature range for materials used in *hydrogen components* shall be –40 °C to +85 °C except for:

a) *Hydrogen components* situated in an internal combustion engine compartment for which the temperature range shall be –40 °C to +105 °C,
b) *Hydrogen components* either installed on an internal combustion engine, or directly exposed to the operating temperature of an internal combustion engine, for which the temperature range shall be –40 °C to +120 °C.

2.4.5.2. Gas Temperatures

The average gas temperature shall be between –40 °C to +85 °C in normal conditions including filling or discharging.

2.4.6. *Filling cycles*

This paragraph is only applicable to Class 0 *hydrogen components*.

2.4.6.1. General

The number of *filling cycles* for the *hydrogen components* approved in accordance with this Regulation shall be 5,000 cycles except as permitted in **paragraphs 2.4.6.2. and 2.4.6.3.** of this Regulation.

2.4.6.2. Extended number of *filling cycles*

The vehicle manufacturer may specify an extended number of *filling cycles* for the *hydrogen components* based on the design lifetime mileage of the vehicle and range with maximum fuel capacity, but shall not be less than 5,000 cycles, i.e.:

Design lifetime mileage of the vehicle, L
Range with maximum fuel capacity, R
Number of *filling cycles* = L/R, but not less than 5,000

2.4.6.3. Reduced Number of *Filling Cycles*

Provided that a *usage monitoring and control system* is installed as part of the *hydrogen system,* the number of *filling cycles* for *hydrogen components* approved in accordance with this Regulation shall be specified by the vehicle manufacturer and may be less than 5,000 cycles and may vary with different applications based on the design lifetime mileage of the vehicle and range with maximum fuel capacity. The *usage monitoring and control system* shall prevent any further use of the vehicle when the specified number of *filling cycles* is exceeded, until the *hydrogen components* that have exceeded that value are replaced with new *hydrogen components*.

The safety concept of the *usage monitoring and control system* shall be approved in accordance with **annex 9** of this Regulation.

2.4.7. *Duty cycles*

2.4.7.1. General

The number of *duty cycles* for *hydrogen components* approved in accordance with this Regulation shall be 50,000 cycles except as permitted in **paragraph 2.4.7.2.** of this Regulation.

2.4.7.2. Reduced or extended number of *duty cycles*

The vehicle manufacturer may specify a reduced or extended number of *duty cycles* for each *hydrogen component* based on the design lifetime mileage of the vehicle divided by 20, i.e.:

Design lifetime mileage of the vehicle, l (km)
Number of *duty cycles* = l(km)/20.

PART I: SPECIFIC COMPONENTS OF MOTOR VEHICLES USING COMPRESSED GASEOUS HYDROGEN

3. APPLICATION FOR APPROVAL

3.1. The application for approval of a *specific component* or *multifunctional component* shall be submitted by the holder of the trade name or mark or by his duly accredited representative.

3.2. The application for type approval shall be accompanied by the following documents in triplicate:

a) a detailed description of the type of the *specific component* according to **annex 1** to this Regulation,
b) A drawing of the *specific component* sufficiently detailed and on an appropriate scale with a list of parts including material data and intended operating mode,
c) Verification of compliance with the specifications prescribed in **paragraph 6.** of this Regulation.

3.3. At the request of the Technical Service responsible for conducting approval tests, two samples of the *specific component* shall be provided unless otherwise stated in this Regulation.

3.4. The competent authority shall verify the existence of satisfactory arrangements for ensuring effective control of conformity of production before type approval is granted.

4 MARKINGS

4.1. The samples of the *specific component* submitted for approval shall bear the trade name or mark of the *manufacturer* and the type; and in addition for *flexible fuel lines* the manufacturing month and year. The marking shall be legible and indelible.

4.2. All *specific components* shall have a space large enough to accommodate the approval mark. This space shall be shown on the drawings referred to **in paragraph 3.2. b)** of this Regulation.

5. APPROVAL

5.1. If the *specific component* samples submitted for approval meet the relevant requirements of **paragraph 6**. of this Regulation, approval of the type of *specific component* shall be granted.

5.2. An approval number shall be assigned to each type of *specific component* type approved. Its first two digits shall indicate the series of amendments to this Regulation incorporating the most recent major technical amendments made at the time of granting

the approval (00 for the Regulation in its original form). The same Contracting Party shall not assign the allocated code to another type of *specific component*.

5.3. Notice of approval or of refusal or of extension of approval of a *specific component* in accordance with this Regulation shall be communicated to the Contracting Parties to the Agreement applying this Regulation by the Administrative Department by means of a form conforming to the model in **annex 4** to this Regulation.

5.4. In addition to the markings prescribed in **paragraph 4.1.** of this Regulation and for *containers* in **annex 7** to this Regulation, there shall be affixed conspicuously in the space referred to in **paragraph 4.2.** of this Regulation, to all *specific components* conforming to a type approved under this Regulation, an international approval mark consisting of:

a) A circle surrounding the letter "E“ followed by the distinguishing number of the country that has granted approval (see note 2/ below).

b) The number of this Regulation, followed by the letter "R", a dash and the approval number to the right of the circle prescribed in **a)** above. This approval number consists of the *specific component* type approval number that appears on the certificate completed for this type (see **paragraph 5.2.** of this Regulation and **annex 4** to this Regulation) proceeded by two figures indicating the sequence of the latest series of amendments to this Regulation.

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

5.6. **Annex 3** to this Regulation gives an example of the arrangement of the aforesaid approval mark.

2/ 1 for Germany, 2 for France, 3 for Italy, 4 for the Netherlands, 5 for Sweden, 6 for Belgium, 7 for Hungary, 8 for the Czech Republic, 9 for Spain, 10 for Yugoslavia, 11 for the United Kingdom, 12 for Austria, 13 for Luxembourg, 14 for Switzerland, 15 (vacant), 16 for Norway, 17 for Finland, 18 for Denmark, 19 for Romania, 20 for Poland, 21 for Portugal, 22 for the Russian Federation, 23 for Greece, 24 for Ireland, 25 for Croatia, 26 for Slovenia, 27 for Slovakia, 28 for Belarus, 29 for Estonia, 30 (vacant), 31 for Bosnia and Herzegovina, 32 for Latvia, 33 (vacant), 34 for Bulgaria, 35-36 (vacant), 37 for Turkey, 38-39 (vacant), 40 for The former Yugoslav Republic of Macedonia, 41 (vacant), 42 for the European Community (Approvals are granted by its Member States using their respective ECE symbol), 43 for Japan, 44 (vacant), 45 for Australia and 46 for Ukraine. Subsequent numbers shall be assigned to other countries in the chronological order in which they ratify or accede to the Agreement Concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these Prescriptions, and the numbers thus assigned shall be communicated by the Secretary-General of the United Nations to the Contracting Parties to the Agreement.

6. SPECIFICATIONS FOR HYDROGEN COMPONENTS

6.1. GENERAL PROVISIONS

6.1.1. The *hydrogen components* shall function in a correct and safe way as specified in this Regulation. They shall remain functional under the mechanical, thermal and chemical service conditions specified in **paragraph 2.4.** of this Regulation, and shall also reliably withstand these conditions without leaking or visibly deforming.

6.1.2. The materials of components which are in contact with hydrogen shall be compatible with hydrogen and expected additives and production contaminants.

6.1.3. Material compatibility with the service conditions defined in **paragraph 2.4.** of this Regulation shall be demonstrated either by the material tests in **annexes 7 and 8** to this Regulation, or by a previously approved test certificate.

6.1.4. All *hydrogen components* that are designed for uni-directional flow shall have the flow direction clearly indicated.

6.1.5. *Specific components* shall be type approved in accordance with the relevant electromagnetic compatibility requirements of Regulation No. 10, 02 series of amendments, or equivalent.

6.1.6. *Specific components* where used in the *hydrogen system* include:

a) Class 0 components. These components where used may include:
Automatic valve,
Container,
Container assembly,
Fittings,
Flexible fuel line,
Heat exchanger,
Hydrogen filter,
Manual valve,
Non-return valve,
Pressure regulator,
Pressure relief device,
Pressure relief valve,
Receptacle.
Removable storage system connector,
Sensors (pressure or temperature or hydrogen or flow sensors) if used as a *safety device*.

b) The *usage monitoring and control system* referred to in **paragraph 2.4.6.3.** of this Regulation,

c) The vehicle interface system defined in **paragraph 14.3.9.** of this Regulation,

d) The *excess flow system* defined in **paragraph 14.1.16**. of this Regulation,

e) The overpressure protection system, e.g. *pressure relief valve*, defined in **paragraph 14.1.18.** of this Regulation,

f) The heat exchanger failure detection system defined in **paragraph 14.1.19.** of this Regulation

6.1.7. The functions of *specific components* may be combined or fitted together with other *specific components* or *hydrogen components* as *a multifunctional component*, but for the purposes of this Regulation will be classified as a *specific component*. A *multifunctional component* shall be type approved in accordance with the requirements for the *specific components* that it combines.

6.1.8. Welded fittings or connections shall be described in a production process for each individual type of welding. Welded connections upstream of the *first pressure regulator* shall be hydraulically pressure tested to three times *nominal working pressure* without rupturing. Welded connections downstream of the *first pressure regulator* shall be hydraulically pressure tested to three times *maximum allowable working pressure* without rupturing.

6.1.9. Unless indicated otherwise, the requirements of this Regulation and its annexes shall take precedence over any standards referred to herein.

6.1.10. The documentation and test reports shall be sufficiently detailed to enable an independent third party test facility to reproduce the appropriate type approval tests and test results.

6.2. PROVISIONS REGARDING CONTAINERS

6.2.1. *Containers* of Types 1 to 4 as defined in **paragraph 2.2**. of this Regulation, shall be type approved pursuant to the provisions laid down in **annex 7** to this Regulation.

6.2.2. The shape of a *container* is free provided that it fulfils all the appropriate provisions laid down in **annex 7** to this Regulation.

6.2.3. *Container assembly*

6.2.3.1. A *container assembly* shall be approved as one *container* if both the *container assembly* and constituent containers are approved in accordance with the provisions laid down in **annex 7** to this Regulation.

6.2.3.2. Alternatively a *container assembly* shall be approved as one *container* if the *container assembly* fulfils the provisions laid down in **annex 7** to this Regulation. The constituent *containers* need not fulfil all the provisions laid down in **annex 7** to this Regulation provided that the *container assembly* fulfils all the provisions of annex 7.

6.2.3.3. For all types of *container*, the *container assembly* shall fulfil the requirements of **paragraphs B12, B18 and B19** of **annex 7** to this Regulation. The *container assembly* shall be encased inside a protective housing shell.

6.2.3.4. A maximum of four *containers* per *container assembly* shall be permitted.

6.2.3.5. *Flexible fuel lines* shall not be used as integral interconnecting fuel lines in a *container assembly*.

6.3. PROVISIONS REGARDING SPECIFIC COMPONENTS OTHER THAN CONTAINERS OR CONTAINER ASSEMBLIES

6.3.1. *Specific components* other than *containers* or *container assemblies* shall be type approved according to **annex 8** to this Regulation.

6.3.2. Unless otherwise stated in this Regulation, the parts of a *removable storage system connector* mounted on the *removable storage system* and on the vehicle shall be treated as separate components.

6.4. PROVISIONS REGARDING RIGID FUEL LINES

Rigid fuel lines upstream of the *first pressure regulator* shall be bent through 180° at the minimum bending radius specified by the *manufacturer* and shall then be hydraulically pressure tested to three times *nominal working pressure* without rupturing. *Rigid fuel lines*, downstream of the *first pressure regulator* shall be bent through 180° at the minimum bending radius specified by the *manufacturer* and shall then be hydraulically pressure tested to three times MAWP without rupturing.

6.5. PROVISIONS REGARDING ELECTRICAL COMPONENTS

Electrical components of equipment in contact with hydrogen shall:

6.5.1. be insulated in such a manner that no current passes through hydrogen containing parts,

6.5.2. have the electrical system of the device insulated from the:
a) body of the component,
b) *container* or *container assembly*.

7. MODIFICATIONS OF A TYPE OF A SPECIFIC COMPONENT AND EXTENSION OF APPROVAL

7.1. Every modification of a *specific component* shall be notified to the Administrative Department that granted the type approval. The Administrative Department may then either:

7.1.1. Consider that the modifications made are unlikely to have an appreciably adverse effect, and that the component still meets the requirements of this Regulation; or

7.1.2. Require a further report from the Technical Service responsible for carrying out the tests. modifications of *containers* require approval testing as specified in **paragraph A7 of annex 7** to this Regulation.

7.2. Notice of confirmation, extension or refusal of approval shall be communicated by the procedure specified in **paragraph 5.3.** of this Regulation to the Contracting Parties to the Agreement that apply this Regulation.

7.3. The competent authority issuing the extension of approval shall assign a series number to each communication form (specified in **paragraph 5.3.** of this Regulation) issued for such an extension, and shall inform the other Contracting Parties to the Agreement with a form conforming to the model in **annex 4** to this Regulation.

8. CONFORMITY OF PRODUCTION

The conformity of production procedures shall comply with those set out in the Agreement, Appendix 2 (E/ECE/324-E/ECE/TRANS/505/Rev.2) and with the following requirements:

8.1. A *hydrogen component* type approved according to this Regulation shall be manufactured so as to conform to the type approved by meeting the requirements specified in **paragraph 6.** of this Regulation.

8.2. The approval authority that has granted type approval may at any time verify the conformity control methods applied in each production facility. The normal frequency of these verifications shall be once every two years.

9. PENALTIES FOR NON-CONFORMITY OF PRODUCTION

9.1. The approval granted in respect of a *specific component* in accordance with this Regulation may be withdrawn if the requirements laid down in **paragraph 8.** of this Regulation are not complied with.

9.2. If a Contracting Party to the Agreement that applies this Regulation withdraws an approval it has previously granted, it shall immediately notify the other Contracting Parties applying this Regulation by means of a communication form conforming to the model in **annex 4** to this Regulation.

10. PRODUCTION DEFINITELY DISCONTINUED

If the holder of the approval for a *specific component* type approved in accordance with this Regulation, permanently ceases to manufacture the component, he shall immediately inform the authority which granted the approval. Upon receiving the relevant communication, that authority shall inform the other Contracting Parties to the Agreement applying this Regulation of that communication, by means of a communication form conforming to the model in **annex 4** to this Regulation.

11. NAMES AND ADDRESSES OF TECHNICAL SERVICES RESPONSIBLE FOR CONDUCTING APPROVAL TESTS AND OF ADMINISTRATIVE DEPARTMENTS

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 Administrative Departments which grant approval and to which forms certifying approval or extension or refusal or withdrawal of approval issued in other countries, are to be sent.

PART II: VEHICLES WITH REGARD TO THE INSTALLATION OF SPECIFIC COMPONENTS FOR THE USE OF COMPRESSED GASEOUS HYDROGEN

12. APPLICATION FOR APPROVAL

12.1. The application for *approval of a vehicle type* with regard to the installation of *specific components* for the use of compressed gaseous hydrogen shall be submitted by the vehicle manufacturer or by his duly accredited representative.

12.2. The application shall be accompanied by a description of the vehicle comprising all the relevant particulars referred to in **annex 2** to this Regulation in triplicate.

12.3. A vehicle, representative of the *vehicle type* to be type approved, shall be submitted to the Technical Service conducting the approval tests.

12.4. The competent authority shall verify the existence of satisfactory arrangements for ensuring effective control of conformity of production before type approval is granted.

13. APPROVAL

13.1. If the vehicle submitted for type approval pursuant to this Regulation is fitted with *specific components* in accordance with **Part I** of this Regulation and meets the requirements of **Part II** of this Regulation, approval of that *vehicle type* shall be granted.

13.2. An approval number shall be assigned to each *vehicle type* approved. Its first two digits shall indicate the series of amendments to this Regulation incorporating the most recent major technical amendments made at the time of granting the approval (00 for the Regulation in its original form). The same Contracting Party shall not assign the approval number to another *vehicle type*.

13.3. Notice of approval or of refusal or of extension of *approval of a vehicle type* in accordance with this Regulation shall be communicated to the Contracting Parties to the Agreement applying this Regulation by means of a form conforming to the model in **annex 6** to this Regulation.

13.4. There shall be affixed to every *vehicle type* approved under this Regulation, conspicuously and in a readily accessible space specified on the approval form referred to in **paragraph 13.3.** of this Regulation, an international approval mark consisting of:

13.4.1. A circle surrounding the letter "E“ followed by the distinguishing number of the country that has granted approval (see footnote 3/ below).

13.4.2. The number of this Regulation, followed by the letter "R", a dash and the approval number to the right of the circle prescribed in **paragraph 13.4.1.** above. This approval number consists of the *vehicle type* approval number that appears on the certificate completed for this type (see **paragraphs 13.2. and 13.3.** of this Regulation and **annex 6** to this Regulation).

13.5. 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 13.4.1.** of this Regulation need not be repeated. In such a case, the Regulation and approval numbers and the additional symbols of all the Regulations under which approval has been granted in the country that has granted approval under this Regulation shall be placed in vertical columns to the right of the symbol prescribed in **paragraph 13.4.1.** of this Regulation.

13.6. The type approval mark shall be clearly legible and be indelible.

13.7. The type approval mark shall be placed close to or on the statutory plate of the vehicle.

13.8. **Annex 5** to this Regulation gives examples of the arrangement of the type approval mark referred to above.

3/ 1 for Germany, 2 for France, 3 for Italy, 4 for the Netherlands, 5 for Sweden, 6 for Belgium, 7 for Hungary, 8 for the Czech Republic, 9 for Spain, 10 for Yugoslavia, 11 for the United Kingdom, 12 for Austria, 13 for Luxembourg, 14 for Switzerland, 15 (vacant), 16 for Norway, 17 for Finland, 18 for Denmark, 19 for Romania, 20 for Poland, 21 for Portugal, 22 for the Russian Federation, 23 for Greece, 24 for Ireland, 25 for Croatia, 26 for Slovenia, 27 for Slovakia, 28 for Belarus, 29 for Estonia, 30 (vacant), 31 for Bosnia and Herzegovina, 32 for Latvia, 33 (vacant), 34 for Bulgaria, 35-36 (vacant), 37 for Turkey, 38-39 (vacant), 40 for The former Yugoslav Republic of Macedonia, 41 (vacant), 42 for the European Community (Approvals are granted by its Member States using their respective ECE symbol), 43 for Japan, 44 (vacant), 45 for Australia and 46 for Ukraine. Subsequent numbers shall be assigned to other countries in the chronological order in which they ratify or accede to the Agreement Concerning the Adoption of Uniform Technical Prescriptions for Wheeled Vehicles, Equipment and Parts which can be Fitted and/or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these Prescriptions, and the numbers thus assigned shall be communicated by the Secretary-General of the United Nations to the Contracting Parties to the Agreement.

