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agenda item 8.)

PROPOSAL FOR A NEW DRAFT REGULATION

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF:

I. SPECIFIC COMPONENTS OF MOTOR VEHICLES USING LIQUID HYDROGEN
II. VEHICLE WITH REGARD TO THE INSTALLATION OF SPECIFIC COMPONENTS FOR THE USE OF LIQUID HYDROGEN

Transmitted by the members of the informal group "hydrogen / fuel cell - vehicles"

Note: The text reproduced below was prepared by the members of the informal group on "hydrogen / fuel cell – vehicles" proposing a draft Regulation under the 1958 Agreement in order to introduce new provisions for the type approval of hydrogen vehicles. The proposal is based on the text of a document distributed without a symbol (informal document No. 3) during the forty-fifth session of GRPE (TRANS/WP.29/GRPE/45, para. 43).

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

Draft Regulation N° xxx

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF:

I. Specific components of motor vehicles using liquid hydrogen
II. Vehicle with regard to the installation of specific components for the use of liquid hydrogen

1. SCOPE

This Regulation applies to:

1.1. Part I: Specific components integrated in the hydrogen system of motor vehicles of categories M and N using liquid hydrogen.

1.2. Part II: Vehicles with regard to the installation of specific components integrated in the hydrogen system for the use of liquid hydrogen.

2. DEFINITIONS

2.1. "Approval of a vehicle" means the approval of a vehicle type with regard to its hydrogen system as original equipment;

2.2. "Automatic valve" means a valve that is not operated manually, but by an actuator (e.g. pneumatic or electric actuator).

2.3. "Boil off management system" means a system that renders boil off gas harmless in normal conditions.

2.4. "Boil off system" means a system that in normal conditions vents the boil-off before the pressure relief device of the container(s) opens.

2.5. "Burst pressure" means the pressure that causes the bursting of a pressure vessel subjected to a constant increase of pressure during a destructive test.

2.6. "Check valve or non-return valve" means a valve that allows hydrogen to flow in only one direction.

2.7. "Container" means any system used for the storage of cryogenic hydrogen.

2.8. "Equipment of the container" means all devices that are fixed directly to the inner tank or outer jacket of the container.

2.9. "Fitting or screwed connection system" means a connector used in a piping, tubing or hose system.

2.10. "Flexible fuel line" means flexible tubing or a hose through which hydrogen flows.

2.11. "Fuel level sensor" means a device that measures the level of the liquid hydrogen in the container.

2.12. "Fuel supply line" means the line that supplies hydrogen to the hydrogen conversion system(s).

2.13. "Ground clearance of the vehicle" means the distance between the ground plane and the underside of the vehicle.

2.14. "H_2" means hydrogen.

2.15. "Heat exchanger" means a device for heating the hydrogen.

2.16. "Hydrogen component" means a component which is in direct contact with hydrogen or which forms part of a system installed because of the use of hydrogen.

2.17. "Hydrogen conversion system" means any system designed for the consumption of hydrogen.

2.18. "Hydrogen system" means the complete assembly of hydrogen components and connecting parts installed on motor vehicles using hydrogen excluding the propulsion system(s) and/or auxiliary power unit(s).

2.19. "Impermissible fault range" of a process variable means the range within which an unwanted event is to be expected, e.g. the corresponding pressure where from plastic deformation or bursting of the inner tank occurs as shown in Figure 1. In the case of steel inner tanks, the lower limit of the impermissible fault range corresponds to a pressure higher than 136 per cent of the Maximum Allowable Working Pressure (MAWP) of the inner tank. For other materials an equivalent level of safety is to be applied.

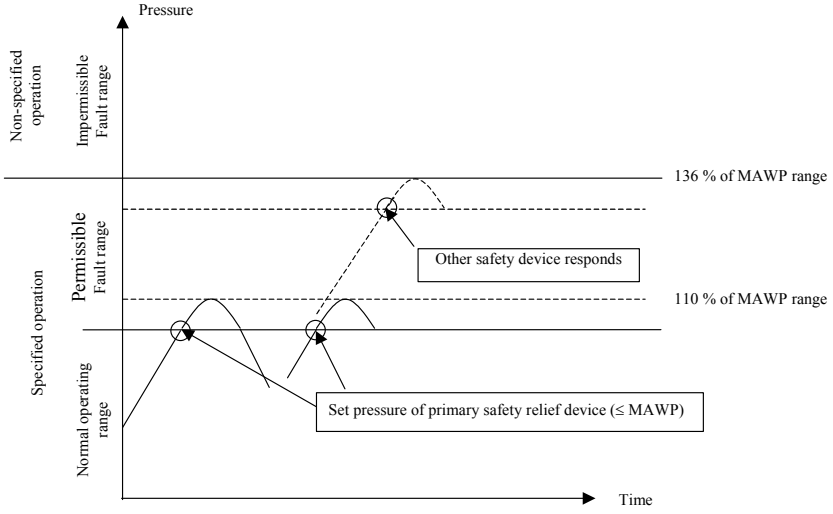


Figure 1 – Ranges of a steel inner tank

2.20. "Inner tank" means the part of the container that contains the cryogenic hydrogen.