14. REQUIREMENTS FOR THE INSTALLATION OF SPECIFIC COMPONENTS FOR THE USE OF COMPRESSED GASEOUS HYDROGEN WITHIN MOTOR VEHICLES

14.1. GENERAL

14.1.1. 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 specified in **paragraph 2.4.** of this Regulation without leaking or visibly deforming. The number of *hydrogen components*, connections and the length of lines shall be kept to the minimum compatible with safety and the correct functioning of the *hydrogen system*.

14.1.2. *Specific components* of the *hydrogen system* shall be type approved pursuant to Part I of this Regulation.

14.1.3. The materials used in the *hydrogen system* shall be compatible with gaseous hydrogen and expected additives and production contaminants, and expected temperatures and pressures.

14.1.4. The temperature range shall be in accordance with **paragraph 2.4.5.** of this Regulation.

14.1.5. 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. This shall not apply if a *hydrogen component* is adequately protected and no part of the *hydrogen component* is located outside this protective structure.

14.1.6. The *hydrogen system* shall be installed such that it is protected against damage so far as is reasonably practical, such as damage due to moving vehicle components, impacts, grit or due to the loading or unloading of the vehicle or the shifting of loads. This paragraph also applies to *pressure relief device* vents.

14.1.7. No component of the *hydrogen system* shall be located near the exhaust of an internal combustion engine or other heat source, unless such components are adequately shielded against heat.

14.1.8. The ventilating or heating system for a passenger compartment and places where leakage or accumulation of hydrogen is possible shall be kept apart so that hydrogen is not drawn into the vehicle.

14.1.9. Reasonable precautions shall be taken to avoid failure of other circuits affecting the *hydrogen system*.

14.1.10. The *hydrogen system* shall be pressurized to *nominal working pressure* using *leak test gas* and tested for leakage with a surface active agent without formation of bubbles for three minutes, or by using a demonstrated equivalent method the permitted leakage rate is applicable to tests with 100 per cent hydrogen only. Permitted leakage rates for other gases or gas mixtures shall be converted to an equivalent leakage rate to that for 100 per cent hydrogen.

14.1.11. In the event of hydrogen leakage or venting, hydrogen shall not be allowed to accumulate in enclosed or semi-enclosed spaces.

14.1.12. *Hydrogen components* that could leak hydrogen and that are mounted within the passenger or luggage compartment or other non-ventilated compartment shall be enclosed by a gas tight housing in accordance with **paragraph 14.10.** of this Regulation or by an equivalent solution.

14.1.13. The location of the *container* or *container assembly* shall take into account possible sources of corrosion, e.g. due to road de-icing salt, leakage of acid batteries.

14.1.14. A minimum overpressure of 0.2 MPa shall be maintained in the *container* or *container assembly* at ambient temperature.

14.1.15. All *pressure relief devices*, other safety components and vent lines shall be protected against unauthorised interference so far as is reasonably practicable.

14.1.16. An *excess flow system* shall be part of the *hydrogen system*.

14.1.17. *Automatic valves* shall fail to the safest mode of operation for the particular application, i.e. fail-safe.

14.1.18. 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 a *pressure relief valve* shall be:

14.1.18.1. lower than or equal to the mawp for the appropriate section of the *hydrogen system*,

14.1.18.2. higher than or equal to 1.3 times the *nominal working pressure* for the appropriate section of the *hydrogen system.*

14.1.19. A system shall be provided to detect failure in either circuit of a heat exchanger and prevent hydrogen from entering the other circuit(s), if the interface(s) is not able to withstand loss of pressure in either circuit.

14.2. INSTALLATION OF A CONTAINER ON-BOARD A VEHICLE

14.2.1. A *container* or *container assembly* shall be permanently installed on-board the vehicle and shall only be removed for maintenance. A *container* or *container assembly* shall not be installed in the internal combustion engine compartment.

14.2.2. Notwithstanding the provisions of **paragraph 14.2.1.** of this Regulation, a *removable storage system* may be removed from the vehicle for refilling. The *container(s)* or *container assembly* and the *hydrogen components* forming the *removable storage system* shall be permanently installed within the *removable storage system.*

14.2.3. A *container* or *container assembly* can fulfil integrated functions of the vehicle. A *container* or *container assembly* shall be designed to fulfil the integrated function requirements plus the *container* requirements.

14.2.4. A *container* or *container assembly* including *safety devices* shall be mounted and fixed so that the following accelerations can be absorbed (without degrading the function of *safety devices*) when the *container* or *container assembly* is full. No uncontrolled release of hydrogen is permitted.

Vehicles of categories M1 and N1:
a) +/-20 g in the direction of travel
b) +/-8 g horizontally perpendicular to the direction of travel

Vehicles of categories M2 and N2:
a) +/-10 g in the direction of travel
b) +/-5 g horizontally perpendicular to the direction of travel

Vehicles of categories M3 and N3:
a) +/-6.6 g in the direction of travel
b) +/-5 g horizontally perpendicular to the direction of travel

A calculation method can be used instead of practical testing if its equivalence can be demonstrated by the applicant for approval to the satisfaction of the technical service.

14.2.5. The provision of **paragraph 14.2.4.** shall not apply if the vehicle is approved according to Regulations Nos. 94 and 95, nonetheless, no uncontrolled release of hydrogen is permitted.

14.2.6. *Pressure relief device(s)* in accordance with **paragraph 14.5.** of this Regulation shall form the fire protection system for a *container* or *container assembly* to prevent rupture. Thermal insulation or other protective measures shall not influence the response and performance of the *pressure relief device(s).*

14.2.7. A *container* or *container assembly* with non-metallic *liner(s)* shall not be installed inside the vehicle unless integrated into a system which ensures that permeated hydrogen will be vented outside the vehicle, e.g. it is installed inside a gas tight housing in accordance with **paragraph 14.10.** of this Regulation.

14.3. REMOVABLE STORAGE SYSTEM

14.3.1. The components of a *hydrogen system* within a *removable storage system* shall fulfil all the requirements of this Regulation as if it were permanently installed in the vehicle unless otherwise stated below.

14.3.2. A *removable storage system* shall protect the *container(s)* or *container assembly* and *hydrogen components* forming the *removable storage system* from damage during the handling operations necessary for installation, removal, storage and handling. The *manufacturer* shall demonstrate that reasonable measures have been taken to the satisfaction of the Technical Service in charge of approval.

14.3.3. Effective measures shall be taken to prevent unauthorised removal of the *removable storage system.*

14.3.4. A single interface for the flow of hydrogen shall be provided between the *removable storage system* and the part of the *hydrogen system* permanently installed in the vehicle. The *nominal working pressure* of the *hydrogen system* at the interface shall be less than or equal to 3.0 MPa*.*

14.3.5. When the *removable storage system* is installed in the vehicle the connection with the part of the *hydrogen system* permanently installed in the vehicle shall be made without the use of tools and shall be capable of fulfilling the requirements of **paragraphs 14.1.10. and 14.2.4.** of this Regulation.

14.3.6. At the time of disconnection of the *removable storage system*, the volume of hydrogen released shall not exceed 200 Ncm^3 and shall not be released near a possible ignition source. The build up of hydrogen due to successive disconnections shall be prevented.

14.3.7. The part of the *removable storage system connector* permanently fitted to the vehicle shall be of a unique design for the applicable vehicle type and shall not be compatible with standard refilling nozzles for either hydrogen or other gaseous fuels.

14.3.8. The flow of hydrogen from a *removable storage system* shall be prevented if a *removable storage system* is installed with a higher *maximum allowable working pressure* than that of the permanent part of the vehicle's *hydrogen system.*

14.3.9. Opening of the *automatic valve(s)* mounted on a *container(s)* or a *container assembly* shall not be possible when the *removable storage system* is not correctly connected to the permanently fixed section of the vehicle's *hydrogen system*. A vehicle interface

system shall verify that a correct connection between the *removable container system* and the vehicle is established before permitting the *automatic valve(s)* to open. The vehicle interface system shall also verify that the *removable storage system* is compatible with the vehicle's *hydrogen system* before permitting the *automatic valve(s)* to open.

14.3.10. Disconnection or removal of the *removable storage system* shall not be possible unless the *automatic valve* mounted on a *container(s)* or a *container assembly* is in the closed position and no combustion sources are in operation, for example, heaters on the vehicle.

14.3.11. Use of the *hydrogen system* shall be prevented if a partial or total failure of the *removable storage system connector* or electrical connectors between the *removable storage system* and the vehicle occurs, that may affect the safety of the *hydrogen system*.

14.3.12. The installation and removal operations for the *removable storage system* shall be illustrated on a label attached to the vehicle close to the mounting point of the *removable storage system*. The label shall also state the *nominal working pressure* of the container(s) or *container assembly* and the *removable storage system connector.*

14.3.13. A label shall be attached to the *removable storage system* stating the *nominal working pressure* of the container(s) or *container assembly* and the *removable storage system connector.*

14.3.14. The vehicle type approval mark specified in **paragraph 13.4.** of this Regulation shall be reproduced on the *removable storage system*.

14.4. AUTOMATIC VALVE(S) OR NON-RETURN VALVE(S) FOR ISOLATING A CONTAINER OR CONTAINER ASSEMBLY

14.4.1. The flow of hydrogen from a *container* or *container assembly* into the *fuel supply line* shall be secured with an *automatic valve* (idle closed). This valve shall be mounted directly on or within either every *container* or one *container* in a *container assembly*.

14.4.2. The *receptacle* shall be integrated with a *non-return valve*. If the *receptacle* is not mounted directly on either the *container* or one *container* in a *container assembly*, the refilling line shall be secured by a *non-return valve* or an *automatic valve* integrating the function of a *non-return valve.* This valve shall be mounted directly on either the *container* or one *container* in a *container assembly*.

14.4.3. If a single line is used into the *container* or *container assembly* for both refilling and fuel supply, it shall be secured as described in **paragraph 14.4.2.** of this Regulation on the refilling line at the junction between the refilling line and the *fuel supply line*.

14.4.4. In the event of breakage of the refilling lines or *fuel supply line(s)*, the isolating valves referred to in **paragraphs 14.4.1. and 14.4.2.** of this Regulation shall not be separated from the *container* or *container assembly*.

14.4.5. *Automatic valve(s)* isolating each *container* or *container assembly*, shall close in the event of either a malfunction of the *hydrogen system* that results in the release of hydrogen or severe leakage between the *container* or *container assembly* and the *hydrogen conversion system(s)*.

14.4.6. The *automatic valve* for the *fuel supply line* of the *propulsion system* shall be operated such that the hydrogen supply to the *propulsion system* is cut off when the *propulsion system* is switched off, irrespective of the position of the activation switch, and shall remain so until the *propulsion system* is required to operate.

14.4.7. The *automatic valve* for the *fuel supply line* of other *hydrogen conversion system(s)* shall be operated such that the hydrogen supply to other *hydrogen conversion system(s)* is cut off when the respective *hydrogen conversion system* is switched off, irrespective of the position of the activation switch, and shall remain so until the *hydrogen conversion system* is required to operate.

14.5. PRESSURE RELIEF DEVICE(S)

14.5.1. A *pressure relief device* shall be directly 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*, in such a manner that it shall discharge the hydrogen into an atmospheric outlet that vents to the outside of the vehicle.

14.5.2. It shall not be possible to isolate the *pressure relief device* from *container* protected by the *pressure relief device*, by the normal operation or failure of another component.

14.5.3. The vent of a *pressure relief device* shall not discharge into a wheel arch, nor shall it be aimed at a heat source such as the exhaust or at other *containers* or *container assemblies* if fitted. Additionally it shall discharge such that hydrogen cannot enter the inside of the vehicle.

14.5.4. The internal dimensions of the vent shall not impede the function of the *pressure relief device*.

14.5.5. The vent of the *pressure relief device* shall be protected against blockage, e.g. by dirt, ice, and ingress of water etc., so far as is reasonably practicable.

14.5.6. The outlet of the *pressure relief device* shall be orientated such that if the vent becomes detached from the *pressure relief device*, the resulting gas flow does not impinge directly on other *containers* or *container assemblies* unless they are protected.

14.6. PRESSURE RELIEF VALVE(S)

14.6.1. A *pressure relief valve* shall be installed in such a manner that it shall discharge the hydrogen into an atmospheric outlet that vents to the outside of the vehicle.

14.6.2. It shall not be possible to isolate the *pressure relief valve* from the *hydrogen components* or section of the *hydrogen system* that it protects, by the normal operation or failure of another component.

14.6.3. The vent of a *pressure relief valve* shall not discharge into a wheel arch, nor shall it be aimed at a heat source such as the exhaust or at any *container* or *container assembly*. Additionally it shall discharge such that hydrogen cannot enter the inside of the vehicle.

14.6.4. The vent of the *pressure relief valve* shall be protected against blockage, e.g. by dirt, ice, and ingress of water etc., so far as is reasonably practicable.

14.7. RIGID AND FLEXIBLE FUEL LINES

14.7.1. *Rigid fuel lines* shall be secured such that they shall not be subjected to critical vibration or other stresses.

14.7.2. *Flexible fuel lines* shall be secured such that they shall not be subjected to torsional stresses and abrasion is avoided.

14.7.3. *Rigid fuel lines* and *flexible fuel lines* shall be designed to reasonably minimise stresses in the lines during removal or installation of adjoining *hydrogen components*.

14.7.4. At fixing points, *rigid fuel lines* and *flexible fuel lines* shall be fitted in such a way that galvanic and crevice corrosion are prevented.

14.7.5. *Rigid fuel lines* and *flexible fuel lines* shall be routed to reasonably minimise exposure to accidental damage whether inside the vehicle, e.g. due to placing or movement of luggage or other loads, or outside the vehicle, e.g. due to rough ground or vehicle jacks, etc.

14.7.6. At passages through the vehicle body or other *hydrogen components*, the fuel lines shall be fitted with grommets or other protective material.

14.7.7. If *fittings* are installed in the passenger or enclosed luggage compartment, the fuel lines and *fittings* shall be enclosed in a sleeve which meets the same requirements as specified for a gas tight housing in **paragraph 14.10.** of this Regulation.

14.7.8. Class 0 metallic *rigid fuel lines* shall be seamless and shall elongate by at least 14 per cent before rupture.

14.8. FITTINGS BETWEEN HYDROGEN COMPONENTS

14.8.1. The material used in *fittings* shall be chosen in such a way that galvanice and crevice corrosion are prevented.

14.8.2. The number of joints shall be limited to a minimum.

14.8.3. Any joints shall be made in locations where access is possible for inspection and also for leak testing.

14.9. REFILLING SYSTEM

14.9.1. 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.

14.9.2. The *receptacle* shall be installed such that access for refilling shall not be required in the passenger, luggage, or in any other unventilated compartment.

14.9.3. The *receptacle* shall not be mounted within the external energy absorbing elements, e.g. bumper.

14.9.4. The *nominal working pressure* of the *receptacle* shall be equal to the *nominal working pressure* of the Class 0 *hydrogen components* upstream of and including the *first pressure regulator*.

14.9.5. It shall be ensured that the *propulsion system* or *hydrogen conversion system(s)* excluding *safety devices* are not operating and that the vehicle is immobilised while the *receptacle* is connected to the refilling infrastructure.

14.9.6. A label shall be provided close to the *receptacle*, for example, inside a refilling hatch, showing the following information:

H_2 gas
"xx" MPa

Where "xx" = *nominal working pressure* of the *container(s)*.

14.10. GAS TIGHT HOUSING

14.10.1. The gas tight housing shall be vented to the atmosphere.

14.10.2. The ventilation opening of the gas tight housing shall be at the highest point of the housing when installed in the vehicle. It shall not ventilate into a wheel arch, nor shall it

be aimed at a heat source such as the exhaust. Additionally it shall vent such that hydrogen cannot enter the inside of the vehicle.

14.10.3. The electrical connections and components in the gas tight housing shall be constructed such that no sparks are generated.

14.10.4. During testing the vent line shall be hermetically sealed and the gas tight housing shall then meet the leakage requirements of **paragraph 14.1.10.** of this Regulation at an over pressure of 0.01 MPa and without any permanent deformations.

14.10.5. Any connecting system shall be secured by clamps, or other means, to the gas tight housing or sleeve and the lead-through to ensure that a joint is formed meeting the leakage requirements of **paragraph 14.10.4.** of this Regulation.

14.11. ELECTRICAL INSTALLATION

14.11.1. The electrical components of the *hydrogen system* shall be protected against overloads.

14.11.2. The metallic components of the *hydrogen system* shall have electrical continuity with the vehicle's earth, e.g. chassis.

14.11.3. During the refilling process the *hydrogen system* shall have the means to provide electrical continuity with the refilling facilities before hydrogen transfer is permitted.

14.11.4. Power supply connections shall not permit the ingress of hydrogen where *hydrogen components* are present or hydrogen leaks are possible.

14.12. SAFETY INSTRUMENTED SYSTEMS

14.12.1. *Safety instrumented systems* shall be fail-safe or redundant.

14.12.2. If *safety instrumented systems* are fail-safe or self-monitoring electronic systems, the special requirements according to **annex 9** to this Regulation are to be applied.

14.13. INFORMATION FOR PERIODIC REQUALIFICATION

The vehicle manufacturer shall provide information for periodic requalification by inspection during the *service life* on the basis of use under the service conditions specified in **paragraph 2.4.** of this Regulation. The information shall include the following items:

a) Frequency of the periodic requalification inspection,
b) Check of the mandatory markings on the *container*, *container assembly*, or *removable storage system* (as applicable).
c) Visual inspection of the *container* or *container assembly*,

d) Inspection of the *pressure relief device(s), pressure relief valve(s)*, and associated vents,
e) Inspection of the *automatic valve(s)*,
f) Inspection of other *hydrogen components* directly mounted on the *container* or *container assembly* and other safety related components,
g) Check of the gas tightness of the *hydrogen system*.

14.14. IDENTIFICATION OF VEHICLES OF CATEGORIES M2 AND M3 EQUIPPED WITH A HYDROGEN SYSTEM

14.14.1. Vehicles of categories M2 and M3 equipped with a *hydrogen system* shall carry a label as specified in **annex 10** to this Regulation.

14.14.2. The label shall be installed on the front and rear of the vehicle and one to the side of each set of doors.

15. MODIFICATION OF A VEHICLE TYPE OR HYDROGEN SYSTEM AND EXTENSION OF APPROVAL

15.1. Every modification of the *vehicle type* or of its installation of *specific components* for the use of hydrogen shall be notified to the Administrative Department that granted approval of the *vehicle type*. The Administrative Department may then either:

15.1.1. Consider that the modifications made are unlikely to have an appreciably adverse effect, and that the vehicle still complies with the requirements of this Regulation; or

15.1.2. Require a further report from the Technical Service responsible for carrying out the tests.

15.2. Notice of confirmation, extension or refusal of approval shall be communicated by the procedure specified in **paragraph 13.3**. of this Regulation to the Contracting Parties to the Agreement that apply this Regulation.

15.3. The competent authority issuing the extension of approval shall assign a series number to each communication form (specified in **paragraph 13.3.** of this Regulation) issued for such an extension.

16. CONFORMITY OF PRODUCTION

The conformity of production procedures shall comply with those set out in the Agreement, Appendix 2 (E/ECE/324- E/ECE/TRANS/505/rev.2) and with the following requirements:

16.1. A *vehicle type,* type approved according to this Regulation shall be manufactured so as to conform to the type approved by meeting the requirements specified in **paragraph 14.** of this Regulation.

16.2. The approval authority that has granted type approval may at any time verify the conformity control methods applied in each production facility. The normal frequency of these verifications shall be once every two years.

17. PENALTIES FOR NON-CONFORMITY OF PRODUCTION

17.1. The type approval granted in respect of a *vehicle type* in accordance with this Regulation may be withdrawn if the requirements laid down in **paragraph 16.** of this Regulation are not complied with.

17.2. If a Contracting Party to the Agreement that applies this Regulation withdraws an approval it has previously granted, it shall immediately notify the other Contracting Parties applying this Regulation by means of a communication form conforming to the model in **annex 6** to this Regulation.

18. PRODUCTION DEFINITELY DISCONTINUED

If the holder of the approval permanently ceases to manufacture a type of vehicle approved in accordance with this Regulation, he shall immediately inform the authority that granted the approval. Upon receiving the relevant communication, that authority shall inform the other Contracting Parties to the Agreement applying this Regulation, by means of a communication form conforming to the model in **annex 6** to this Regulation.

19. NAMES AND ADDRESSES OF TECHNICAL SERVICES RESPONSIBLE FOR CONDUCTING APPROVAL TESTS AND OF ADMINISTRATIVE DEPARTMENTS

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 Administrative Departments which grant approval and to which forms certifying approval or extension or refusal or withdrawal of approval issued in other countries, are to be sent.

Annex 1

ESSENTIAL CHARACTERISTICS OF SPECIFIC COMPONENTS

1. *Automatic valve*:
1.1. Make:
1.2. Type:
1.3. Description and drawings:
1.4. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
1.5. Material(s):
1.6. Number of *filling cycles* or *duty cycles* as appropriate:

2. *Non-return valve:*
2.1. Make:
2.2. Type:
2.3. Description and drawings:
2.4. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
2.5. Material(s):
2.6. Number of *filling cycles* or *duty cycles* as appropriate:

3. *Container* and *container assembly:*
A statement of service shall be provided in accordance with the requirements of **annex 7** to this Regulation.

4. *Fittings*:
4.1. Make:
4.2. Type:
4.3. Description and drawings:
4.4. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
4.5. Material(s):
4.6. Number of *filling cycles* or *duty cycles* as appropriate:

5. *Flexible fuel lines:* yes/no 1/
5.1. Make:
5.2. Type:
5.3. Description and drawings:
5.4. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
5.5. Material(s):
5.6. Number of *filling cycles* or duty cycles as appropriate:

6. Heat exchanger: yes/no 1/
6.1. Make:
6.2. Type:
6.3. Description and drawings:
6.4. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
6.5. Material(s):
6.6. Number of *filling cycles* or *duty cycles* as appropriate:

7. *Hydrogen filter:* yes/no 1/
7.1. Make:
7.2. Type:
7.3. Description and drawings:
7.4. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
7.5. Material(s):
7.6. Number of *filling cycles* or *duty cycles* as appropriate:

8. *Manual valve:* yes/no 1/
8.1. Make:
8.2. Type:
8.3. Description and drawings:
8.4. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
8.5. Material(s):
8.6. Number of *filling cycles* or *duty cycles* as appropriate:

9. Pressure or temperature or flow sensor 1/: yes/no 1/
9.1. Make:
9.2. Type:
9.3. Operating principles including description and drawings:
9.4. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
9.5. Material(s):
9.6. Number of *filling cycles* or duty cycles as appropriate:

10. *Pressure regulator:* yes/no 1/
10.1. Make:
10.2. Type:
10.3 Drawings:
10.4. Number of main adjustment points:
10.5. Description of principle of adjustment through main adjustment points:
10.6. Number of idle adjustment points:
10.7. Description of principles of adjustment through idle adjustment points:

10.8. Other adjustment possibilities: if so and which (description and drawings):
10.9. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
10.10. Number of *filling cycles* or *duty cycles* as appropriate:

11. *Pressure relief device*:
11.1. Make:
11.2. Type:
11.3. Description and drawings:
11.4. Normal maximum operating temperature: 2/ °C
(in accordance with **paragraph 2.4.5.** of this Regulation)
11.5. *Nominal working pressure(s)* 2/: MPa
11.6. Material:
11.7. Set (trigger) temperature: 2/
11.8. Number of *filling cycles* (Class 0 only):

12. *Pressure relief valve*: yes/no 1/
12.1. Make:
12.2. Type:
12.3. Description and drawings:
12.4. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
12.5. Material:
12.6. Set pressure: 2/
13.7. Number of *duty cycles*:

13. *Receptacle*:
13.1. Make:
13.2. Type:
13.3. Operating principles including description and drawings:
13.4. *Nominal working pressure* 2/: MPa
13.5. Material:
13.6. Number of *filling cycles* (Class 0 only):

14. *Removable storage system connector*:
14.1. Make:
14.2. Type:
14.3. Operating principles including description and drawings:
14.4. *Nominal working pressure(s)* and *maximum allowable working pressure(s)* 2/: MPa
14.5. Material:
14.6. Number of *duty cycles*:

1/ Strike out what does not apply.
2/ Specify the tolerance.

Annex 2

ESSENTIAL CHARACTERISTICS OF THE VEHICLE, HYDROGEN RELATED PROPULSION SYSTEM AND OTHER HYDROGEN RELATED SYSTEMS

0. Description of the *vehicle type*
0.1. Make:
0.2. Type(s):
0.3. Name and address of the vehicle manufacturer:

1. Description of the *hydrogen system* used for the propulsion of the vehicle 1/
1.1. Description of the *propulsion system*:
1.2. Name and address of the *manufacturer*:
1.3. *Manufacturer's propulsion system* code(s) (as marked on the *propulsion system*, or other means of identification):

1.4. *Automatic valve(s):*
1.4.1. Make(s):
1.4.2. Type(s):
1.4.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
1.4.4. Approval number:
1.4.5. Number of *filling cycles* or *duty cycles* as appropriate:

1.5. *Non-return valve(s):*
1.5.1. Make(s):
1.5.2. Type(s):
1.5.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
1.5.4. Approval number:
1.5.5. Number of *filling cycles* or duty cycles as appropriate:

1.6. *Container(s)* and *container assembly:*
1.6.1. Make(s):
1.6.2. Type(s):
1.6.3. Capacity: litres (water)
1.6.4. Approval number
1.6.5. *Nominal working pressure*: MPa
1.6.6. Number of *filling cycles*:

1.7. *Excess flow system*:
1.7.1. Make(s):
1.7.2. Type(s):

1.7.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa

1.8. *Fittings:*
1.8.1. Make(s):
1.8.2. Type(s):
1.8.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
1.8.4. Approval number:
1.8.5. Number of *filling cycles* or *duty cycles* as appropriate:

1.9. *Flexible fuel lines(s):* yes/no 1/
1.9.1. Make(s):
1.9.2. Type(s):
1.9.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
1.9.4. Approval number:
1.9.5. Number of *filling cycles* or *duty cycles* as appropriate:

1.10. Heat exchanger(s): yes/no 1/
1.10.1. Make(s):
1.10.2. Type(s):
1.10.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
1.10.4. Approval number:
1.10.5. Number of *filling cycles* or *duty cycles* as appropriate:

1.11. *Hydrogen filter(s):* yes/no 1/
1.11.1. Make(s):
1.11.2. Type(s):
1.11.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
1.11.4. Approval number:
1.11.5. Number of *filling cycles* or *duty cycles* as appropriate:

1.12. *Manual valve(s):* yes/no 1/
1.12.1. Make(s):
1.12.2. Type(s):
1.12.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
1.12.4. Approval number:
1.12.5. Number of *filling cycles* or *duty cycles* as appropriate:

1.13. Pressure or temperature or flow sensor(s) 1/: yes/no 1/
1.13.1. Make(s):

1.13.2. Type(s):
1.13.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
1.13.4. Approval number:
1.13.5. Number of *filling cycles* or *duty cycles* as appropriate:

1.14. *Pressure regulator(s):* yes/no 1/
1.14.1. Make(s):
1.14.2. Type(s):
1.14.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/*:* MPa
1.14.4. Approval number:
1.14.5. Number of *filling cycles* or *duty cycles* as appropriate:

1.15. *Pressure relief device*:
1.15.1. Make(s):
1.15.2. Type(s):
1.15.3. Normal maximum operating temperature: 2/ °C
(in accordance with **paragraph 2.4.5.** of this Regulation)
1.15.4. Approval number:
1.15.5. *Nominal working pressure(s)* 2/: MPa
1.15.6. Number of *filling cycles* (Class 0 only):

1.16. *Pressure relief valve*: yes/no 1/
1.16.1. Make(s):
1.16.2. Type(s):
1.16.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
1.16.4. Approval number:
1.16.5. Number of or *duty cycles* as appropriate:

1.17. *Receptacle*:
1.17.1. Make(s):
1.17.2. Type(s):
1.17.3. *Nominal working pressure:* 2/ MPa
1.17.4. Approval number:
1.17.5. Number of *filling cycles* (Class 0 only):

1.18. *Removable storage system connector*:
1.18.1. Make(s):
1.18.2. Type(s):
1.18.3. *Nominal working pressure(s)* and *maximum allowable working pressure(s)* 2/: MPa
1.18.4. Approval number:
1.18.5. Number of *duty cycles*:

2. Description of the *hydrogen system(s)* used for purposes other than the propulsion of the vehicle 1/
2.1. Description of the *hydrogen system(s):*
2.2. Name and address of the *manufacturer(s):*
2.3. *Manufacturer's* system code(s) (as marked on the system, or other means of identification):

2.4. *Automatic valve(s):* yes/ same component as used in *propulsion system* 1/
2.4.1. Make(s):
2.4.2. Type(s):
2.4.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
2.4.4. Approval number:
2.4.5. Number of *filling cycles* or *duty cycles* as appropriate:

2.5. *Non-return valve(s):* yes/ same component as used in *propulsion system* 1/
2.5.1. Make(s):
2.5.2. Type(s):
2.5.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
2.5.4. Approval number:
2.5.5. Number of *filling cycles* or *duty cycles* as appropriate:

2.6. *Container(s)* and *container assembly:* yes/ same component as used in *propulsion system* 1/
2.6.1. Make(s):
2.6.2. Type(s):
2.6.3. Capacity: litres (water)
2.6.4. Approval number
2.6.5. *Nominal working pressure* 2/: MPa
2.6.6. Number of *filling cycles*:

2.7. *Excess flow system*: yes/ same component as used in *propulsion system* 1/
2.7.1. Make(s):
2.7.2. Type(s):
2.7.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa

2.8. *Fittings*: yes/ same component as used in *propulsion system* 1/
2.8.1. Make(s):
2.8.2. Type(s):
2.8.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
2.8.4. Approval number:

2.8.5. Number of *filling cycles* or *duty cycles* as appropriate:

2.9. *Flexible fuel lines(s):* yes/no/same component as used in *propulsion system* 1/
2.9.1. Make(s):
2.9.2. Type(s):
2.9.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
2.9.4. Approval number:
2.9.5. Number of *filling cycles* or *duty cycles* as appropriate:

2.10. Heat exchanger(s): yes/no/same component as used in *propulsion system* 1/
2.10.1. Make(s):
2.10.2. Type(s):
2.10.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
2.10.4. Approval number:
2.10.5. Number of *filling cycles* or *duty cycles* as appropriate:

2.11. *Hydrogen filter(s):* yes/no/same component as used in *propulsion system* 1/
2.11.1. Make(s):
2.11.2. Type(s):
2.11.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
2.11.4. Approval number:
2.11.5. Number of *filling cycles* or *duty cycles* as appropriate:

2.12. *Manual valve(s):* yes/no/same component as used in *propulsion system* 1/
2.12.1. Make(s):
2.12.2. Type(s):
2.12.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
2.12.4. Approval number:
2.12.5. Number of *filling cycles* or *duty cycles* as appropriate:

2.13. Pressure or temperature or flow sensor(s) 1/: yes/no/same component as used in *propulsion system* 1/
2.13.1. Make(s):
2.13.2. Type(s):
2.13.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
2.13.4. Approval number:
2.13.5. Number of *filling cycles* or *duty cycles* as appropriate:

2.14. *Pressure regulator(s):* yes/no/same component as used in *propulsion system* 1/
2.14.1. Make(s):
2.14.2. Type(s):
2.14.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
2.14.4. Approval number:
2.14.5. Number of *filling cycles* or *duty cycles* as appropriate:

2.15. *Pressure relief device*: yes/ same component as used in *propulsion system* 1/
2.15.1. Make(s):
2.15.2. Type(s):
2.15.3. Normal maximum operating temperature: 2/ °C
(in accordance with **paragraph 2.4.5.** of this Regulation)
2.15.4. Approval number:
2.15.5. *Nominal working pressure(s)* 2/: MPa
2.15.6. Number of *filling cycles* (Class 0 only):

2.16. *Pressure relief valve*: yes/no/same component as used in *propulsion system* 1/
2.16.1. Make(s):
2.16.2. Type(s):
2.16.3. *Nominal working pressure(s)* and if downstream of the *first pressure regulator, maximum allowable working pressure(s)* 2/: MPa
2.16.4. Approval number:
2.16.5. Number of *duty cycles*:

2.17. *Receptacle*: yes/ same component as used in *propulsion system* 1/
2.17.1. Make(s):
2.17.2. Type(s):
2.17.3. *Nominal working pressure* 2/: MPa
2.17.4. Approval number:
2.17.5. Number of *filling cycles* (Class 0 only):

2.18. *Removable storage system connector*:
2.18.1. Make(s):
2.18.2. Type(s):
2.18.3. *Nominal working pressure(s)* and *maximum allowable working pressure(s)* 2/: MPa
2.18.4. Approval number:
2.18.5. Number of *duty cycles*:

3. Further documentation:
3.1. Process diagram (flow chart) for the *hydrogen system*
3.2. System layout including electrical connections, and other external system inputs or outputs, etc.
3.3. Key to symbols used in documentation:
3.4. Adjustment data:

3.5. Cooling/heating system(s) including *nominal* or *maximum allowable working pressures* and normal operating temperatures

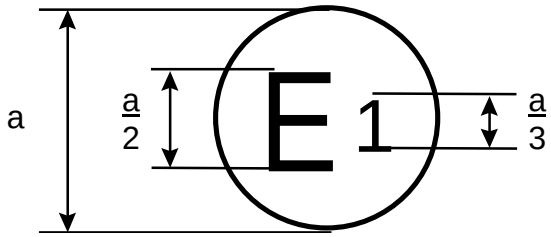
3.6. Drawings showing requirements for installation and operation.

1/ strike out what does not apply.

2/ specify the tolerance.

Annex 3

ARRANGEMENT OF THE SPECIFIC COMPONENT APPROVAL MARKS
(See **paragraph 5.4.** of this Regulation)



xx R-002439

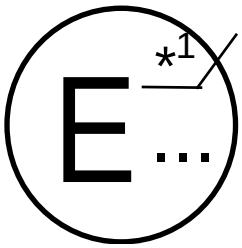
Where: $a \geq 4$ mm

The above approval mark affixed to the *Hydrogen Component* shows that this component has been type approved in Germany (E1), pursuant to the Regulation No. xx under approval number 002439. The first two digits of the approval number indicate that the approval was granted in accordance with the requirements of Regulation No. xx in its original form.

Annex 4

COMMUNICATION CONCERNING THE APPROVAL, OR REFUSAL, OR EXTENSION, OR WITHDRAWAL, OR PRODUCTION DEFINITELY DISCONTINUED OF A SPECIFIC COMPONENT PURSUANT TO REGULATION NO. xx
(Maximum format: A4 (210 x 297 mm)

Issued by: Name of administration:



Concerning: APPROVAL GRANTED 2/
APPROVAL EXTENDED 2/
APPROVAL REFUSED 2/
APPROVAL WITHDRAWN 2/
PRODUCTION DEFINITELY DISCONTINUED 2/
of a *specific component* pursuant to Regulation No. xx

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

1. *Specific Component* considered:
Automatic Valve 2/
Non-return Valve 2/
Container 2/
Fittings 2/
Flexible Fuel Line 2/
Heat exchanger 2/
Hydrogen Filter
Hydrogen Sensor
Manual Valve 2/
Pressure sensor 2/
Temperature sensor 2/
Flow sensor 2/
Pressure or hydrogen remaining indicator
Pressure Regulator 2/
Pressure Relief Device 2/
Pressure Relief Valve 2/
Receptacle 2/
Removable Storage System Connector 2/

2. Trade name or mark:.....
3. *Manufacturer's* name and address: .....
.....
4. *Nominal Working Pressure*/ *MAWP* 2/ = ...MPa
Operating Temperature Range: -40°C to +85/+105/+120°C 2/
Number of *Filling Cycles* or *Duty Cycles* 2/: .....
Service Life: .....years
5. If applicable, name and address of *Manufacturer's* representative: .....
.....
6. Submitted for approval on: .....
7. Technical Service responsible for conducting approval tests:.....
.....
8. Date of report issued by that service: .....
9. No. of report issued by that service: .....
10. Approval granted/refused/extended/withdrawn 2/
11. Reason(s) of extension (if applicable): .....
.....
12. Place: .....
13. Date: .....
14. Signature: .....
15. The documents filed with the application or extension of approval can be obtained upon request.

_____

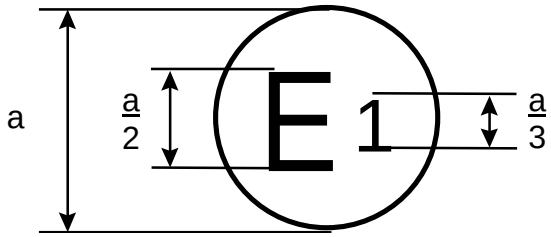
1/ Distinguishing number of the country that has granted/extended/refused/withdrawn approval (see approval provisions in the Regulation).

2/ Strike out what does not apply.

Annex 5

ARRANGEMENTS OF APPROVAL MARKS FOR A VEHICLE TYPE WITH REGARD TO THE INSTALLATION OF A HYDROGEN SYSTEM

Model A
(See **paragraph 13.4.** of this Regulation)

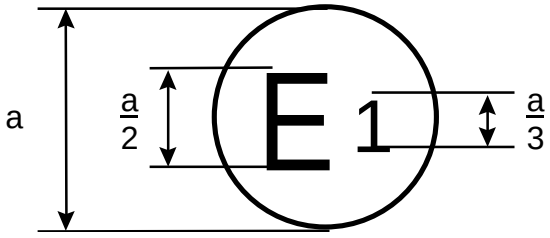


xx R-002439

Where: a ≥ 8 mm

The above approval mark affixed to a vehicle shows that the vehicle has, with regard to the installation of a *Hydrogen System* for the use of compressed gaseous hydrogen, has been type approved in Germany (E1), pursuant to the Regulation No. xx under approval number 002439. The first two digits of the approval number indicate that the approval was granted in accordance with the requirements of Regulation No. xx in its original form.