2.21. "LH_2" means liquefied hydrogen.

2.22. "Manual valve" means a manually operated valve.

2.23. "Maximum Allowable Working Pressure (MAWP)" means the maximum pressure to which a component is designed to be subjected to and which is the basis for determining the strength of the component under consideration.

2.24. "Normal operating range" of a process variable means the range planned for its values (see Figure 1). In the case of inner tanks, the normal operating range of the inner tank pressure is between 0 MPa and the set pressure of the primary safety relief device which is lower or equal to the Maximum Allowable Working Pressure (MAWP) of the inner tank.

2.25. "Outer jacket" means the part of the container that encases the inner tank(s) and its insulation system.

2.26. "Outer pressure" means the pressure acting on the convex side of the inner tank or outer jacket, e.g. in case of vacuum inside the inner tank and/or the outer jacket.

2.27. "Permissible fault range" of a process variable means the range between the normal operating range and the impermissible fault range (see Figure 1).

2.28. "Pressure" means gauge pressure against atmospheric pressure, unless otherwise stated.

2.29. "Pressure regulator" means a device used to control the delivery pressure of gaseous fuel to the hydrogen conversion system.

2.30. "Pressure relief device" means a device which prevents a pre-determined pressure from being exceeded (e.g. Maximum Allowable Working Pressure (MAWP) of a component) by releasing the pressure.

2.31. "Propulsion system" means the internal combustion engine or fuel cell system used to propel the vehicle.

2.32. "Rm" means minimum ultimate tensile strength.

2.33. "Rp" means minimum yield strength.

2.34. "Refuelling connection" or "receptacle" means a device used to fill the container at the filling station.

2.35. "Rigid fuel line" means a tubing that has not been designed to flex in normal operation and through which hydrogen flows.

2.36. "Safety device" means a device that ensures safe operation within the normal operating range or the permissible fault range of the system.

2.37. "Safety instrumented systems" are process control systems that prevent an impermissible fault range from being reached by an automatic intervention in the process.

2.38. "Specific component" means a hydrogen component that is subject to type approval. Specific components used in the hydrogen system include:

- container;
- pressure relief valve;
- automatic valve (if first automatic valve downstream of the container or if a safety device);
- manual valve (if first manual valve downstream of the container or if a safety device);
- refuelling connection or receptacle;
- check valve or non-return valve (if safety device);
- pressure regulator (if upstream of first automatic shut off valve);
- flexible fuel line (if upstream of first automatic shut off valve or other safety devices);
- heat exchanger (if upstream of first automatic shut off valve);
- pressure, temperature and flow sensor (if safety device).

Many of the components mentioned above can be combined or fitted together as a "multifunctional component".

2.39. "Test pressure" (P_{test}) means the pressure that a component is subjected to during acceptance testing.

2.40. "Thermal autonomy" is the time of the pressure increase in the inner tank measured from a starting pressure of 0 MPa at the corresponding boiling point of hydrogen (-253 °C) up to the moment when the set pressure of the primary pressure relief device is reached. The thermal autonomy is a measure of the quality of the insulation of the container.

2.41. "Vehicle type" means a vehicle fitted with specific components for the use of hydrogen which do not differ with respect to the following conditions:

2.41.1. the manufacturer;

2.41.2. the type designation established by the manufacturer;

2.41.3. the essential aspects of construction and design:

2.41.3.1. chassis/floor pan (obvious and fundamental differences);

2.41.3.2. the installation of the hydrogen equipment (obvious and fundamental differences).

PART I

APPROVAL OF SPECIFIC COMPONENTS OF MOTOR VEHICLES USING LIQUID 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. It shall be accompanied by the documents, in triplicate, containing the information identified below:

3.2.1. a detailed description of the type of the specific component according to annex 1 of this Regulation;

3.2.2. a drawing of the specific component, sufficiently detailed and on an appropriate scale with list of parts including material data and the intended operating mode;

3.2.3. in case of an approval for a container, a piping and instrumentation drawing;

3.2.4. a description of manufacturing process;

3.2.5. a 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 at least two samples of the specific component shall be provided if not otherwise stated in the annexes. Supplementary samples shall be supplied upon request.