Model B
(See **paragraph 13.4.** of this Regulation)



xx 002439
83 021628

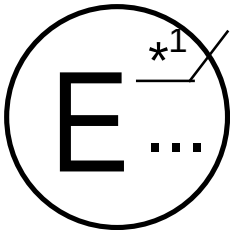
Where: a ≥ 8 mm

The above approval mark affixed to a vehicle shows that the vehicle has been type approved in Germany (E1), pursuant to the Regulations Nos. xx and 83. The approval numbers indicate that, at the dates when the respective approvals were given, Regulation No. xx was in its original form and Regulation No. 83 included the 02 series of amendments

Annex 6

COMMUNICATION CONCERNING THE APPROVAL, OR REFUSAL, OR EXTENSION, OR WITHDRAWAL, OR PRODUCTION DEFINITELY DISCONTINUED OF A VEHICLE TYPE WITH REGARD TO THE INSTALLATION OF A HYDROGEN SYSTEM PURSUANT TO REGULATION No. xx
(Maximum format: A4 (210 x 297 mm)

Issued by: Name of administration:



Concerning: APPROVAL GRANTED 2/

APPROVAL EXTENDED 2/

APPROVAL REFUSED 2/

APPROVAL WITHDRAWN 2/

PRODUCTION DEFINITELY DISCONTINUED 2/

of a *vehicle type* with regard to the installation of a *hydrogen system* pursuant to Regulation No. xx

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

1. Trade name or mark of vehicle: .....
2. *Vehicle type*: .....
3. Vehicle category: .....
4. Vehicle manufacturer's name and address: .....
   .....
5. If applicable, name and address of vehicle manufacturer's representative: .....
   .....
6. Description of the vehicle with regard to the installation of *hydrogen system* (add drawing if appropriate): .....
7. *Hydrogen system*

7.1. Trade name or mark of components and their approval numbers:

7.1.1. *Container or container assembly*: .....

7.1.2. Other components: .....

8. Submitted for approval on: .....
9. Technical Service responsible for conducting approval tests: .....
   .....
10. Date of report issued by that service: .....

11. No. of report issued by that service .....
12. Approval granted/refused/extended/withdrawn 2/
13. Reason(s) of extension (if applicable): .....
14. Place: .....
15. Date: .....
16. Signature: .....
17. The documents filed with the application or extension of approval can be obtained upon request.

Drawings, diagrams and scheme plans regarding the components and the installation of the *hydrogen system* considered to be of importance for the purpose of this Regulation:

.....
.....

Where applicable drawings of the various equipment and their position in the vehicle:

.....
.....

_____

1/ Distinguishing number of the country that has granted/extended/refused/withdrawn approval (see approval provisions in the Regulation).

2/ Strike out what does not apply.

Annex 7

REQUIREMENTS AND APPROVAL TEST PROCEDURES FOR CONTAINERS

Contents Page

Annex 7: Part A

PROVISIONS REGARDING THE APPROVAL OF CONTAINERS

A1: REFERENCES

The following standards contain provisions that, through reference in this text, constitute provisions of this annex. Where standards other than ISO standards are referenced they may be replaced by equivalent national standards.

International Organisation for Standardization (ISO) Standards

ISO 306:1994	Plastics - Thermoplastic Materials - Determination Of Vicat Softening Temperature (VST)
ISO 527-2:1993	Plastics - Determination of Tensile Properties – Part 2: Test Conditions For Moulding And Extrusion Plastics (Incorporating Technical Corrigendum 1:1994)
ISO 2808:1997	Paints And Varnishes - Determination Of Film Thickness
ISO 3146:2000/Cor 1:2002	Plastics - Determination of melting behaviour (melting temperature or melting range) of semi-crystalline polymers by capillary tube and polarizing-microscope methods
ISO 4624:2002	Plastics And Varnishes - Pull-off Test For Adhesion
ISO 6506-1:1999	Metallic Materials - Brinell Hardness Test - Part1: Test Method
ISO 7225:1994	Gas cylinders - Precautionary labels
ISO 7866:1999	Gas Cylinders - Refillable Seamless Aluminium Alloy Gas Cylinders - Design, Construction And Testing
ISO 9809-1:1999	Gas Cylinders - Refillable Seamless Steel Gas Cylinders - Design, Construction And Testing - Part 1: Quenched And Tempered Steel Cylinders With Tensile Strength Less Than 1100 MPa
ISO 9809-2:2000	Gas Cylinders - Refillable Seamless Steel Gas Cylinders - Design, Construction And Testing - Part 2: Quenched And Tempered Steel Cylinders With Tensile Strength Greater Than Or Equal To 1 100 MPa
ISO 11114-1: 1997	Transportable Gas Cylinders – Compatibility Of Cylinder And Valve Materials With Gas Contents – Part 1: Metallic Materials
ISO/DIS 11114-4	Transportable Gas Cylinders – Compatibility Of Cylinders And Valve Materials With Gas Contents – Part 4: Test Methods For Selecting Metallic Materials Resistant To Hydrogen Embrittlement

European Committee for Standardization (CEN) Standards

EN 1964-3:2000	Transportable Gas Cylinders – Specification For The Design And Construction Of Refillable Transportable Seamless Steel Gas Cylinders Of Water Capacities From 0.5 Litre Up To And Including 150 Litres – Part 3: Cylinders Made Of Seamless Stainless Steel With An R_m Value Of Less Than 1100 MPa
EN 12862:2000	Transportable Gas Cylinders – Specification For The Design And Construction Of Refillable Transportable Welded Aluminium Alloy Gas Cylinders
EN 13322-2:2003	Transportable Gas Cylinders – Refillable Welded Steel Gas Cylinders – Design And Construction – Part 2: Stainless Steel

American Society for Testing and Materials (ASTM) Standards

ASTM B117-02	Standard Practice For Operating Salt Spray (Fog) Apparatus
ASTM D522-93a (2001)	Standard Test Method For Mandrel Bend Test Of Attached Organic Coatings
ASTM D1308-02	Standard Test Method For Effect of Household Chemicals on Clear and Pigmented Organic Finishes
ASTM D2343-95	Standard Test Methods For Tensile Properties Of Glass Fibre Strands, Yarns And Rovings Used In Reinforced Plastics
ASTM D2344/D2344M-00e1	Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates
ASTM D2794-93(1999)e1	Standard Test Method For Resistance of Organic Coatings To The Effects of Rapid Deformation (Impact)
ASTM D3170-01	Standard Test Method For Chipping Resistance Of Coatings
ASTM D3359-02	Standard Test Methods For Measuring Adhesion By Tape Test
ASTM D3418-99	Standard Test Method For Transition Temperatures Of Polymers by Differential Scanning Calorimetry
ASTM D4018-99	Standard Test Methods For Properties Of Continuous Filament Carbon And Graphite Fiber Tows
ASTM G154-00ae1	Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials

A2. GENERAL REQUIREMENTS

A2.1. GENERAL

The service conditions do not include external loads that may arise from vehicle collisions, or integration of the *container* into the vehicle, etc. *Containers* need not be designed for continuous exposure to mechanical or chemical attack, e.g. leakage from cargo that may be carried on vehicles or severe abrasion damage from road conditions.

A2.2. FIRE PROTECTION

The *container*, *pressure relief device(s)* and any added insulation or protective material shall collectively protect the *container* from rupture when exposed to fire. The arrangement of the fire protection system shall be specified.

A2.3. OPENING THREADS

Openings with tapered or straight threads may be used in all *container* types. Threads shall comply with a recognised international or national standard. Threads shall be clean cut, even, without surface discontinuities, and to gauge.

A2.4. EXTERIOR ENVIRONMENTAL PROTECTION

Any coatings applied to *containers* shall be such that the application process does not adversely affect the mechanical properties of the *container*. The coating shall facilitate subsequent in-service inspection and the *manufacturer* shall provide guidance on coating treatment during such inspection to ensure the continued integrity of the *container*.

A3. APPROVAL REQUIREMENTS

A3.1. GENERAL

In addition to the requirements given in paragraph 3. of this Regulation, the *manufacturer* shall complete all documents referred to in **Table 7A.1** and submit them to the competent authority when applying for approval.

Table 7A.1 – *Container* type approval documents

Document	**Annex 7 Reference**
Statement of service	**A3.2.**
Container drawings	**A3.3.**
Material specifications and test data	**A3.4.**
Container specifications and test data	**A3.5.**
Manufacturing data	**A3.6.**
Stress analysis	**A3.7.**

A3.2. STATEMENT OF SERVICE

The *manufacturer's* statement of service and all necessary information to ensure the proper handling, use and in-service inspection of the *container* shall be supplied to the purchaser of the *container*.

The statement of service shall include the information given in **Table 7A.2** as a minimum.

A3.3. CONTAINER DRAWINGS

Drawings shall show the following information as a minimum:

a) Title, reference number, date of issue and revision number,
b) Reference to this Regulation and the *container* type,
c) Principal geometrical dimensions including tolerances,
d) *Container* materials,
e) *Container* mass and internal volume including tolerances,
f) Details of the exterior protective coating,
g) *Container* fire protection system.

A3.4. MATERIAL SPECIFICATIONS AND TEST DATA

A detailed description of all principal material properties and tolerances used in the *container* design shall be provided according to **Table 7A.3**. The material specifications shall be verified by appropriate material tests and the results from these tests shall be provided according to **Table 7A.3**.

If more samples than required are tested, all results shall be documented.

A3.5. CONTAINER SPECIFICATIONS AND TEST DATA

Type approval tests shall be conducted on *finished containers* that are representative of normal production and complete with identification marks.

The *container* design specifications for each test that is required shall be provided according to **Table 7A.4**. The design specifications shall be verified by appropriate *container* tests and the results from these tests shall be provided according to **Table 7A.4**.

All results shall be documented if more *containers* or *liners* than required are tested.

A3.6. MANUFACTURING DATA

Manufacturing data, including tolerances where appropriate, shall be provided, such as:

a) Tube extrusion, cold deformation, tube drawing, end forming, welding, heat treatment and cleaning processes for the metal manufacturing of Type 1, 2 and 3 *containers*,
b) Acceptance criteria for non-destructive examination (NDE),
c) Composite manufacturing processes and *auto-frettage* according to **paragraph A4.2.** of this annex for the manufacturing of Type 2, 3 and 4 *containers*,
d) Final manufacturing inspection of surface finish, thread details and principal dimensions.

Table 7A.2 – Statement Of Service

Manufacturer Identification	*Manufacturer* name: *Manufacturer* address:
Container Identification	*Container* identification: *Nominal working pressure*: MPa Type: Diameter 1/: mm Length 1/: mm Internal volume: litres Empty weight: kg *Container* threads:
Container *Service Life*	Maximum *service life*: years Maximum number of *filling cycles*: cycles
Container Fire Protection System	Prd *manufacturer*: Prd identification: Prd drawing number(s):
Container Support Method	Support method: neck/cylinder mounting 2/ Support drawing number(s):
Container Protective Coatings	Purpose of protection: Protective coating drawing number(s):
Container Design Description	*Container* drawing numbers:
Container corrosion Inhibitor	*Container* corrosion inhibitor used: yes/no 2/ Corrosion inhibitor manufacturer: Corrosion inhibitor identification:
Additional information	
Container statement of service	The *manufacturer* hereby states that the *container* design is suitable for use during the specified *service life* in the service conditions defined in **paragraph 2.4.** of this Regulation. *Manufacturer*: Name, position and signature: Place, date:

1/ May be replaced by other dimensions defining the shape of the *container.*
2/ Delete as appropriate.

Table 7A.3 - Material Specifications And Test Data

Material specification		Applicable to Material						Details	
		Steel	Aluminium alloy	Plastic *liner*	Fibre	Resin	Coating		
	Material manufacturer	✓	✓	✓	✓	✓			
	Type of material	✓	✓	✓	✓	✓			
	Material identification	✓	✓	✓	✓	✓			
	Heat treatment definition	✓	✓						
	Chemical composition	✓	✓						
	Cold- or cryoforming procedure	✓							
	Welding procedure definition	✓1/	✓1/						
	Test data							Specified material value	Test value
2/	Tensile test	✓	✓	✓					
3/	Charpy impact test	✓							
4/	Bend test	✓1/	✓1/						
5/	Macroscopic examination	✓1/							
6/	Corrosion test		✓						
7/	Sustained load cracking test		✓						
B2.	Softening/melting temperature			✓					
B3.	Glass transition temperature, tg					✓			
B4.	Resin shear strength, ilss					✓			
B5.	Coating test						✓		
8/	Hydrogen compatibility test	✓	✓	✓	✓	✓			
Manufacturer: Name, position and signature: Place, Date: Technical Service: Inspector's signature: Place, Date:									

Notes:

1/ For *containers* with welded *liners* only.

2/ a) For steel *containers* or *liners* refer to paragraph 10.2. of **ISO 9809-1** or paragraph 10.2. of **ISO 9809-2** as appropriate,
b) For stainless steel *containers* or *liners* refer to paragraph 7.1.2.1. of **EN 1964-3**,
c) For welded stainless steel *liners* refer to paragraph 8.4. of **EN 13322-2**.
d) For aluminium alloy *containers* or *liners* refer to paragraph 10.2. of **ISO 7866**,
e) For welded aluminium alloy *liners* refer to paragraphs 7.2.3. and 7.2.4. of **EN 12862**,
f) For non-metallic *liners* refer to **paragraph B1.** of this annex.

3/ a) For steel *containers* or *liners* refer to paragraph 10.4. of **ISO 9809-1** or paragraph 10.4. of **ISO 9809-2** as appropriate,
b) For stainless steel *containers* or *liners* refer to paragraph 7.1.2.4. of **EN 1964-3**,
c) For welded stainless steel *liners* refer to paragraph 8.6. of **EN 13322-2**.

4/ a) For welded stainless steel *liners* refer to paragraph 8.5. of **EN 13322-2**,
b) For welded aluminium alloy *liners* refer to paragraphs 7.2.5., 7.2.6. and 7.2.7. of **EN 12862**.

5/ For welded stainless steel *liners* refer to paragraph 8.7. of **EN 13322-2**.

6/ a) For aluminium alloy *containers* or *liners* refer to annex A of **ISO 7866**,
b) For welded aluminium alloy *liners* refer to annex A of **EN 12862**.

7/ a) For aluminium alloy *containers* or *liners* refer to annex B of **ISO 7866,** but excluding the second paragraph of clause B.2.,
b) For welded aluminium alloy *liners* refer to annex B of **EN 12862**, but excluding paragraph B.2.2.

8/ a) This test is not required for:
i) Steels that conform to paragraphs 6.3. and 7.2.2 of **ISO 9809-1**,
ii) Aluminium alloys that conform to paragraph 6.1. of **ISO 7866**,
b) For other metallic *containers* or *liners* hydrogen compatibility of the material, including welds, shall be demonstrated in accordance with **ISO 11114-1**, **ISO/DIS 11114-4** or **paragraph B7.** of this annex as appropriate,
c) For non-metallic materials hydrogen compatibility shall be demonstrated.

Table 7A.4 - *Container* specifications and test data

Test and Annex 7 Reference		Applicable To *Container* Type				Specified Design Value	Test Value
		1	**2**	**3**	**4**		
B9.	Burst Test	✓	✓	✓	✓		
B10.	Ambient Temperature Pressure Cycling Test	✓	✓	✓	✓		
B11.	LBB Performance Test	✓	✓	✓	✓		
B12.	Bonfire Test	✓	✓	✓	✓		
B13.	Penetration Test	✓	✓	✓	✓		
B14.	Chemical Exposure Test		✓	✓	✓		
B15.	Composite Flaw Tolerance Test		✓	✓	✓		
B16.	Accelerated Stress Rupture Test		✓	✓	✓		
B17.	Extreme Temperature Pressure Cycling Test		✓	✓	✓		
B18.	Impact Damage Test			✓	✓		
B19.	Leak Test				✓		
B20.	Permeation Test				✓		
B21.	Boss Torque Test				✓		
B22.	Hydrogen Gas Cycling Test				✓		
Container identification: *Manufacturer*: Name, position and signature: Place, date: Technical Service: Inspector's signature: Place, date:							

A3.7. STRESS ANALYSIS

A stress analysis shall be carried out. A table summarizing the calculated stresses shall be provided for information purposes only.

A3.8. MATERIAL REQUIREMENTS

A3.8.1. General

Materials used shall be suitable for the service conditions specified in **paragraph 2.4.** of this Regulation. Incompatible materials shall not be in contact with each other.

A3.8.2. Steel

A3.8.2.1. Steels for *containers* and *liners* shall conform to the material requirements of paragraphs 6.1 to 6.4 of **ISO 9809-1**or paragraphs 6.1. to 6.3. of **ISO 9809-2** as appropriate.

A3.8.2.2. Stainless steels for *containers* and *liners* shall conform to paragraphs 4.1. to 4.4. of **EN 1964-3**.

A3.8.2.3. Welded stainless steels for *liners* of Type 3 *containers* shall conform to paragraphs 4.1. to 4.3. of **EN 13322-2** as appropriate.

A3.8.3. Aluminium alloy

A3.8.3.1. Aluminium alloys for *containers* and *liners* shall conform to the material requirements of paragraphs 6.1. and 6.2. of **ISO 7866**.

A3.8.3.2. Welded aluminium alloys for *liners* of Type 3 *containers* shall conform to paragraphs 4.2. and 4.3. of **EN 12862**.

A3.8.4. Plastic *liner* materials

The material for plastic *liners* may be thermosetting or thermoplastic.

A3.8.5. Fibres

The *container manufacturer* shall keep on file for the intended life of the *container* design the published specifications for composite materials including principal test results, i.e. tensile test, the material *manufacturer's* recommendations for storage, conditions and shelf life.

The *container manufacturer* shall keep on file, for the intended life of each batch of *containers*, the fibre *manufacturer's* certification that each shipment conforms to the *manufacturer's* specifications for the product.

A3.8.6. Resins

The polymeric material for impregnation of the fibres may be thermosetting or thermoplastic resin.

A3.9. *BURST PRESSURE* RATIOS

The minimum *burst pressure* ratios, i.e. the minimum actual *burst pressure* of the *container* divided by its *nominal working pressure*, shall not be less than the values given in **Table 7A.5.**

Table 7A.5 - Minimum *Burst Pressure* Ratios

		Container Type			
Construction		Type 1	Type 2	Type 3	Type 4
All metal		2.25			
Over-wrap	Glass		2.75 (2.50 1/)	3.65 (3.50 1/)	3.65
	Aramid		2.35	3.10 (3.00 1/)	3.10
	Carbon		2.35	2.35	2.35
	Hybrid		2/		

Notes:

1/ The minimum *burst pressure* ratios may be reduced to the bracketed values, if the calculated stress ratios, i.e. stress in the fibre at the minimum *burst pressure* ratio times *nominal working pressure* divided by the stress in the fibre at *nominal working pressure*, conform to the un-bracketed values. The stress ratio calculations shall:

a) Be based on an analysis method with capability for non-linear materials (special purpose computer program or finite element analysis program),
b) Include correct modelling of the elastic-plastic stress-strain curve for the *liner* material,
c) Include correct modelling of mechanical properties of the composite,
d) Include calculations made at *auto-frettage pressure*, zero pressure after *auto-frettage*, *nominal working pressure* and minimum *burst pressure*,
e) Take into account the pre-stress from winding tension.

2/ For *container* designs using hybrid reinforcement, i.e. two or more different structural fibre types, consideration shall be given to the load share between the different fibres based on the different elastic modulii of the fibres. The calculated stress ratios for each individual structural fibre type shall conform to the un-bracketed values. Verification of the stress ratios may also be performed using strain gauges. The minimum *burst pressure* ratio shall be chosen such that the calculated stress in the structural fibres at the minimum *burst pressure* ratio times *nominal working pressure* divided by the calculated stress in the structural fibre at *nominal working pressure* meets the stress ratio requirements for the fibres used.

A4. CONTAINER MANUFACTURING REQUIREMENTS

A4.1. TYPE 1 CONTAINERS

A forming process shall not be used to close the ends of aluminium alloy *containers*. The base ends of steel *containers* that have been closed by forming, shall be inspected using NDE or equivalent techniques. Metal shall not be added in the process of closure at the end. Each *container* shall be examined before end forming operations for thickness and surface finish.

After end forming, *containers* shall be heat treated to the hardness range specified for the design. Localised heat treatment is not permitted.

For *containers* subjected to coldforming or cryoforming processes, heat treatment of the preform component is not required. *Containers* that have been coldformed or cryoformed shall not be subjected to any subsequent heat treatment or to additional heat application, such as welding.

When a neck ring, foot ring or attachments for support are provided, it shall be of material compatible with that of the *container* and shall be securely attached by a method other than welding, brazing or soldering.

A4.2. TYPE 2, 3 AND 4 CONTAINERS

A4.2.1. Composite filament winding

When composite containers are fabricated from a *liner over-wrapped* with continuous filament windings, the filament winding operations shall be computer or mechanically controlled. During winding the principal parameters shall be monitored and kept within specified tolerances, and documented in a winding record. The principal parameters are:

a) Fibre type including tex value and sizing,
b) Number of fibre tows per bandwidth,
c) Type of resin and resin components mix ratio,
d) Manner of impregnation, weight or volume fraction of resin or fibre,
e) Winding program reference and winding angle,
f) Number of winding rotations hoop,
g) Number of windings cycles helical (Type 3 and 4 *containers* only),
h) Band width,
i) Winding tension,
j) Winding speed,
k) Temperature of the resin.

A4.2.2. Curing of thermosetting resins

After completion of filament winding, thermosetting resins shall be cured by heating using a predetermined and controlled time-temperature profile. The time-temperature history shall be documented during the curing.

The maximum curing time and temperature for *containers* with aluminium alloy *liners* shall be below the time and temperature that adversely affect the properties of the metal.

For Type 4 *containers* the curing temperature for thermosetting resins shall be at least 10 °C below the softening temperature of the plastic *liner*.

A4.2.3. *Auto-frettage*

Auto-frettage, if used, shall be carried out before the hydraulic test. The *auto-frettage pressure* shall be within the limits established by the *manufacturer*.

A4.2.4. Metallic *liners*

For metallic *liners* subjected to coldforming or cryoforming processes, heat treatment of the preform component is not required. *Liners* that have been coldformed or cryoformed shall not be subjected to any subsequent heat treatment or to additional heat application, such as welding.

Welding of stainless steel *liners* shall conform to paragraphs 6.1., 6.2. and 6.4. of **EN 13322-2.** Welding of aluminium alloy *liners* shall conform to paragraphs 4.1.2. and 6.1. of **EN 12862**.

A4.3. CONTAINER MARKINGS

On each *container,* and where applicable the outer surface of a group of permanently encapsulated *containers*, the *manufacturer* shall provide clear permanent markings with a font not less than 6 mm high. Marking shall be made either by labels incorporated into resin coatings, adhesive labels, low stress stamps used on the thickened ends of Type 1 and 2 *containers*, or any combination of the above. Adhesive labels and their application shall be in accordance with **ISO 7225**, or an equivalent standard. Multiple labels are allowed and should be located such that mounting brackets do not obscure them. Every *container* type approved in accordance with this Regulation shall bear a marking place with the following data clearly legible:

a) Name of the *manufacturer*,
b) A unique serial number for every *container*,
c) The marking "H_2 GAS",
d) *Nominal working pressure* (MPa) at 15 ^{0}C,
e) Year and month of manufacture, e.g. 2000/01,

f) Approval mark in accordance with **paragraph 5.4.** of this Regulation,
g) The marking "DO NOT USE AFTER yyyy/mm" where yyyy/mm is the year and month of manufacture plus the approved *service life* of the *container.* However, yyyy/mm may be based on the date of dispatch of the *container* from the *manufacturer*, provided that it has been stored in a dry location without internal pressure.
h) The marking "Number of *filling cycles* xxxxx" where xxxxx is the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation.

A5. BATCH TEST REQUIREMENTS

A5.1. BATCH TEST

A5.1.1. General

The *manufacturer* shall conduct batch testing on *finished containers* that are representative of normal production. The *finished containers* to be tested shall be randomly selected from each *batch*. A *batch* shall not exceed 200 *finished containers* plus those *finished containers* to be used in destructive tests, or one shift of successive production, whichever is greater.

With reference to **Table 7A.6**, the following batch tests are required:
a) One *finished container* shall be subjected to the ambient temperature pressure cycle test at the frequency given in **paragraph A5.1.2.** of this annex,
b) One *finished container* shall be subjected to the burst test. If a *finished container* passes the ambient temperature pressure cycle test the same *container* may be subjected to the burst test,
c) One *finished container*, *liner* or heat-treated test sample that is representative of *finished containers* or *liners*, shall be subjected to the other tests specified in **Table 7A.6** of this annex,
d) If an exterior environmental protective coating is used, e.g. organic coating/paint, one *finished container* or test sample that is representative of the *batch* shall be subjected to the coating batch test.

If more *containers* than required are subjected to the tests, all results shall be documented.

All *containers* represented by a batch test that fail to meet the specified requirements shall follow the procedures specified in **paragraph A5.2.** of this annex.

Table 7A.6 - Batch Tests

Test and annex reference		Applicable to *container* type				Specified design value	Test value
		1	**2**	**3**	**4**		
1/	Tensile test	✓	✓5/	✓5/	✓5/		
2/	Charpy impact test	✓	✓5/	✓5/			
3/	Bend test			✓5/			
4/	Macroscopic examination			✓5/			
B2.	Softening/melting temp. Test				✓5/		
B6.	Coating batch test	✓	✓	✓	✓		
B9.	Burst test	✓	✓	✓	✓		
B10.	Ambient temperature pressure cycle test	✓	✓	✓	✓6/		
B19.	Leak test				✓6/		
B21.	Boss torque test				✓6/		

Notes:

1/ a) For steel *containers* or *liners* refer to paragraph 10.2. of **ISO 9809-1** or paragraph 10.2. of **ISO 9809-2** as appropriate,
b) For stainless steel *containers* or *liners* refer to paragraph 7.1.2.1. of **EN 1964 -3,**
c) For welded stainless steel *liners* refer to paragraph 8.4. of **EN 13322-2**.
d) For aluminium alloy *containers* or *liners* refer to paragraph 10.2. of **ISO 7866,**
e) For welded aluminium alloy *liners* refer to paragraphs 7.2.3. and 7.2.4. of **EN12862**,
f) For non-metallic *liners* refer to **paragraph B1.** of this annex.

2/ a) For steel *containers* or *liners* refer to paragraph 10.4. of **ISO 9809-1** or paragraph 10.4. of **ISO 9809-2** as appropriate,
b) For stainless steel *containers* or *liners* refer to paragraph 7.1.2.4. of **EN 1964-3**,
c) For welded stainless steel *liners* refer to paragraph 8.6. of **EN 13322-2**.

3/ a) For welded stainless steel *liners* refer to paragraph 8.5. of **EN 13322-2**,
b) For welded aluminium alloy *liners* refer to paragraphs 7.2.5., 7.2.6. and 7.2.7. of **EN 12862**.

4/ For welded stainless steel *liners* refer to paragraph 8.7. of **EN 13322-2**.

5/ Test on *liner* material.

6/ The following test sequence shall be used for *container* Type 4: boss torque test (**B21.**), followed by an ambient temperature pressure cycling test (**B10.**), followed by a leak test (**B19.**).

A5.1.2. Frequency of ambient temperature pressure cycling test

Finished containers shall be subjected to the ambient temperature pressure cycling test at a test frequency defined as follows:

a) One *container* from each *batch* shall be pressure cycled for 3.0 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation,
b) If on 10 sequential production *batches* of a design family, i.e. similar materials and processes, none of the pressure cycled *containers* in **a)** above should leak or rupture within 4.5 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation, then the pressure cycle test can be reduced to one *container* from every 5 *batches* of production with the container selected from the first of the 5 batches,
c) If on 10 sequential production *batches* of a design family, none of the pressure cycled *containers* in **a)** above should leak or rupture within 6.0 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation, then the pressure cycle test can be reduced to one *container* from every 10 *batches* of production with the container selected from the first of the 10 batches,
d) Should more than 3 months have expired since the last *batch* of production, then a *container* from the next *batch* of production shall be pressure cycle tested in order to maintain the reduced frequency of batch testing in **b)** or **c)** above,
e) Should any reduced frequency pressure cycle test *container* in **b)** or **c)** above fail to meet 3.0 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation, then the batch pressure cycle test frequency in **a)** shall be reintroduced for at least 10 production *batches* in order to re-establish the reduced frequency of batch pressure cycle testing in **b)** or **c)** above,
f) Should any *container* in **a), b)** or **c)** above fail within 3.0 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation, then the cause of failure shall be determined and corrected following the procedures in **paragraph A5.2.** of this annex. The pressure cycle test shall then be repeated on an additional three *containers* from that *batch*. Should any of the three additional *containers* fail to meet 3.0 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation, the *batch* shall be rejected. The *manufacturer* shall demonstrate that *containers* produced since the last successful batch test meets all batch test requirements.

A5.2. FAILURE TO MEET TEST REQUIREMENTS

In the event of failure to meet the test requirements, retesting or reheat treatment and retesting shall be carried out as follows:

a) If there is evidence of a fault in carrying out a test, or an error of measurement, a further test shall be performed. If the result of this test is satisfactory, the first test shall be ignored,
b) If the test has been carried out in a satisfactory manner, the cause of the test failure shall be identified.

If the failure is considered to be due to the heat treatment applied, the *manufacturer* may subject all the *containers* of that *batch* to a further heat treatment.

If the failure is not due to the heat treatment applied, all the identified defective *containers* shall be rejected or repaired by an approved method. The non-rejected *containers* shall then be considered as a new *batch*.

In both cases all the relevant prototype or batch tests needed to prove the acceptability of the new *batch* shall be repeated. If one or more tests prove even partially unsatisfactory, all *containers* of the *batch* shall be rejected.

A6. PRODUCTION EXAMINATION AND TEST REQUIREMENTS

Production examination and tests shall be carried out on all *containers* during manufacture and after completion, as follows:

a) Verification that the principal dimensions and mass of the *finished container* and of any *liner* and *over-wrap* are within design tolerances,
b) Verification of compliance with principal manufacturing parameters, in accordance with **paragraph A3.6.** of this annex, including examination of any specified surface finish with special attention to deep drawn surfaces and folds or laps in the neck or shoulder of forged or spun end enclosures or openings,
c) For metallic *containers* and *liners*, NDE in accordance with annex B of **ISO 9809** or annex C of **EN 1964-3** or annex B of **EN 13322-2** as appropriate, or a demonstrated equivalent method capable of detecting the maximum defect size allowed, to verify that the maximum defect size does not exceed the size specified in the design as determined below.

In addition welded stainless steel *liners* shall also be examined in accordance with paragraph 6.8.2. of **EN 13322-2,** and welded aluminium alloy *liners* shall be examined in accordance with paragraphs 6.2.1. (second paragraph), and 6.2.3. of **EN 12862**.

The design of Type 1, 2 and 3 *containers* shall identify the maximum allowable defect size at any location in the metal *container* or *liner* that will not grow to a critical size within either the specified retest period or *service life* if no retest is specified. The critical defect size is defined as the limiting through-wall (*container* or *liner*) thickness defect that would allow stored gas to be discharged without rupturing the *container*. Defect sizes for the rejection criteria for ultrasonic scanning or equivalent, shall be smaller than the maximum allowable defect sizes. For Type 2 and 3 *containers*, it shall be assumed that there is no damage to non-metallic materials due to any time-dependent mechanisms. The allowable defect size for NDE shall be determined by an appropriate method.

a) Hardness test for metallic *containers* and *liners* in accordance with **paragraph B8.** of this annex and fulfil the requirements therein,
b) Hydraulic test, in accordance with **paragraph B23.** of this annex and fulfil the requirements therein,
c) Leak test for Type 4 *containers*, in accordance with **paragraph B19.** of this annex and fulfil the requirements therein,
d) Verification of markings, in accordance with **paragraph A4.3.** of this annex.

A summary of the required production examination and tests for each *container* is provided in **Table 7A.7**.

Table 7A.7 - Production Examination And Tests

Production examination and tests & annex 7 reference		Applicable to *container* Type			
		1	2	3	4
	Principal design dimensions	✓	✓	✓	✓
A3.6	Principal manufacturing parameters	✓	✓	✓	✓
	NDE	✓	✓1/	✓1/	
B8	Hardness test	✓	✓1/	✓1/	
B19	Leak test				✓
B23	Hydraulic test	✓	✓	✓	✓
A4.3	Markings	✓	✓	✓	✓

Note: 1/ - Test on metallic *liner*

A7. MODIFICATIONS

Modifications may be approved by the reduced test programme specified in Table 7A.8. Any major changes that are not covered by Table 7A.8 shall be subjected to full approval testing.

Table 7A.8: Approval testing of modifications	Type of test											
	Materials **B1 – B8,** as applicable	Hydrogen compatibility **8/ to Table 7A.3**	Burst **B9**	Ambient temp. pressure cycling **B10**	Lbb Performance **B11**	Bonfire **B12**	Penetration **B13**	Chemical exposure **B14**	Composite flaw tolerance **B15**	Acc. Stress rupture –**B16**	Impact damage test **B18**	Permeation **B20** Boss torque **B21** Hydrogen cycling **B22**
Fibre manufacturer			2, 3, 4	2, 3, 4	2, 3, 4					2, 3, 4	3, 4	
Metallic *container* or *liner* material	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2	1, 2, 3	1, 2, 3	1, 2, 3	2, 3	2, 3	3	
Plastic *liner* material	4	4		4				4				4
Fibre material	2, 3, 4	4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	3, 4	
Resin material		4					2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	3, 4	
Diameter change ≤ 20 %			1, 2, 3, 4	1, 2, 3, 4								
Diameter change >20 %			1, 2, 3, 4	1, 2, 3, 4		1, 2, 3, 4	1, 2, 3, 4		2, 3, 4		3, 4	
Length change ≤ 50 %			1, 2, 3, 4			-						
Length change> 50 %			1, 2, 3, 4	1, 2, 3, 4		1, 2, 3, 4					3, 4	
Nominal working pressure change ≤20% 1/			1, 2, 3, 4	1, 2, 3, 4								
Nominal working pressure change >20% 1/			1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4					
Dome shape			1, 2, 3, 4	1, 2, 3, 4								4
Opening size			1, 2, 3, 4	1, 2, 3, 4								
Coating change	2, 3, 4							2, 3, 4				
End boss design												4*[2]
Change in manufacturing process 3/			1, 2, 3, 4	1, 2, 3, 4								
Fire protection system						1, 2, 3, 4						

Notes: for example: 2,3 indicates that a test is required for Type 2 and 3 *containers* only

1/ - only when thickness change is proportional to diameter or pressure change

2/ - a hydrogen cycle test is not required if the stresses in the neck are equal to the original or reduced by the design change (e.g. Reducing the diameter of internal threads, or changing the boss length), the liner to boss interface is not affected, and the original materials are used for boss, liner, and seals.

3/ – any deviation from the parameters specified in paragraph A3.6 of this annex is considered to be a change in manufacturing process.G

Annex 7: Part B

APPROVAL TEST PROCEDURES FOR CONTAINERS

TESTS OF CONTAINER MATERIALS

B1. TENSILE TEST

B1.1. Sampling

The test applies to Type 4 *containers* only.
The test applies to plastic *liner* materials only.
Type approval testing - number of *liners* to be tested: 2

B1.2. Procedure

Mechanical properties for plastic *liner* materials shall be tested at -40°C in accordance with **ISO 527-2.**

B1.3. Requirements

The test results shall be within the *manufacturer's* specifications.

B1.4. Results

The tensile yield strength and ultimate elongation of plastic *liner* materials shall be presented in a test summary, e.g. **Table 7A.3** of this annex.

B2. SOFTENING TEMPERATURE TEST

B2.1. Sampling

The test applies to Type 4 *containers* only.
The test applies to polymeric materials only.
Type approval testing - number of *liners* to be tested: 1
Batch testing - number of *liners* to be tested: 1

B2.2. Procedure

The softening temperature of polymeric materials from finished *liners* shall be determined based on the A50 method in **ISO 306**.

B2.3. Requirement

The softening temperature shall be ≥ 100 °C.

B2.4. Results

The softening temperature shall be presented in a test summary, e.g. **Table 7A.3** of this annex.

B3. GLASS TRANSITION TEMPERATURE TEST

B3.1. Sampling

The test applies to Type 2, 3 and 4 *Containers*.
The test applies to composite resin materials only.
Type approval testing - number of samples to be tested: 3

B3.2. Procedure

The glass transition temperature of resin materials shall be determined in accordance with **ASTM D3418.**

B3.3. Requirements

The test results shall be within the *manufacturer's* specifications.

B3.4. Results

Final results from the test shall be documented by a test report and presented in a test summary, e.g. **Table 7A.3** of this annex. The glass transition temperature to be presented shall be the minimum measured value.

B4. RESIN SHEAR STRENGTH TEST

B4.1. Sampling

The test applies to Type 2, 3 and 4 *containers*.
The test applies to composite resin materials only.
Type approval testing - number of samples to be tested: 3

B4.2. Procedure

Resin materials shall be tested on a sample coupon representative of the *over-wrap* in accordance with **ASTM D2344.**

B4.3. Requirement

After boiling in water for 24 hours the minimum shear strength of the composite shall be 13.8 MPa.

B4.4. Results

The minimum resin shear strength shall be presented in a test summary, e.g. **Table 7A.3** of this annex.

B5. COATING TEST

B5.1. Sampling

The test applies to all *container* Types where exterior environmental protective coating is used, e.g. organic coating/paint.
Type approval testing - number of samples to be tested: as specified in the appropriate standards.