3.4. The component 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 also the manufacturing month and year. This 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 3.2.2. above.

4.3. Every container shall also bear a marking place with the following data clearly legible:

4.3.1. The inner tank:
- the name and address of inner tank manufacturer,
- the serial number,
- a marking confirming successful final acceptance test.

4.3.2. The outer jacket:
- the marking "Liquid hydrogen"
- a prohibition of additional welding, milling and stamping
- an allowed orientation of the tank in the vehicle
- an identification plate with the following markings:
    - name of the manufacturer
    - serial number
    - water volume in litres
    - Maximum Allowable Working Pressure (MAWP) [MPa]
    - year and month of manufacturing (e.g. 2003/01)
    - approval mark according to paragraph 5.4.
    - date of the evacuation of the insulation
    - operating temperature range according to paragraph 14.1.7. of this Regulation

  the identification plate shall be legible while installed.

5. APPROVAL

5.1. If the specific component samples submitted for approval meet the relevant requirements of paragraphs 6.1. to 6.13. 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 or multifunctional component approved. Its first two digits (00 for the Regulation in its original form) shall indicate the series of amendments incorporating the most recent major technical amendments made to the Regulation at the time of issue of the approval. The same Contracting Party shall not assign the same number to another type of equipment.

5.3. Notice of approval or of refusal or of extension of approval of a hydrogen component type pursuant to this Regulation shall be communicated to the Parties to the Agreement applying this Regulation, by means of a form conforming to the model in annex 4 of this Regulation.

5.4. In addition to the markings prescribed in paragraphs 4.1. and 4.3. there shall be affixed, conspicuously and in the space referred to in paragraph 4.2. above, to all specific components conforming to a type approved under this Regulation, an international approval mark consisting of:

5.4.1. A circle surrounding the letter "E" followed by the distinguishing number of the country which has granted approval; 1/

5.4.2. 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 5.4.1. This approval number consists of the component type approval number which appears on the certificate completed for this type (see paragraph 5.2. and annex 4) preceded 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 be indelible.

5.6. Annex 3 to this Regulation gives examples of the arrangements of the aforesaid approval mark.

6. SPECIFICATIONS REGARDING 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 reliably withstand the electrical, mechanical, thermal and chemical operating conditions.

6.1.2. Materials of the components which are in contact with hydrogen shall be compatible with it according to annex 8C to this Regulation.

6.1.3. The materials of the components in contact with cryogenic temperatures shall be compatible with cryogenic temperatures according to EN 1252-1:1998/AC:1998.

1/ 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 (vacant), 36 for Lithuania; 37 for Turkey, 38 (vacant), 39 for Azerbaijan, 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, 46 for Ukraine, 47 for South Africa and 48 for New Zealand. 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.

6.1.4. Those parts of a component whose correct and safe functioning is liable to be influenced by hydrogen or high pressure shall be submitted to the relevant test procedures described in the annexes of this Regulation. In particular the provisions of paragraphs 6.2. to 6.13. shall be fulfilled.

6.1.5. All components with directional flow shall have the flow direction clearly indicated.

6.1.6. The requirements of this Regulation and its annexes shall take precedence over the requirements of any standards referred to in this Regulation.

6.2. Provisions regarding hydrogen container(s)

6.2.1. The hydrogen container(s) shall be type-approved pursuant to the provisions laid down in annexes 7A of this Regulation. *[The performance of hydrogen container(s) made from materials other than metal shall be demonstrated to be equivalent to the requirements of annex 7A of this Regulation according to existing International Standards.]*

6.3. General provisions regarding other components of the hydrogen system

6.3.1. The hydrogen system upstream of the first pressure regulator, excluding the hydrogen container, shall have a Maximum Allowable Working Pressure (MAWP) equal to the maximum pressure the component is subjected to but at least 1.5 times the set pressure of the primary safety relief device of the inner tank and a coefficient of safety not less than that of the inner tank.

6.3.2. Components downstream of pressure regulator(s) shall be protected against over-pressurisation and shall be designed for at least 1.5 times the outlet pressure (Maximum Allowable Working Pressure (MAWP)) of the first pressure regulator upstream.

6.3.3. The insulation of the components shall prevent liquefaction of the air in contact with the outer surfaces, unless a system is provided for collecting and vaporizing the liquefied air. Then the materials of the components nearby shall be compatible with an atmosphere enriched with oxygen according to EN 1797:2001.

6.4. Provisions regarding pressure relief devices

6.4.1. Pressure relief devices for the inner tank.

6.4.1.1. The primary pressure relief device for the inner tank shall limit the pressure inside the tank to not more than 110 per cent of the Maximum Allowable Working Pressure (MAWP). This device shall be a safety valve or equivalent.

6.4.1.2. The secondary pressure relief device for the inner tank shall be installed to ensure that the pressure in the tank cannot under any circumstances exceed the permissible fault range of the inner tank. In the case of steel inner tanks, the secondary pressure relief

device shall limit the pressure in the tank to 136 per cent of the Maximum Allowable Working Pressure (MAWP) of the inner tank. For other materials, an equivalent level of safety shall be applied. The secondary pressure relief device shall not operate below 110 per cent of the set pressure of the primary pressure relief device.

6.4.1.3. The sizing of the safety devices shall be done in accordance with prEN 13648-3:2000 or CGA S-1.2:1995 and CGA S-1.3:1995.

6.4.1.4. The two devices according to paragraphs 6.4.1.1. and 6.4.1.2. may be connected to the inner tank by the same fuel line.

6.4.1.5. The rating of the pressure relief devices shall be clearly marked. Tampering with the devices shall be prevented by means of a lead seal or equivalent system.

6.4.1.6. Pressure relief valves shall, after discharge, close at a pressure higher than 90 per cent of the set pressure of the pressure relief valve. They shall remain closed at all lower pressures.

6.4.1.7. The pressure relief devices shall be type-approved pursuant to the provisions of annex 7B to this Regulation.

6.4.2. Pressure relief devices for other components.

6.4.2.1. Whenever there is a risk of cryogenic liquid or vapour becoming trapped between two items of equipment on a line, a pressure relief device or an equivalent measure shall be provided.

6.4.2.2. Upstream of the first pressure regulator the set pressure of the safety device which prevents over-pressurization shall not exceed the Maximum Allowable Working Pressure (MAWP) of the lines and shall not be less than 120 per cent of the Maximum Allowable Working Pressure (MAWP) of the tank, to prevent such valves opening instead of the pressure relief devices for the inner tank.

6.4.2.3. The rating of pressure relief devices downstream of the pressure regulator(s) shall not exceed the Maximum Allowable Working Pressure (MAWP) of the components downstream of the pressure regulator.

6.4.2.4. Pressure relief valves shall, after discharge, close at a pressure higher than 90 per cent of the set pressure of the pressure relief valve. They shall remain closed at all lower pressures.

6.4.2.5. The pressure relief devices shall be type-approved pursuant to the provisions laid down in annex 7B to this Regulation.

6.5. Provisions regarding the lines incorporating pressure relief devices

6.5.1. The pressure relief devices of the container(s) shall be directly connected with the gaseous part.

6.5.2. No isolating device shall be installed between the protected component and the pressure relief device.

6.5.3. The lines before and behind the pressure relief devices shall not impede their function and shall be compatible with the criteria defined in paragraph 6.4.

6.6. Provisions regarding hydrogen valves

6.6.1. Valves which are considered as specific components shall be type-approved pursuant to the provisions laid down in annex 7C to this Regulation.

6.7. Provisions regarding heat exchangers

6.7.1. Notwithstanding the provision of paragraph 6.3.1. the Maximum Allowable Working Pressure (MAWP) of the heat exchanger shall be the highest Maximum Allowable Working Pressure (MAWP) of the different circuits.

6.7.2. The exhaust gases from the propulsion system shall not under any circumstances be used directly in the heat exchanger.

6.7.3. A safety system shall be provided to detect failure of the heat exchanger and prevent any cryogenic liquid or gas from entering the other circuit and the system located downstream of it, if it has not been designed for this.

6.7.4. The heat exchangers that are considered as specific components shall be type-approved pursuant to the provisions laid down in annex 7D of this Regulation.

6.8. Provisions regarding refuelling connections or receptacles

6.8.1. The refuelling connections or receptacles shall be protected against contamination.

6.8.2. The refuelling connections or receptacles shall be type-approved pursuant to the provisions laid down in annex 7E to this Regulation.

6.9. Provisions regarding pressure regulators

6.9.1. The pressure regulators which are considered as specific components shall be type-approved pursuant to the provisions laid down in annex 7F to this Regulation.

6.10. Provisions regarding sensors

6.10.1. The sensors which are considered as specific components shall be type-approved pursuant to the provisions laid down in annex 7G to this Regulation.

6.11. Provisions regarding flexible fuel lines

6.11.1. Flexible fuel lines which are considered as specific components shall be type-approved pursuant to the provisions laid down in annex 7H to this Regulation.

6.12. General provisions regarding electrical components of the hydrogen system

6.12.1. Electrically operated devices containing hydrogen shall, to prevent electric sparks in the case of fracture:
(a) be insulated in a manner that no current is caused to enter and flow through hydrogen containing parts;
(b) have the electrical system of the device insulated from the body of the vehicle;
(c) the electric circuit insulation resistance (batteries and fuel cells excluded), shall exceed 1 kΩ for each volt of the nominal voltage.