B5.2. Procedure and requirement

Coatings shall be evaluated using the following test methods:

a) Adhesion strength in accordance with **ISO 4624**, using method A or B as appropriate. The coating shall exhibit an adhesion rating of 4.
b) Flexibility in accordance with **ASTM D522**, using Method B with a 12.7 mm mandrel at the specified thickness at -20 °C. Test samples shall be prepared in accordance with **ASTM D522**. There shall not be any visually apparent cracks.
c) Impact resistance in accordance with **ASTM D2794**. The coating at room temperature shall pass a forward impact test of 18 J.
d) Chemical resistance in general accordance with **ASTM D1308**. The test shall be conducted using the open spot test method and 100 hours exposure to a 30 per cent sulphuric acid solution (battery acid with a specific gravity of 1.219) and 24 hours exposure to a polyalkalene glycol, e.g. brake fluid. There shall be no evidence of lifting, blistering or softening of the coating. The adhesion shall meet a rating of 3 when tested in accordance with **ASTM D3359**. This test is not necessary if a test is undertaken in accordance with **paragraph B14.** of this annex.
e) Light and water exposure in accordance with **ASTM G154**, using an exposure of 1000 hours. There shall be no evidence of blistering. The adhesion shall meet a rating of 3 when tested in accordance with **ISO 4624.** The maximum gloss loss allowed is 20 per cent.
f) Salt spray exposure in accordance with **ASTM B117**, using an exposure of 500 hours. Undercutting shall not exceed 3 mm at the scribe mark. There shall be no evidence of

blistering. The adhesion shall meet a rating of 3 when tested in accordance with **ASTM D3359.**

g) Resistance to chipping at room temperature using the **ASTM D3170**. The coating shall have a rating of 7A or better, and there shall not be any exposure of the substrate.

B5.3. Results

Final results from the test shall be presented in a test summary, e.g. **Table 7A.3** of this annex.

B6. COATING BATCH TEST

B6.1. Sampling

The test applies to all *container* Types where exterior environmental protective coating is used, e.g. organic coating/paint.
Batch testing - number of *containers*/samples to be tested per *batch*: in accordance with **paragraph A5.1.** of this annex.

B6.2. Procedure and Requirement

Coatings shall be evaluated using the following test methods:

a) Coating thickness measurement in accordance with **ISO 2808**. The thickness shall meet the design requirements,

b) Adhesion strength in accordance with **ISO 4624**, using Method A or B as appropriate. The coating shall exhibit an adhesion rating of 4.

B6.3. Results

Final results from the test shall be presented in a test summary, e.g. **Table 7A.3** of this annex.

The *manufacturer* shall keep the coating thickness and adhesion strength values on file throughout the *service life* of the *container*.

B7. HYDROGEN COMPATIBILITY TEST

B7.1. Sampling

The test applies to Type 1, 2 and 3 *containers* in accordance with note 8/ to Table 7A.3 of this annex.

Type approval testing - number of *containers* or *liners* to be tested: 3

B7.2. Procedure

Special consideration shall be given to safety when conducting this test.

At ambient temperature use hydrogen to pressure cycle for 3.0 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation, either:

a) The *container* between ≤ 2.0 MPa and ≥ 1.25 times the *nominal working pressure*, or
b) The *liner* between the pressure levels that will provide an equivalent *liner* wall stress as would be present at ≤ 2.0 MPa and ≥ 1.25 times the *nominal working pressure* for the *container*.

B7.3. Requirement

The *containers* or *liners* shall not fail before reaching 3.0 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation.

B7.4. Results

Final results from the test shall be documented by a test report and presented in a test summary, e.g. **Table 7A.3** of this annex.

The *manufacturer* shall keep the results on file throughout the *service life* of the *container*.

B8. HARDNESS TEST

B8.1. Sampling

The test applies to all *containers* and *liners* of Type 1, 2 and 3 *containers*.
The test applies to metallic materials only.
Production testing - number of *containers* or *liners* to be tested: all.

The test shall be carried out after the final heat treatment.

B8.2. Procedure

A hardness test shall be carried out on the parallel wall at the centre and at one of the domed ends of each *container* or *liner* in accordance with **ISO 6506-1**.

B8.3. Requirement

The hardness value shall be in the range specified for the design.

B8.4. Results

The hardness value shall be presented in a test summary, e.g. **Table 7A.3** of this annex. The *manufacturer* shall keep the results on file throughout the *service life* of the *container*.

TESTS OF FINISHED CONTAINERS

B9. BURST TEST

B9.1. Sampling

The test applies to all *container* Types.
Type approval testing - number of *finished containers* to be tested: 3
Type approval testing - number of *liners* to be tested: 1 (additional test for Type 2 *containers* only)
Batch testing - number of *finished containers* to be tested per *Batch*: in accordance with **paragraph A5.1.** of this annex.

B9.2. Procedure

The *container* shall be hydraulically burst tested at ambient temperature using the following procedure:

The rate of pressurization shall be ≤ 1.4 MPa/s for pressures higher than 80 per cent of the *nominal working pressure* times the *burst pressure* ratio stated in **paragraph A3.9.** of this annex. If the rate exceeds 0.35 MPa/s at pressures higher than 80 per cent of the *nominal working pressure* times the *burst pressure* ratio, then either the *container* shall be placed in series between the pressure source and the pressure measurement device, or the time at pressure above the *nominal working pressure* times the *burst pressure* ratio shall exceed 5 seconds.

B9.3. Requirement

The *burst pressure* of the *container* shall exceed the *nominal working pressure* times the *burst pressure* ratio stated in **paragraph A3.9.** of this annex.
The *burst pressure* of the *liner* shall exceed 1.25 times the *nominal working pressure*.

B9.4. Results

The *burst pressure* shall be presented in a test summary, e.g. **Table 7A.4** of this annex. The *manufacturer* shall keep the *burst pressure* value on file throughout the *service life* of the *container*.

B10. AMBIENT TEMPERATURE PRESSURE CYCLING TEST

B10.1. Sampling

The test applies to all *container* Types.
Type approval testing - number of *finished containers* to be tested: 2
Batch testing - number of *finished containers* to be tested per *batch*: in accordance with **paragraph A5.1.** of this annex.

B10.2. Procedure

Pressure cycling shall be performed at ambient temperature in accordance with the following procedure:

a) Fill the *container* to be tested with a non-corrosive fluid such as oil, inhibited water or glycol.

b) Pressure cycle for 3.0 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation, between ≤ 2.0 MPa and ≥ 1.25 times *nominal working pressure* at a rate not exceeding 10 cycles per minute.

For type approval, *containers* shall be cycled until failure occurs or up to 9 times the number of *filling cycles*.

For batch testing, *containers* shall be destroyed either by continuing the cycling until failure occurs or in accordance with the burst testing procedure of paragraph B9.2 of this annex. For batch testing of Type 4 *containers*, the test sequence given in **note 6/** to **Table 7A.6** to this annex shall be followed before destroying the *container*.

B10.3. Requirement

The *containers* shall not fail before reaching 3.0 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation. For type approval, the *containers* shall either reach 9.0 times the number of *filling cycles* without failure, in which case the LBB test in **paragraph B19.** of this annex is not required, or they shall fail by leakage and not by rupture.

B10.4. Results

The number of cycles to failure, along with the location and description of the failure initiation shall be documented and presented in a test summary, e.g. **Table 7A.4** of this annex.

The *manufacturer* shall keep the results on file throughout the *service sife* of the *container*.

B11. LEAK-BEFORE-BREAK (LBB) PERFORMANCE TEST

B11.1. Sampling

The test applies to all *container* Types. The test is not required if the *container* design is already proven to exceed 9.0 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation, when tested in accordance with **paragraph B10.** of this annex.
Type approval testing - number of *finished containers* to be tested: 3

B11.2. Procedure

The *container* shall be tested using the following procedure:

a) Fill the *container* to be tested with a non-corrosive fluid such as oil, inhibited water or glycol,

b) Pressure cycle the *container* between ≤ 2.0 MPa and ≥ 1.5 times *nominal working pressure* at a rate of ≤ 10 cycles per minute to 3.0 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation.

B11.3. Requirement

The *containers* tested shall either fail by leakage or shall exceed 3.0 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation without failure.

B11.4. Results

The number of cycles to failure, along with the location and description of the failure initiation, shall be presented in a test summary, e.g. **Table 7A.4** of this annex.

B12. BONFIRE TEST

B12.1. Sampling

The test applies to all *container* Types.
Type approval testing - number of *finished containers* to be tested: minimum 1

B12.2. Procedure

Special consideration shall be given to safety when conducting this test.

The *container* shall be pressurized to *nominal working pressure* with hydrogen or a gas with a higher thermal pressure build up. The pressurized *container* shall be tested as follows:

a) Place the *container* in a horizontal position approximately 100 mm above a uniform fire source with a length of 1.65 m. The arrangement of the fire shall be recorded in sufficient detail to ensure the rate of heat input to the *container* is reproducible. Any failure or inconsistency of the fire source during a test shall invalidate the result,

b) If the *container* is ≤ 1.65 m, it shall be positioned centrically above the fire source,

c) If the *container* is > 1.65 m and it is fitted with a *pressure relief device* at only one end, the fire source shall commence at the opposite end,

d) If the *container* is > 1.65 m and it is fitted with *pressure relief devices* at more than one location along its length, the centre of the fire source shall be centred midway between those *pressure relief devices* that are separated by the greatest horizontal distance,

e) If the *container* is > 1.65 m and it is additionally protected by thermal insulation, 2 fire tests shall be performed at *nominal working pressure*. The *container* shall be positioned centrically above the fire source in one test, while the fire shall commence at one of the *container* ends in the other,

f) Metallic shielding shall be used to prevent direct flame impingement on *container* valves, *fittings*, or *pressure relief devices*. The metallic shielding shall not be in direct contact with the *pressure relief devices*. Any failure during the test of a valve, *fitting* or tubing that is not part of the intended protection system for the design shall invalidate the result,

g) Surface temperatures shall be monitored by at least three thermocouples located along the bottom of the *container* and spaced not more than 0.75 m apart. Metallic shielding shall be used to prevent direct flame impingement on the thermocouples. Alternatively, thermocouples may be inserted into blocks of metal measuring less than 25 mm x 25 mm x 25 mm,

h) The fire source shall provide direct flame impingement on the *container* surface across its entire diameter immediately following ignition,

i) Thermocouple temperatures and the *container* pressure shall be recorded at intervals of ≤ 10 seconds during the test,

j) Within 5 minutes of ignition and for the remaining duration of the test the temperature of at least one thermocouple shall indicate at least 590 °C,

B12.3. Requirement

The *Container* shall only vent through the *Pressure Relief Device(s)* and shall not rupture.

B12.4. Results

The results shall be presented in a test summary, e.g. **Table 7A.4** of this annex, and shall include the following data for each *container* as a minimum:

a) The elapsed time from ignition of the fire to the start of venting through the *pressure relief device(s),*

b) The maximum pressure and time of evacuation until a pressure ≤ 1.0 MPa is reached.

B13. PENETRATION TEST

B13.1. Sampling

The test applies to all *container* Types.
Type approval testing - number of *finished containers* to be tested: 1

B13.2. Procedure

The *container*, complete with protective coating, shall be tested in the following sequence:

a) Pressurize with compressed gas to *nominal working pressure* ± 1.0 MPa,

b) Penetrate at least one sidewall of the *container* by an armour piercing bullet with a diameter of 7.62 mm or greater. The projectile shall impact the sidewall at an approximate angle of 45°.

B13.3. Requirement

The *Container* shall not rupture.

B13.4. Results

The approximate size of the entrance and exit openings and their locations shall be presented in a test summary, e.g. **Table 7A.4** of this annex.

B14. CHEMICAL EXPOSURE TEST

B14.1. Sampling

The test applies to Type 2, 3 and 4 *containers*.
Type approval testing - number of *finished containers* to be tested: 1

B14.2. Procedure

The *container*, including coating if applicable, shall be tested in the following sequence:

a) The upper section of the *container* shall be divided into five distinct areas and marked for pendulum impact preconditioning and fluid exposure. The five areas

shall each be nominally 100 mm in diameter. The five areas do not need to be oriented along a single line, but shall not overlap,

b) The approximate centre of each of the five areas shall be preconditioned by the impact of a pendulum body. The steel impact body of the pendulum shall have the shape of a pyramid with equilateral triangle faces and a square base, the summit and the edges being rounded to a radius of 3 mm. The centre of percussion of the pendulum shall coincide with the centre of gravity of the pyramid; its distance from the axis of rotation of the pendulum being 1 m and the total mass of the pendulum referred to its centre of percussion shall be 15 kg. The energy of the pendulum at the moment of impact shall not be less than 30 J, and as close to that value as possible. During pendulum impact, the *container* shall be held in position by the end bosses or by the intended mounting brackets. The *container* shall be unpressurized during preconditioning,

c) Each of the 5 preconditioned areas shall be exposed to one of five solutions. The five solutions are:
   i) Sulphuric acid – 19 per cent solution by volume in water,
   ii) Sodium hydroxide – 25 per cent solution by weight in water,
   iii) Methanol/gasoline - 5/95 per cent concentration,
   iv) Ammonium nitrate – 28 per cent solution by weight in water,
   v) Windshield washer fluid (50 per cent by volume solution of methyl alcohol and water).

d) During the exposure, orientate the *container* with the fluid exposure areas uppermost. Place a pad of glass wool approximately 0.5 mm thick and 100 mm in diameter on each of the five preconditioned exposure areas. Apply an amount of the test fluid to the glass wool sufficient to ensure that the pad is wetted evenly across its surface and through its thickness for the duration of the test,

e) Pressure cycle between ≤ 2MPa and ≥ 1.25 times *nominal working pressure* for the number of *filling cycles* calculated in accordance with **paragraph 2.4.6.** of this Regulation, at a maximum pressurisation rate of 2.75 MPa/s,

f) Pressurize to 1.25 times *nominal working pressure* and hold at that pressure for a minimum of 24 hours until the elapsed exposure time (pressure cycling and pressure hold) to the environmental fluids equals at least 48 hours,

g) Burst test in accordance with **paragraph B9.2.** of this annex.

B14.3. Requirement

The *container* shall achieve a *burst pressure* of ≥ 1.8 times *nominal working pressure*.

B14.4. Results

The *burst pressure* shall be presented in a test summary, e.g. **Table 7A.4** of this annex.

B15. COMPOSITE FLAW TOLERANCE TEST

B15.1. Sampling

The test applies to Type 2, 3 and 4 *containers*.
Type approval testing - number of *finished containers* to be tested: 1

B15.2. Procedure

The *container*, complete with protective coating, shall be tested in the following sequence:

a) Flaws in the longitudinal direction shall be cut into the *over-wrap*. The flaws shall be greater than the visual inspection limits as specified by the *manufacturer*, and at least the following flaws shall be cut in the longitudinal direction into the *container* sidewall:
   i) 25mm long by 1.25mm deep,
   ii) 200mm long by 0.75mm deep.
b) Pressure cycle the flawed *Container* between ≤ 2.0 MPa and ≥ 1.25 times *nominal working pressure* at ambient temperature for 3.0 times the number of *filling cycles* in accordance with **paragraph 2.4.6.**of this Regulation.

B15.3. Requirement

The *container* shall not leak or rupture within 0.6 times the number of *filling cycles* in accordance with **paragraph 2.4.6.** of this Regulation, but may fail by leakage during the remaining test cycles.

B15.4. Results

The number of cycles to failure, along with the location and description of the failure initiation shall be presented in a test summary, e.g. **Table 7A.4** of this annex.

B16. ACCELERATED STRESS RUPTURE TEST

B16.1. Sampling

The test applies to Type 2, 3 and 4 *containers*.
Type approval testing - number of *finished containers* to be tested: 1

B16.2. Procedure

The *container*, free of any protective coating, shall be tested in the following sequence:

a) Pressurise to 1.25 times *nominal working pressure* for 1000 hours at 85 °C,
b) Burst test in accordance with **paragraph B9.2.** of this annex.

B16.3. Requirement

The *container* shall achieve a *burst pressure* of ≥ 0.85 times the *nominal working pressure* times the *burst pressure* ratio given in **paragraph A3.9.** of this annex.

B16.4. Results

The *burst pressure* shall be presented in a test summary, e.g. **Table 7A.4** of this annex.

B17. EXTREME TEMPERATURE PRESSURE CYCLING TEST

B17.1. Sampling

The test applies to Type 2, 3 and 4 *containers*.
Type approval testing - number of *finished containers* to be tested: 1

B17.2. Procedure

The *containers*, with the composite wrapping free of any protective coating, shall be hydrostatically cycle tested in the following sequence:

a) Condition for 48 hours with a temperature ≥ 85 °C and a relative humidity ≥ 95 per cent,
b) Pressure cycle between ≤ 2.0 MPa and ≥ 1.25 times *nominal working pressure* at a temperature ≥ 85 °C and a relative humidity ≥ 95 per cent, for 1.5 times the number of *filling cycles* calculated in accordance with **paragraph 2.4.6.** of this Regulation,
c) Stabilise at ambient conditions,
d) Condition the *container* and test fluid to a temperature ≤ -40 °C as measured on the container surface and in the fluid,
e) Pressure cycle between ≤ 2.0 MPa and ≥ *nominal working pressure* at ≤ -40 °C, for 1.5 times the number of *filling cycles* calculated in accordance with **paragraph 2.4.6.** of this Regulation,
f) Leak test 1/ in accordance with **paragraph B1.** of this annex,
g) Burst test in accordance with **paragraph B9.2.** of this annex.

Note: 1/ - Applies to Type 4 *containers* only.

B17.3. Requirement

The *containers* shall be cycle tested without showing evidence of rupture, leakage, or fibre unravelling.

Type 4 *containers* shall meet the leak test requirements.

The *containers* shall not burst at less than 85 per cent of the *nominal working pressure* times the *burst pressure* ratio given in **paragraph A3.9.** of this annex.

B17.4. Results

The *burst pressure* shall be presented in a test summary, e.g. **Table 7A.4** of this annex.

B18. IMPACT DAMAGE TEST

B18.1. Sampling

The test applies to Type 3 and 4 *containers*.
Type approval testing - number of *finished containers* to be tested: minimum 1 (all impact tests may be performed on one *container, or* individual impacts on a maximum of 3 *containers*).

B18.2. Procedure

The drop tests shall be performed at ambient temperature without internal pressurisation or attached valves. A plug may be inserted in the threaded ports to prevent damage to the threads and seal surfaces.

The surface onto which the *container* is dropped shall be a smooth, horizontal concrete pad or similar rigid floor.

The *container* shall be tested in the following sequence:

a) Drop once from a horizontal position with the bottom 1.8 m above the ground,
b) Drop once onto each end of the *container* from a vertical position with a potential energy ≥ 488 J, but in no case shall the bottom end be more than 1.8 m above the ground,
c) Drop once at a 45° angle, and then for non-symmetrical or non-cylindrical *containers* rotate the *container* through 90° along its longitudinal axis and drop again at a 45° angle, with its centre of gravity 1.8 m above the ground. However, if the bottom is closer to the ground than 0.6 m, the drop angle shall be changed to maintain a minimum height of 0.6 m and the centre of gravity 1.8 m above the ground.
d) No attempt shall be made to prevent bouncing of the *container*, but it may be prevented from falling over during the vertical drop test.
e) Pressure cycle the *container* between ≤ 2.0 MPa and ≥ 1.25 times *nominal working pressure* for three times the number of *filling cycles* calculated in accordance with **paragraph 2.4.6.** of this Regulation.