6.12.2. Electrical connections inside internal luggage and passenger compartments shall comply with insulation class IP 40 according to IEC 60529:2001.

6.12.3. All other electrical connections shall comply with insulation class IP 54 according to IEC 60529:2001.

6.12.4. In case of power supply bushing to establish an isolated and tight electrical connection, it shall be of a hermetic sealed type.

6.13. If a test method other than those specified in paragraphs 6.1. to 6.12. above and the relevant annexes is used, its equivalence shall be proved.

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

7.1. Every modification of a type of a specific component shall be notified to the administrative department which granted the type approval. The department may then either:

7.1.1. consider that the modifications made are unlikely to have an appreciable adverse effect, and that the component still meets the requirements; or

7.1.2. require a further report from the technical service responsible for carrying out the tests.

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

7.3. The competent authority issuing the extension of approval shall assign a series number to each communication form drawn up for such an extension and has to inform the other Contracting Parties with the form according to annex 4.

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) with the following requirements:

8.1. A hydrogen component approved to this Regulation shall be so manufactured as to conform to the type approved by meeting the requirements set forth in paragraph 6. above.

8.2. The authority which 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.

8.3. The compulsory tests of the hydrogen containers are described in annex 7A to this Regulation.

8.4. Every flexible fuel line assembly shall be tested at a pressure of 1.5 times the Maximum Allowable Working Pressure (MAWP) of the part of the hydrogen system it is installed in.

9. PENALTIES FOR NON-CONFORMITY OF PRODUCTION

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

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

10. PRODUCTION DEFINITELY DISCONTINUED

If the holder of the approval permanently ceases to manufacture a type of component approved in accordance with this Regulation, he shall so inform the authority which granted the approval. Upon receiving the relevant communication, that authority shall inform thereof the other Contracting Parties to the 1958 Agreement applying this

Regulation by means of a communication form conforming to the model in annex 4 of this Regulation.

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

The Contracting Parties to the 1958 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 or production definitely discontinued, issued in other countries, are to be sent.

PART II

APPROVAL OF VEHICLES WITH REGARD TO THE INSTALLATION OF SPECIFIC COMPONENTS FOR THE USE OF LIQUID 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 hydrogen shall be submitted by the vehicle manufacturer or by his duly accredited representative.

12.2. The application shall be accompanied by 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 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 approval pursuant to this Regulation is provided with all the necessary specific components for the use of hydrogen and meets the requirements of paragraph 14. below, approval of that vehicle type shall be granted.

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

13.3. Notice of approval or of refusal or of extension of approval of a hydrogen vehicle type pursuant to this Regulation shall be communicated to the 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, conspicuously and in a readily accessible space specified on the approval form referred to in paragraph 13.3. above, to every vehicle type approved under 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 which has granted approval. 1/*

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.*

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

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

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

1/ 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 (vacant), 36 for Lithuania; 37 for Turkey, 38 (vacant), 39 for Azerbaijan, 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, 46 for Ukraine, 47 for South Africa and 48 for New Zealand. 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.

13.8. *Annex 5 of this Regulation give examples of the arrangement of the aforesaid approval mark.]*

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

14.1. General

14.1.1. The hydrogen system shall function in a correct and safe way. It shall reliably withstand the electrical, mechanical, thermal and chemical operating conditions.

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 hydrogen in its liquid and/or gaseous state according to annex 8C to this Regulation.

14.1.4. All components of the hydrogen system shall be mounted and connected in accordance with best practice.

14.1.5. The hydrogen system shall show no leaks other than the boil-off at Maximum Allowable Working Pressure (MAWP), i.e. stay bubble-free is using leak-detecting spray.

14.1.6. The hydrogen system shall be installed such that it is protected against damage, such as damage due to moving vehicle components, collision, grit or due to the loading or unloading of the vehicle or the shifting of those loads.

14.1.7. The operating temperatures should be:

Internal Combustion Engine Compartment	On Board (All types of propulsion systems)
-40 °C to +120 °C	-40 °C to +85 °C

14.1.8. Further requirements.

14.1.8.1. No component of the hydrogen system, including any protective materials which form part of such components, shall project beyond the outline of the vehicle.

14.1.8.2. 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.

14.1.8.3. The ventilating or heating system of passengers 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. Appropriate automatic measures shall be adopted in coordination with the refuelling station to ensure that no uncontrolled hydrogen release occurs during the filling procedure.