B18.3. Requirements

The *container* shall not leak or rupture within 0.6 times the number of *filling cycles* calculated in accordance with **paragraph 2.4.6.** of this Regulation, but may fail by leakage during the remaining test cycles.

B18.4. Results

The number of cycles to failure, along with the location and description of the failure initiation shall be presented in a test summary, e.g. **Table 7A.4** of this annex.

B19. LEAK TEST

B19.1. Sampling

The test applies to Type 4 *containers* only.
Type approval testing - number of *finished containers* to be tested: 1
Batch testing - number of *finished containers* to be tested per *batch*: in accordance with **paragraph A5.1.** of this annex.
Production testing - number of *finished containers* to be tested: all

B19.2. Procedure

The *container* shall be thoroughly dried and pressurised to *nominal working pressure* with *leak test gas*.

For batch testing, follow the test sequence given in **note 6/** to **Table 7A.6** to this annex.

B19.3. Requirement

Any leakage detected through cracks, pores, unbonds or similar defects shall cause the *container* to be rejected. Permeation through the wall in accordance with **paragraph B20.** of this annex is not considered to be leakage.

B19.4. Results

The total leakage value shall be presented in a test summary, e.g. **Table 7A.4** of this annex. The leakage rate is applicable to tests carried out with 100 per cent hydrogen only. Leakage rates for other gases or gas mixtures shall be converted to an equivalent leakage rate to that for 100 per cent hydrogen.

The *manufacturer* shall keep the total leakage value on file throughout the *service life* of the *container*.

B20. PERMEATION TEST

B20.1. Sampling

The test applies to Type 4 *containers* only.
Type approval testing - number of *finished containers* to be tested: 1

B20.2. Procedure

Special consideration shall be given to safety when conducting this test.

The *container* shall be tested in the following sequence:
a) Pressurize with hydrogen gas to *nominal working pressure*,
b) Place in an enclosed sealed chamber at ambient temperature and monitor for permeation for ≥ 500 hours.

B20.3. Requirement

The steady state permeation rate shall be less than 1.0 Ncm^3 per hour of hydrogen per litre internal volume of the *container*.

B20.4. Results

The steady state permeation rate shall be presented in a test summary, e.g. **Table 7A.4** of this annex.

B21. BOSS TORQUE TEST

B21.1. Sampling

The test applies to Type 4 *containers* only.
Type approval testing - number of *finished containers* to be tested: 1
Batch testing - number of *finished containers* to be tested per *batch*: in accordance with **paragraph A5.1.** of this annex.

B21.2. Procedure

The *container* shall be tested in the following sequence:
a) Restrain the body of the *container* against rotation,
b) Apply a torque of 2 times the valve or *pressure relief device* installation torque specified by the *manufacturer* to each end boss of the *container*; first in the direction to tighten the threaded connection, then in the direction to loosen, and finally again in the direction to tighten,

For type approval, the following tests shall also be conducted:

a) Leak test in accordance with **paragraph B19.** of this annex,
b) Burst test in accordance with **paragraphs B9.2. & 9.3.** of this annex.

For batch testing, follow the test sequence given in **note 6**/ to **Table 7A.6** to this annex.

B21.3. Requirement

For type approval, the *container* shall meet the leak and burst test requirements.
For batch testing, the *container* shall meet the leak test requirements.

B21.4. Results

The applied torque, leakage and *burst pressure* shall be presented in a test summary, e.g. **Table 7A.4** of this annex. The leakage rate is applicable to tests carried out with 100 per cent hydrogen only. Leakage rates for other gases or gas mixtures shall be converted to an equivalent leakage rate to that for 100 per cent hydrogen.

The *manufacturer* shall keep the results on file throughout the *service life* of the *container*.

B22. HYDROGEN GAS CYCLING TEST

B22.1. Sampling

The test applies to Type 4 *containers* only.
Type approval testing - number of *finished containers* to be tested: 1

B22.2. Procedure

Special consideration shall be given to safety when conducting this test.

The *container* shall be tested in the following sequence:

a) Use hydrogen gas to pressure cycle the *container* between ≤ 2.0 MPa and ≥ *nominal working pressure* for 1000 cycles. The filling time shall not exceed 5 minutes. Unless otherwise specified by the *manufacturer*, temperatures during venting shall not exceed the values specified in **paragraph 2.4.5.** of this Regulation.
b) Leak test in accordance with **paragraph B19.** of this annex,
c) Section the *container* and inspect the *liner* and *liner*/end boss interface for evidence of any deterioration, such as fatigue cracking or electrostatic discharge.

B22.3. Requirement

The *container* shall meet the leak test requirements.

The *liner* and *liner*/end boss interface shall be free of any deterioration, such as fatigue cracking or electrostatic discharge.

B22.4. Results

The total leakage value shall be presented in a test summary, e.g. **Table 7A.4** of this annex.

B23. HYDRAULIC TEST

B23.1. Sampling

The test applies to all *container* Types.
Production testing - number of *finished containers* to be tested: all

B23.2. Procedure and Requirement

a) The *container* shall be pressurized to ≥ 1.5 times *nominal working pressure*. Under no circumstance may the pressure exceed the *auto-frettage pressure*.
b) The pressure shall be maintained for at least 30 seconds to ensure complete expansion. If the pressure cannot be maintained due to failure of the test apparatus, it is permissible to repeat the test at a pressure increased by 0.7 MPa. Not more than two such repeat tests are permitted.
c) For Type 1, 2 or 3 *containers*, the *manufacturer* shall define the appropriate limit of permanent volumetric expansion for the test pressure used, but in no case shall the permanent expansion exceed 5 per cent of the total volumetric expansion measured under the test pressure. Permanent expansion is defined as the residual volumetric expansion after the pressure has been released.
d) For Type 4 *containers*, the *manufacturer* shall define the appropriate limit of elastic expansion for the test pressure used, but in no case shall the elastic expansion of any *container* exceed the average *batch* value by more than 10 per cent. Elastic expansion is defined as the total expansion less the permanent expansion (see c) above).
e) Any *container* that does not meet the defined expansion limit shall be rejected, but may still be used for batch test purposes.

B23.3. Results

The results shall be presented in a test summary, e.g. **Table 7A.4** of this annex.

The *manufacturer* shall keep the results on file throughout the *service life* of the *container*.

Annex 8

REQUIREMENTS AND APPROVAL TEST PROCEDURES FOR SPECIFIC COMPONENTS OTHER THAN CONTAINERS

Contents Page

Annex 8: Part A

PROVISIONS REGARDING THE APPROVAL OF SPECIFIC COMPONENTS OTHER THAN CONTAINERS

A1. REFERENCES

The following standards contain provisions that, through reference in this text, constitute provisions of this annex. Where standards other than ISO standards are referenced they may be replaced by equivalent national standards.

International Organisation for Standardization (ISO) Standards

ISO 6957: 1988	Copper Alloys - Ammonia Test For Stress Corrosion Resistance
ISO 7866:1999	Gas Cylinders - Refillable Seamless Aluminium Alloy Gas Cylinders - Design, Construction And Testing
ISO 9227: 1990	Corrosion Tests In Artificial Atmospheres - Salt Spray Tests
ISO 9809-1:1999	Gas Cylinders - Refillable Seamless Steel Gas Cylinders - Design, Construction And Testing – Part 1: Quenched And Tempered Steel Cylinders With Tensile Strength Less Than 1100 MPa
ISO 11114-1: 1997	Transportable Gas Cylinders – Compatibility Of Cylinder And Valve Materials With Gas Contents – Part 1: Metallic Materials
ISO/DIS 11114-4: 2002	Transportable Gas Cylinders – Compatibility Of Cylinders And Valve Materials With Gas Contents – Part 4: Test Methods For Selecting Metallic Materials Resistant To Hydrogen Embrittlement
ISO/WD 17268: 2001	Gaseous Hydrogen – Land Vehicle Filling Connectors

American Society for Testing and Materials (ASTM) Standards

ASTM D572:	Test for Accelerated Aging of Vulcanised Rubber by Oxygen Pressure Method

A2. GENERAL REQUIREMENTS

A2.1. Unless otherwise stated in this annex all tests shall be performed at 20 °C ± 5 °C.

A2.2. Explosive gas mixtures shall be prevented from developing during the test procedures described in this annex.

A2.3. The test period for leakage and pressure tests shall be not less than 3 minutes.

A2.4. Unless otherwise stated the applied test pressure is to be measured at the inlet of the component under test.

A2.5 If a component is exposed to the pressure due to refilling operations, then *filling cycles* shall be used. If a component is exposed to pressure due to the operation of the vehicle, i.e. switching of the vehicle activation switch, then *duty cycles* shall be used.

A3. APPROVAL REQUIREMENTS

A3.1. GENERAL APPROVAL REQUIREMENTS

A3.1.1. In addition to the requirements given below, the *manufacturer* shall complete all documents referred to in **Part B** of this annex and submit them to the competent authority when applying for type approval.

A3.1.2. The *specific components* shall be subjected to the applicable test procedures laid down in **Table 8A.1** of this annex. The tests shall be conducted on *specific components* that are representative of normal production and complete with identification marks.

A3.1.3. The tests specified in paragraphs **B4. to B8.** of this annex shall be conducted on the same samples of *specific components* in the sequence given in **Table 8A.1** unless otherwise indicated, e.g. for *fittings* the corrosion resistance test (**B4.**) shall be followed by an endurance test (**B5.**), then by an hydraulic pressure cycle test (**B6.**), and finally by an external leakage test (**B8.**). If a *specific component* does not contain metallic sub-components the testing shall commence with the first applicable test.

A3.2. SPECIFIC APPROVAL REQUIREMENTS

A3.2.1. Approval for a *flexible fuel line* shall be given for one of any length with a minimum bending radius specified by the *manufacturer* and when assembled with a specific type of *fitting.*

A3.2.2. Any reinforcing interlayer of a *flexible fuel line* shall be protected against corrosion either by a cover or by using a corrosion resistant material for the reinforcement(s), e.g. stainless steel. If a cover is used the formation of bubbles between layers shall be prevented.

A3.2.3. *Flexible fuel lines* shall have an electrical resistance of less than 1 mega-ohm per meter.

A3.2.4. The profile of *receptacles* shall comply with **ISO 17268**.

SPECIFIC COMPONENT	TYPE OF TEST					
	Material tests **B1, B2 & B3**	Corrosion resistance test **B4**	Endurance test **B5**	Hydraulic pressure cycle test **B6**	Internal leakage test **B7**	External leakage test **B8**
Automatic valves	✓	✓	✓	✓	✓	✓
Fittings	✓	✓	✓	✓		✓
Flexible fuel lines	✓	✓	✓	✓		✓
Heat exchangers	✓	✓		✓		✓
Hydrogen filters	✓	✓		✓		✓
Manual valves	✓	✓	✓	✓	✓	✓
Non-return valves	✓	✓	✓	✓	✓	✓
Pressure regulators	✓	✓	✓	✓	✓	✓
Pressure relief devices	✓	✓	✓	✓	✓	✓
Pressure relief valves	✓	✓	✓	✓	✓	✓
Receptacles	✓	✓	✓	✓	✓	✓
Removable storage system connectors	✓	✓	✓	✓		✓
Sensors for hydrogen systems	✓	✓	✓	✓		✓

Table 8A.1: Applicable Test Procedures For Specific Components Other Than Containers

Annex 8: Part B

APPROVAL TEST PROCEDURES FOR
SPECIFIC COMPONENTS OTHER THAN CONTAINERS

MATERIAL TESTS

B1. HYDROGEN COMPATIBILITY TEST

B1.1. Sampling

The test applies to the materials used in a *specific component* where the material is in contact with hydrogen except:

a) Aluminium alloys that conform to paragraphs 6.1. and 6.2. of ISO 7866,
b) Steels that conform to paragraph 6.3. and 7.2.2. of ISO 9809-1.

Number of material samples to be tested: 3

B1.2. Procedure and Requirements

a) For metallic materials other than those stated above hydrogen compatibility shall be demonstrated in accordance with ISO11114-1 or ISO/DIS 11114-4.
b) Non-metallic materials: hydrogen compatibility shall be demonstrated.

B1.3. Results

The results of the tests shall be presented in a test summary.

B2. AGEING TEST

B2.1. Sampling

All non-metallic materials used in a *specific component* shall be tested.
Number of material samples to be tested: 3

B2.2. Procedure and Requirements

Special consideration shall be given to safety when conducting this test.

The test shall be undertaken in accordance with **ASTM D572.** The sample shall be exposed to oxygen at the maximum material temperature in accordance with **paragraph 2.4.5.1.** of this Regulation at 2.0 MPa for a period of 96 hours. Either the tensile strength and elongation or the microhardness shall comply with the specifications given by the *manufacturer*. No visible cracking of the test samples is allowed.

B2.3. Results

The results of the tests shall be presented in a test summary.

B3. OZONE COMPATIBILITY TEST

B3.1. Sampling

The test applies to elastomer materials where:
a) A sealing surface is exposed directly to air, e.g. facing seal of a *receptacle*,
b) Used as a *flexible fuel line* cover.

Number of material samples to be tested: 3

B3.2. Procedure and Requirements

The test shall be undertaken in accordance with **ISO 1431/1**.
The test samples shall be stressed to 20 per cent elongation and exposed to air at 40 °C with an ozone concentration of 0.5 parts per million for a period of 120 hours.

No visible cracking of the test samples is allowed.

B3.3. Results

The results of the tests shall be presented in a test summary.

TESTS OF SPECIFIC COMPONENTS

B4. CORROSION RESISTANCE TEST

B4.1. Sampling

Number of *specific components* to be tested: 3

B4.2. Procedure and requirements

Test a) Metallic components shall be submitted to a 144 hour salt spray test in accordance with **ISO 9227** with all connections closed and shall meet the requirements therein.

Test b) A copper alloy component shall also be submitted to 24 hours immersion in ammonia in accordance with **ISO 6957** with all connections closed and shall meet the requirements therein.

B4.3. Results

The results of the tests shall be presented in a test summary.

B5. ENDURANCE TEST

B5.1. Sampling

Number of *specific components* to be tested: 3

B5.2. Procedures and requirements

B5.2.1. Automatic, manual & non-return valves

The *specific component* shall be tested in accordance with the following procedure:

a) Pressurize the specific component with dry air, nitrogen, or hydrogen to *nominal working pressure* and subject it to 96 per cent of the total number of test cycles in accordance with **Table 8B.1** of this annex at 20 °C ± 5°C. A complete test cycle shall take place over a period of not less than 10 ± 2 seconds. When the valve is in the closed position the downstream pressure shall decay to 0.5 times the *nominal working pressure* of the component or lower. The *specific component* shall fulfil the requirements of the internal and external leakage tests (paragraphs **B7. and B8.** of this annex respectively) at this temperature.

b) The *Specific Component* shall then be operated through 2 per cent of the total number of test cycles at the minimum material temperature in accordance with **paragraph 2.4.5.1.** of this Regulation after 2 hours conditioning at this temperature. The *specific component* shall fulfil the requirements of the internal and external leakage tests (paragraphs **B7. and B8.** of this annex respectively) at this temperature.

c) The *specific component* shall then be operated through 2 per cent of the total number of test cycles at the maximum material temperature in accordance with **paragraph 2.4.5.1.** of this Regulation after 2 hours conditioning at this temperature and at 1.25 times *nominal working pressure*. The *specific component* shall fulfil the requirements of the internal and external leakage tests (paragraphs **B7. and B8.** of this annex respectively) at this temperature.

SPECIFIC COMPONENT	NO. OF TEST CYCLES
Automatic valve	1.5 times the number of *duty cycles* or *filling cycles* in accordance with **paragraph 2.4.6. or 2.4.7.** of this Regulation, as appropriate to the use of the valve.
Manual valve	100
Non-return valve	2.0 times the number of *duty cycles* or *filling cycles* in accordance with **paragraph 2.4.6. or 2.4.7.** of this Regulation, as appropriate to the use of the valve.

Table 8B.1: Test cycles for valves

B5.2.2. Fittings

Fittings shall be subjected to 25 connection/disconnection cycles.

B5.2.3. Flexible fuel lines

The length of the flexible part of the *flexible fuel line* with its *fittings* attached, to be used in the following test shall be calculated as follows:

$$L = 4.142R + 3.57D$$

where:

L = Length of the flexible part of the *flexible fuel line*
R = Minimum bending radius specified by the *manufacturer*
D= Outside diameter of the *flexible fuel line*

The *flexible fuel line* shall be bent in the manner depicted in **Figure 8B.1** of this annex and attached to a fixture in that position by the *fittings* with which it is to be approved. One end of the *flexible fuel line* shall be attached to a reciprocating manifold and the other end shall be attached to a stationary manifold connected to a hydraulic supply. The *flexible fuel line* shall be pressurized quickly by means of a quick opening solenoid valve, such that one cycle consists of holding the pressure at 1.25 times the *nominal working pressure* for 10 ± 1 seconds (except for *flexible fuel lines* with a required material temperature of 120 ^{0}C where the hold pressure shall be 1.37 times *nominal working pressure*) and then reducing it to less than 0.1 times the *nominal working pressure* for 5 ± 0.5 seconds. The total number of test cycles shall be equal to 2.0 times the number of *filling cycles* or *duty cycles* as appropriate to the use of the *flexible fuel line* in accordance with paragraph **2.4.6. or 2.4.7**. Of this Regulation as appropriate 50 per cent of the test cycles shall be performed at the minimum

and the remaining 50 per cent at the maximum material temperature in accordance with **paragraph 2.4.5.1.** of this Regulation.

Superimposed on the hydraulic pressure cycles is a flexing cycle. The flexing rate shall be 6 ± 2 per cent of the hydraulic pressure cycling rate. This assures that the *flexible fuel line* is in a different configuration on each succeeding pressure cycle impulse. The test fixture is shown in **Figure 8B.1** of this annex with the distance A calculated as:

$$A = 1.75R + D$$

The *flexible fuel line* shall not show any visible signs of damage.