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

14.1.11. Identification of hydrogen-fuelled public service vehicles of categories M2 and M3.

14.1.11.1. Public service vehicles of categories M2 and M3 equipped with a liquid hydrogen system shall carry plates as specified in annex 10.

14.1.11.2. The plates shall be installed on the front and rear of the public service vehicle and on the outside of the doors on the right-hand side.

14.2. Components of a hydrogen on-board system

14.2.1. A hydrogen on-board system shall contain at least the following components:
- Container;
- refuelling connection or receptacle;
- pressure relief device;
- automatic shut-off valve;
- flexible fuel line or rigid fuel line;
- fittings or screwed connection systems;
- hydrogen conversion system(s) (i.e. combustion engine, fuel cell, catalytic heater, etc.);
- safety instrumented system;
- fuel level sensor or flow rate sensor to calculate fuel level;
- fuel level indicator;
- boil-off management system.

14.2.2. The hydrogen system could also include the following components:
- pressure, temperature and flow sensors;
- pressure and temperature indicator;
- pressure regulator;
- gas flow adjuster;
- hydrogen injector(s) or gas/air mixer;
- fuel selection system and electrical systems;
- electronic control unit;
- manual valve;
- heat exchanger;
- non-return or check valves

All specific components according to paragraph 2.38. must have a type-approval.

14.3. Installation of the hydrogen container on-board a vehicle

14.3.1. The hydrogen container shall be permanently installed on-board the vehicle. The hydrogen container may only be removed for maintenance. It shall be adequately protected against any kind of corrosion, e.g. due to road de-icing salt, leakage of acid batteries, etc.

14.3.2. The container can be integrated into the vehicle design to provide complementary functions. In such cases the container shall be designed to fulfil the integrated function requirements plus the tank requirements.

14.3.3. When the vehicle is ready for use the lowest part of the hydrogen container shall not reduce the ground clearance of the vehicle. This shall not apply if the hydrogen container is adequately protected, at the front and the sides and no part of the hydrogen container is located lower than this protective structure.

14.3.4. The hydrogen container(s) including the safety devices affixed at it must be mounted and fixed so that the following accelerations can be absorbed (without damage of the safety related parts) when the hydrogen containers are full. No uncontrolled release of hydrogen is allowed.

Vehicle 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

14.3.5. The provision of paragraph 14.3.4. shall not apply if the vehicle is approved according to EU Directive 96/79/EC or UNECE Regulation No. 94 and EU Directive 96/27/EC or UNECE Regulation No. 95.

14.4. Accessories fitted to the hydrogen container

14.4.1. Automatic shut-off valves or non-return valves.

14.4.1.1. All hydrogen fuel supply lines to the hydrogen conversion system(s), except the boil-off management system shall be secured with an automatic valve (idle closed). These valves shall be mounted directly on or within the container.

14.4.1.2. The refuelling line shall be secured by either a manually or an automatically operated shut off valve which shall always be closed except during the refuelling process. If the receptacle is not mounted directly on the container, a second isolating device is needed. This device may be a manual valve, an automatic valve or a non-return valve. One of these two isolating devices shall be mounted directly on or within the container and the other one shall be integrated in the receptacle.

14.4.1.3. In the event that the container is displaced, the first isolating device and if applicable, the line connecting it to the container shall be protected in such a manner that the shut-off function remains operational and the connection between the device and the container cannot be ruptured.

14.4.1.4. The automatic valves shall be closed idle (fail-safe).

14.4.1.5. The automatic valves shall close if any malfunction of the hydrogen system occurs and in the event of a crash or of a break of the fuel supply line(s).

14.4.1.6. When the propulsion system is switched off, irrespective of the position of the ignition switch, the fuel supply to the propulsion system shall be switched off and remain closed until the propulsion system is required to operate.

14.4.1.7. When another hydrogen conversion system is switched off, irrespective of the position of the activation switch, the fuel supply to the respective conversion system shall be switched off and remain closed until the respective hydrogen conversion system is required to operate.

14.4.2. Pressure relief devices.

14.4.2.1. The pressure relief devices (pressure triggered) shall be fitted to the hydrogen container(s) in such a manner that it must discharge into an atmospheric outlet line that vents outside the vehicle. It shall not discharge at a heat source such as the exhaust. Additionally it shall discharge such that hydrogen cannot enter the inside of the vehicle and/or accumulate in an enclosed or partially enclosed space. In case the secondary pressure relief device is a burst disc and is installed within the inner tank, an appropriate exhaust vent in the outer jacket is required.

14.4.2.2. In the event of accidents it must be ensured so far as is reasonably practicable that the pressure relief device and the associated vent line remain capable of functioning.

14.4.2.3. The vent line of the pressure relief device shall be adequately protected against dirt and water.

14.4.3. Gas tight housing on the hydrogen container(s).

14.4.3.1. All non-welded connections of hydrogen-carrying components and the hydrogen components which can leak, that are mounted within the passenger or luggage compartment, shall be enclosed by a gas tight housing.

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

14.4.3.3. The ventilation opening of the gas tight housing shall be at the highest point of the housing and shall not discharge at a heat source such as the exhaust. Additionally it shall discharge such that hydrogen cannot enter the inside of the vehicle and/or accumulate in an enclosed or partially enclosed space.

14.4.3.4. There shall be no unprotected ignition sources inside the gas tight housing.

14.4.3.5. Any connecting system and lead-through in the body of the vehicle for ventilation of the gas tight housing shall have at least the same cross sectional area as the tube of the pressure relief device.

14.4.3.6. This housing shall be for test purposes hermetically sealed and shall be gas tight at a over pressure of 0.5 kPa, i.e. bubble-free for 1 minute and without any permanent deformation.

14.4.3.7. Any connecting system shall be secured by clamps, or other means, to the gas tight housing and the lead-through to ensure that a gas tight joint is formed.

14.5. Rigid and flexible fuel lines

14.5.1. Rigid fuel lines shall be secured such that they shall not be subjected to abrasion, critical vibration and/or other stresses.

14.5.2. Flexible fuel lines shall be secured such that they shall not be subjected to torsional stresses, abrasion is avoided and cannot be crimped in normal use.

14.5.3. At the fixing points the fuel line, flexible or rigid, shall be fitted in such a way that they cannot make a metal to metal contact to prevent galvanic and crevice corrosion.

14.5.4. Rigid and flexible fuel lines shall be routed to reasonably minimise exposure to accidental damage whether inside 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.

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

14.6. Fittings or gas connections between the components

14.6.1. Stainless steel tubes shall only be joined by stainless steel fittings.

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

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

14.6.4. In a passenger or enclosed luggage compartment, the fuel lines shall be no longer than reasonably required.

14.7. Refuelling connection

14.7.1. The refuelling connection shall be secured against maladjustment and shall be protected from dirt and water. It shall be safe against handing errors.

14.7.2. The refuelling connection shall not be installed in the engine compartment, passenger compartment or in any other unventilated compartment.

14.7.3. The refuelling line shall be secured at the container as described in paragraph 14.4.1.1.

14.7.4. The refuelling connection shall have an isolating device according to paragraph 14.4.1.2.

14.7.5. It shall be ensured that the propulsion system cannot be operated and the vehicle cannot move while the receptacle is connected to the filling station.

14.8. Electrical installation

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

14.8.2. Electric or electronic equipment in the gas tight housing shall be evaluated according to IEC 60079-10:2002 and comply with EN 50014:1997/AC:1998/A1:1998/A2:1999, EN 50015:1998, EN 50016:1995 EN 50017:1998, EN 50018:2002, EN 50019:2000, EN 50020:1994 and EN 50021:1998 if applicable.

14.8.3. The metallic components of the hydrogen system shall have electrical continuity with the vehicle's earth.

14.9. Boil-off under normal conditions

14.9.1. Boil-off gases shall be rendered harmless by a boil-off management system.

14.9.2. The boil-off management system shall be designed to accept the boil-off rate of the container(s) under normal operating conditions.

14.9.3. At start-up and during the operation of the vehicle, a warning system shall be activated to warn the driver in the event of the boil off management system failure.

14.10. All pressure relief devices and vent line(s) shall be protected against vandalism so far as reasonably practicable.

14.11. The passenger compartment, the luggage compartment and all safety-critical components of the vehicle (e.g. the brake system, electrical insulation) shall be protected against adverse temperature effects due to the cryogenic fuel. Possible leakage of the cryogenic fuel shall be considered when assessing the protection that is required.

14.12. Inflammable materials used in the vehicle shall be protected from liquefied air that may condense on un-insulated elements of the fuel system.

14.13. Failure of the heating circuit of the heat exchanger shall not cause leakage form the hydrogen system.

14.14. Safety instrumented systems

14.14.1. Safety instrumented systems shall be fail-safe, redundant or self-monitoring.

14.14.2. If the safety-instrumented systems under paragraph 14.14.1. are fail-safe or self-monitoring electronic systems, the special requirements according to annex 9 are to be applied.