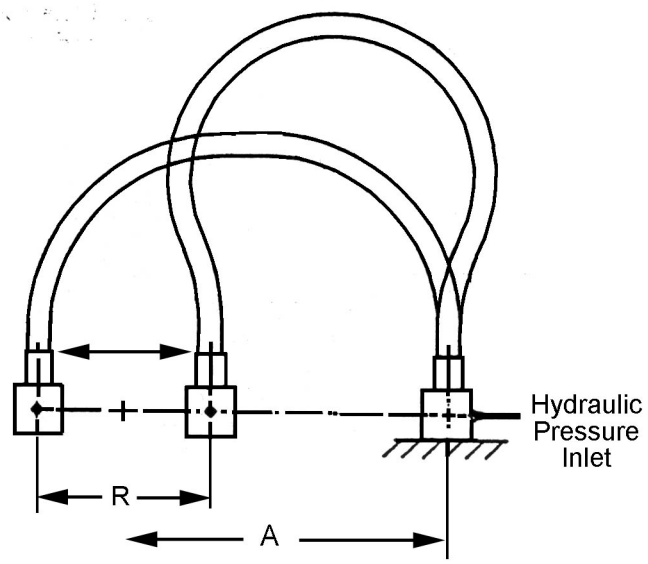


Figure 8B.1: Flex-impulse testing fixture

B5.2.4. Pressure regulators

Pressure regulators shall be tested in accordance with the following procedure:

a) The *pressure regulator* shall be connected to a source of *leak test gas* at *nominal working pressure* and cycled through 95 per cent of the number of *duty cycles* calculated in accordance with **paragraph 2.4.7.** of this Regulation. One cycle shall consist of flow until stable outlet pressure has been attained, after which the gas flow shall be shutoff by a downstream quick closing valve until stable lockup pressure has been achieved. The *pressure regulator* shall then fulfil the requirements of the internal and external leakage tests (**paragraphs B7. and B8.** of this annex respectively) conducted at 20 °C ± 5 °C.

b) The inlet of the *pressure regulator* shall be pressure cycled through 1 per cent of the number of *duty cycles* from *nominal working pressure* to 0.5 times the *nominal*

working pressure or less. Subsequently the *pressure regulator* shall fulfil the requirements of the internal and external leakage tests (**B7. and B8.**) conducted at 20 °C ± 5 °C.

c) The cycling procedure in **a)** above shall be repeated at the maximum material temperature in accordance with **paragraph 2.4.5.1.** of this Regulation and at 1.25 times the *nominal working pressure* for 1 per cent of the number of *duty cycles*. Subsequently the *pressure regulator* shall fulfil the requirements of the internal and external leakage tests (**B7. and B8.**) conducted at the maximum material temperature.

d) The cycling procedure in b) above shall be repeated at the maximum material temperature and at 1.25 times the *nominal working pressure* for 1 per cent of the number of *duty cycles*. Subsequently the *pressure regulator* shall fulfil the requirements of the internal and external leakage tests (**B7. and B8.**) conducted at the maximum material temperature.

e) The cycling procedure in a) above shall be repeated at the minimum material temperature in accordance with **paragraph 2.4.5.1.** of this Regulation and at *nominal working pressure* for 1 per cent of the number of *duty cycles*. Subsequently the *pressure regulator* shall fulfil the requirements of the internal and external leakage tests (**B7. and B8.**) conducted at the minimum material temperature.

f) The cycling procedure in b) above shall be repeated at the minimum material temperature and at *nominal working pressure* for 1 per cent of the number of *duty cycles*. Subsequently the *pressure regulator* shall fulfil the requirements of the internal and external leakage tests (**B7. and B8.**) conducted at the minimum material temperature.

B5.2.5. Pressure relief devices

a) Creep test

Pressure relief devices shall be hydrostatically pressurised to 1.25 times *nominal working pressure* and held for 500 hours at a temperature (T_L) calculated from the following equation:

$$T_L = T\,(0.057)^{(0.34 \log(T/Tf))}$$

where

T_L = Test temperature, ºC
T_f = Activation temperature of the *pressure relief device*, ºC
T = 82 ºC
Log is base 10

Pressure relief devices shall not show signs of creep and shall fulfil the requirements of the internal leakage test (**paragraph B7.** of this annex) after being subjected to the above test.

b) Activation temperature

Following the creep test in a) above, the *pressure relief devices* shall be pressurized with dry air, nitrogen, or hydrogen to *nominal working pressure*. Subsequently the

pressure relief devices shall be exposed to an increasing temperature cycle starting from ambient temperature with a rate not exceeding 10 °C per minute until the specified activation temperature minus 10 °C is reached and then with a rate of not exceeding 2 °C per minute until the *pressure relief devices* activate. The activation temperature shall be within a range of ± 5 per cent of the manufacturer's specified activation temperautre. After activation the *pressure relief devices* shall show no evidence of fragmentation.

B5.2.6. Pressure Relief Valves

Pressurize the *pressure relief valve* for 25 cycles. A test cycle consists of pressurizing the *pressure relief valve* to the activation pressure causing the *pressure relief valve* to open and vent. Once the *pressure relief valve* is venting the inlet pressure shall be reduced causing the *pressure relief valve* to re-seat. The cycle time shall be a period of 10 ± 2 s. For the final cycle the activation pressure shall be reported and shall correspond to the activation pressure specified by the *manufacturer* within a range of ±5 per cent.

B5.2.7. Receptacles

Receptacles shall be submitted to a number of connection/disconnection cycles equal to three times the number of *filling cycles* calculated in accordance with **paragraph 2.4.6.** of this Regulation. For each cycle the *receptacle* shall be pressurised to 1.25 times the *nominal working pressure.*

B5.2.8. Sensors for hydrogen systems

If a sensor is intended to be installed into a *hydrogen component* and is subjected to the same number of *duty cycles* or *filling cycles,* it shall be subjected to the same endurance test as the *hydrogen component* into which it is installed.

B5.2.9. Removable storage system connector

A *removable storage system connector* shall be submitted to a number of connection/disconnection cycles equal to three times the number of *filling cycles* calculated in accordance with **paragraph 2.4.6.** of this Regulation. For each cycle the *removable storage system connector* shall be pressurised to 1.25 times the *nominal working pressure*. Subsequently the *removable storage system connector* shall fulfil the requirements of the external leakage test (**paragraph B8.** of this annex) when the parts of the *removable storage system connector* mounted on the vehicle and on the *removable storage system* are separated and also when connected together.

B5.3. Results

The results of the test shall be presented in a test summary.

B6. HYDRAULIC PRESSURE CYCLE TEST

B6.1. Sampling

Number of *specific components* to be tested: 3

B6.2. Procedure and requirements

B6.2.1. *Pressure relief devices*

Pressure relief devices shall be subjected to 1.5 times the number of *filling cycles* calculated in accordance with **paragraph 2.4.6.** of this Regulation at both the minimum and maximum material temperatures in accordance with **paragraph 2.4.5.1.** of this Regulation.

The pressure shall periodically change from 2 MPa to 1.25 times *nominal working pressure* at a rate not exceeding 4 cycles per minute, except when tested at the minimum material temperature when the maximum test pressure shall be *nominal working pressure*.

If fusible metal is used in a *pressure relief device* it shall show no visible sign of extrusion.

B6.2.2. *Specific components* other than *pressure relief devices*

The *specific components* shall be subjected to 3 times the number of *filling cycles* or *duty cycles* calculated in accordance with **paragraph 2.4.6.** or **2.4.7.** of this Regulation.

The pressure shall periodically change from 2.0 MPa to 1.25 times *nominal working pressure* for components upstream of the *first pressure regulator,* or from 0.1 times *MAWP* to MAWP for components downstream of the *first pressure regulator*, at a rate not exceeding 4 cycles per minute.

Subsequently the *component* shall fulfil the requirements of the internal and external leakage tests (paragraphs **B7. and B8.** of this Regulation).

B6.3. Results

The results of the tests shall be presented in a test summary.

B7. INTERNAL LEAKAGE TEST

B7.1. Sampling

Number of *specific components* to be tested: 3

B7.2. Procedure

The *specific components* shall be tested using *leak test gas* and shall be pressurised at the inlet of the component when it is in its characteristic closed position and with the corresponding outlet port open.

The *specific component* shall be tested at the following conditions:

a) At 20 °C ± 5 °C and at 0.02 times *nominal working pressure* and at *nominal working pressure*. Where an external leakage test (**paragraph B8.** of this annex) is also required at this temperature it may be undertaken before the next stage of this test.

b) At the minimum material temperature in accordance with **paragraph 2.4.5.1.** of this Regulation, after 2 hours conditioning to this temperature and at 0.02 times *nominal working pressure* and at *nominal working pressure*. Where an external leakage test (**paragraph B8.** of this annex) is also required at this temperature it may be undertaken before the next stage of this test.

c) At the maximum material temperature in accordance with **paragraph 2.4.5.1.** of this Regulation, after 2 hours conditioning to this temperature and at 0.02 times *nominal working pressure* and 1.25 times *nominal working pressure*, except for components with a required material temperature of 120 ^{0}C where the higher test pressure shall be 1.37 times *nominal working pressure*.

The component shall be observed for leakage with its outlet port open. The leakage can be determined by a flowmeter installed on the inlet side of the component or by another test method, which has been demonstrated to be equivalent.

B7.3. Requirements

When pressurised the *specific component* shall stay bubble free for three minutes or shall not leak internally at a rate exceeding 10 Ncm^3 per hour. The permitted leakage rate is applicable to tests with 100 per cent hydrogen only. Permitted leakage rates for other gases or gas mixtures shall be converted to an equivalent leakage rate to that for 100 per cent hydrogen.

B7.4. Results

The results of the test shall be presented in a test summary.

B8. External leakage test

B8.1. Sampling

Number of *specific components* to be tested: 3

B8.2. Procedure

The *specific components* shall be tested using *leak test gas* at the following conditions:

a) At 20 °C ± 5°C and at 0.02 times *nominal working pressure* and at *nominal working pressure*.

b) At the minimum required material temperature, in accordance with **paragraph 2.4.5.1.** of this Regulation, after 2 hours conditioning to this temperature and at 0.02 times *nominal working pressure* and at *nominal working pressure*.

c) At the maximum required material temperature, in accordance with **paragraph 2.4.5.1.** of this Regulation, after 2 hours conditioning to this temperature and at 0.02 times *nominal working pressure* and 1.25 times *nominal working pressure*, except for components with a required material temperature of 120 ^{0}C where the higher test pressure shall be 1.37 times *nominal working pressure*.

For heat exchangers this test shall only be undertaken on the hydrogen circuit.

B8.3. Requirements

Throughout the test the *specific component* shall be free from leakage through stem or body seals or other joints, and shall not show evidence of porosity in casting, demonstrated by a surface active agent without formation of bubbles for 3 minutes or measured with a combined leakage and permeation rate less than 10 *Ncm*^{3} per hour (for *flexible fuel lines* only 10 *Ncm*^{3} per hour per meter) or it shall be tested by using a demonstrated equivalent test method. The permitted leakage rate is applicable to tests with 100 per cent hydrogen only. Permitted leakage rates for other gases or gas mixtures shall be converted to an equivalent leakage rate to that for 100 per cent hydrogen.

B8.4 Results

The results of the test shall be presented in a test summary.

Annex 9

SPECIAL REQUIREMENTS TO BE APPLIED TO THE SAFETY ASPECTS OF COMPLEX ELECTRONIC VEHICLE CONTROL SYSTEMS

1. GENERAL

This annex defines the special requirements for documentation, verification and test with respect to the safety aspects of *complex electronic vehicle control systems* as far as this Regulation is concerned.

2. DOCUMENTATION

2.1. Requirements

The vehicle manufacturer shall provide a documentation package, which gives access to the basic design of "the system" and the means by which it is linked to other vehicle systems or by which it directly controls output variables. The function(s) of "the system" and the *safety concept*, as laid down by the vehicle manufacturer, shall be explained. Documentation shall be brief, yet provide evidence that the design and development has had the benefit of expertise from all the system fields that are involved. For periodic technical inspections, the documentation shall indicate the means by which the current operational status of the system can be checked.

Documentation shall be made available in 2 parts:

a) The formal documentation package for the approval, containing the material listed in **paragraphs 2.2. to 2.4.** of this annex, which shall be supplied to the Technical Service at the time of submission of the type approval application. This will be taken as the basic reference for the verification process set out in **paragraph 3.** of this annex.

b) Additional material and analysis data which shall be retained by the vehicle manufacturer, but made open for inspection at the time of type approval.

2.2. Description of the functions of "the system".

A description shall be provided which gives a simple explanation of all the control functions of "the system" and the methods employed to achieve the objectives, including a statement of the mechanism(s) by which control is exercised including:

a) A list of all input and sensed variables shall be provided and the working range of these defined.

b) A list of all output variables that are controlled by "the system" shall be provided and an indication given, in each case, of whether the control is direct or via another

vehicle system. The *range of control* exercised on each such variable shall be defined.

c) Limits defining the *boundary of functional operation* shall be stated where appropriate to system performance.

2.3. System layout and schematics

2.3.1 Inventory of components

A list shall be provided, collating all the *units* of "the system" and mentioning the other vehicle systems that are needed to achieve the control function in question. An outline schematic showing these *units* in combination, shall be provided with both the equipment distribution and the interconnections clearly identified.

2.3.2. Functions of the *units*

The function of each *unit* of "the system" shall be outlined and the signals linking it with other *units* or with other vehicle systems shall be shown. This may be provided by a labelled block diagram or other schematic, or by a description aided by such a diagram.

2.3.3. Interconnections

A circuit diagram shall show interconnections within "the system" for the electric *transmission links*, by a piping diagram for pneumatic or hydraulic *transmission links* and by a simplified diagrammatic layout for mechanical *transmission links*.

2.3.4. Signal flow and priorities

There shall be a clear correspondence between these *transmission links* and the signals carried between *units*. Priorities of signals on multiplexed data paths shall be stated, wherever priority may be an issue affecting performance or safety as far as this Regulation is concerned.

2.3.5. Identification of *units*

Each *unit* shall be clearly and unambiguously marked with the *manufacturer's* identification marking to provide corresponding hardware and documentation association. Where functions are combined within a single *unit* or indeed within a single computer, but shown in multiple blocks in the block diagram for clarity and ease of explanation, only a single identification marking shall be used. The *manufacturer* shall, by the use of this identification marking, affirm that the equipment supplied conforms to the corresponding document.

The identification marking defines the hardware and software version and, where the latter changes such as to alter the function of the *unit*, this identification marking shall also be changed.

2.4. *Safety concept* of the vehicle manufacturer

2.4.1. The vehicle manufacturer shall provide a statement that affirms that the strategy chosen to achieve "the system" objectives will not, under non-fault conditions prejudice the safe operation of systems which are subject to the prescriptions of this Regulation.

2.4.2. In respect of software employed in "the system", the outline architecture shall be explained and the design methods and tools used shall be identified. The *manufacturer* shall be prepared, if required, to show some evidence of the means by which they determined the realisation of the system logic, during the design and development process.

2.4.3. The *manufacturer* shall provide the Technical Service with an explanation of the design provisions built into "the system" so as to generate safe operation under fault conditions. Possible design provisions for failure in "the system" are:

a) Fall-back to operation using a partial system,
b) Change-over to a separate back-up system,
c) Removal of the high level function.

For each of the chosen provisions, the driver shall be warned for example by warning signals or message displays. When the system is not deactivated by the driver, e.g. by turning the vehicle activation switch to "off", or by switching off that particular function if a special switch is provided for that purpose, the warning shall be present as long as the fault condition persists.

2.4.3.1. If the chosen provision selects a partial performance mode of operation under certain fault conditions, then these conditions shall be stated and the resulting limits of effectiveness defined.

2.4.3.2. If the chosen provision selects a second (back-up) means to realise the vehicle control system objective, the principles of the change-over mechanism, the logic and level of redundancy and any built in back-up checking features shall be explained and the resulting limits of back-up effectiveness defined.

2.4.3.3. If the chosen provision selects the removal of the higher level function, all the corresponding output control signals associated with this function shall be inhibited, and in such a manner as to limit the transition disturbance.

2.4.4. The documentation shall be supported, by an analysis which shows, in overall terms, how the system will behave on the occurrence of any one of those specified faults which will have a bearing on vehicle control performance or safety. This may be based on a failure

mode and effect analysis (FMEA), a fault tree analysis (FTA) or any similar process appropriate to system safety considerations. The chosen analytical approach shall be established and maintained by the vehicle manufacturer and shall be made open for inspection by the Technical Service at the time of the type approval.

2.4.5. The documentation shall itemise the parameters being monitored and shall set out, for each fault condition of the type defined in **paragraph 2.4.3.** of this annex, the warning signal to be given to the driver or to service/technical inspection personnel.

3. VERIFICATION AND TEST

3.1. The functional operation of "the system", as laid out in the documents required in **paragraph 2**. of this annex shall be tested as follows:

3.1.1. Verification of the function of "the system"

As the means of establishing the normal operational levels, verification of the performance of the vehicle system under non-fault conditions shall be conducted against the *manufacturer's* basic benchmark specification unless this is subject to a specified performance test as part of the approval procedure of this or another Regulation.

3.1.2. Verification of the *safety concept* of **paragraph 2.4.** of this annex

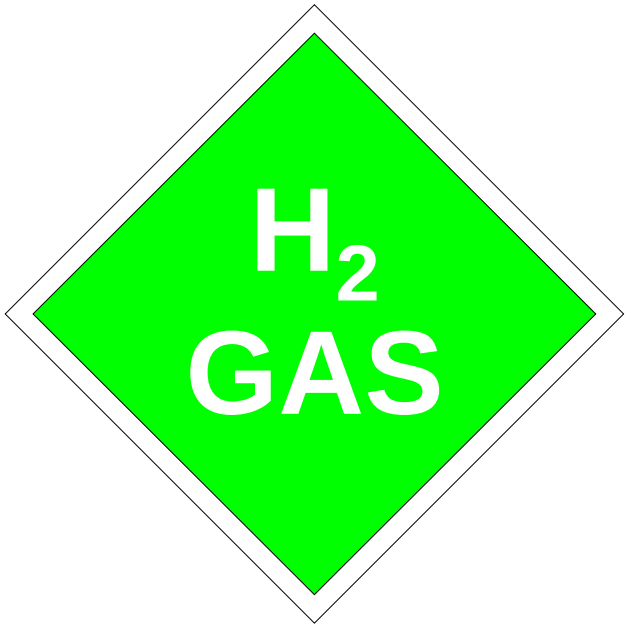
The reaction of "the system" shall, at the discretion of the Technical Service, be checked under the influence of a failure in any individual *unit* by applying corresponding output signals to electrical *units* or mechanical elements in order to simulate the effects of internal faults within the *unit*.

3.1.3. The verification results shall correspond with the documented summary of the failure analysis, to a level of overall effect such that the *safety concept* and execution are confirmed as being adequate.

3.2. The warning signal specified in **paragraph 2.4.3.** of this annex may, in general, be satisfied by one optical signal per complex vehicle system unless any other Regulation applicable to the same equipment specifically requires multiple signals.

Annex 10

PROVISIONS REGARDING HYDROGEN IDENTIFICATION MARKS
FOR PUBLIC SERVICE VEHICLES



The sign consists of an adhesive label that shall be weather resistant.

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

Colours:

Background:	Green
Border:	White
Letters:	White

Either the borders and letters or the background shall be retro-reflective.

Colorimetric and photometric properties shall comply with the requirements of clause 11 of ISO 3864-1:2002 (Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs in workplaces and public areas).

Dimensions:

Border width:	5 mm
Sticker width:	125 mm (across flat sides)
Sticker height:	125 mm (across flat sides)
Font size:	
Font height:	25 mm
Font thickness:	5 mm

The words shall be in upper case characters, centralised to suit the dimensions.