14.15. Periodic requalification

The vehicle manufacturer shall provide information for periodic requalification by inspection during the service life on the basis of use under service conditions specified herein. This information shall include the following items:

- frequency of the periodic requalification inspection
- check of the mandatory marking of the container
- visual inspection of the outer jacket
- inspection of the pressure relief devices
- inspection of the automatic shut-off valve
- check of the gas tightness of the receptacle

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 the specific components for the use of hydrogen shall be notified to the administrative department which approved the vehicle type. The department may then either:

15.1.1. consider that the modifications made are unlikely to have an appreciably adverse effect and that in any case the vehicle still complies with the requirements; 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. above to the Parties to the Agreement which apply this Regulation.

15.3. The competent authority issuing the extension of approval shall assign a series number to each communication form drawn up 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) with the following requirements:

16.1. A vehicle approved to this Regulation shall be so manufactured as to conform to the type approved by meeting the requirements set forth in paragraph 14. above.

16.2. The authority which 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 approval granted in respect of a type of vehicle pursuant to this Regulation may be withdrawn if the requirements laid down in paragraph 16. are not complied with.

17.2. If a Contracting Party to the Agreement which applies this Regulation withdraws an approval it has previously granted, it shall forthwith so 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 so inform the authority which granted the approval. Upon receiving the relevant communication, that authority shall inform thereof the other 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 1958 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 or production definitely discontinued, issued in other countries, are to be sent.

20. REFERENCES

The following referenced documents are indispensable for the application of this document 2/. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CGA S-1.2:1995 *Pressure Relief Device Standards — Part 2: Cargo and Portable Tanks for Compressed Gases*
CGA S-1.3:1995. *Pressure Relief Device Standards — Part 3: Stationary Storage Containers for Compressed Gases*
DIN 50021:1998 *Spray tests with different sodium chloride solutions*
DIN 50916-2:1985 *Testing of copper alloys; stress corrosion cracking test in ammonia, testing of components*

EN 287-1:1992/A1:1997 *Approval testing of welders — Fusion welding — Part 1: Steels*

EN 287-2:1992/A1:1997 *Approval testing of welders — Fusion welding — Part 2: Aluminium and aluminium alloys*

EN 288-3:1992/A1:1997 *Specification and approval of welding procedures for metallic materials — Part 3: Welding procedure tests for the arc welding of steel*

EN 288-4:1992/A1:1997 *Specification and approval of welding procedures for metallic materials — Part 4: Welding procedure tests for the arc welding of aluminium and its alloys*

EN 288-8:1995 *Specification and approval of welding procedures for metallic materials — Part 8 Approval by a pre-production welding test*

2/ In order to set the stage for global harmonization, the ISO standards that are being prepared on the same topic as the EN standards referred to in this Regulation are given in annex 11.

EN 729-2:1994 *Quality requirements for welding — Fusion welding of metallic materials — Part 2: Comprehensive quality requirements*

EN 729-3:1994 *Quality requirements for welding — Fusion welding of metallic materials — Part 3: Standard quality requirements*

EN 1251-2:2000 *Cryogenic vessels — Transportable vacuum insulated vessels of not more than 1000 litres volume — Part 2: Design, fabrication, inspection and testing*

EN 1252-1:1998/AC:1998 *Cryogenic vessels — Materials — Part 1: Toughness requirements for temperatures below –80°C*

EN 1418:1998 *Welding personnel — Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanised and automatic welding of metallic materials*

EN 1626:1999 *Cryogenic vessels — Valves for cryogenic service*

EN 1797: 2001 *Cryogenic vessels —Gas/material compatibility*

EN 10204:1991/A1:1995 *Metallic products — Types of inspection documents*

EN 12300:1998 *Cryogenic vessels — Cleanliness for cryogenic service*

EN 12434:2000 *Cryogenic vessels — Cryogenic flexible hoses*

EN 13371:2001 *Cryogenic vessels — Couplings for cryogenic service*

EN 13648-1:2002 Cryogenic vessels — Safety devices for protection against excessive pressure — Part 1: Safety valves for cryogenic service

EN 13648-2:2002 *Cryogenic vessels — Safety devices for protection against excessive pressure — Part 2: Bursting discs safety device for cryogenic service*

prEN 13648-3: 2000 *Cryogenic vessels — Safety devices for protection against excessive pressure — Part 3: Determination of required discharge — Capacity and sizing*

EN 50014:1997/AC:1998/A1:1998/A2:1999 *Electrical apparatus for potentially explosive atmospheres — General requirements*

EN 50015:1998 *Electrical apparatus for potentially explosive atmospheres — Oil-immersion "o"*

EN 50016:1995 *Electrical apparatus for potentially explosive atmospheres — Pressurized apparatus "p"*

EN 50017:1998 *Electrical apparatus for potentially explosive atmospheres — Powder filling "q"*

EN 50018:2002 *Electrical apparatus for potentially explosive atmospheres — Flameproof enclosure* "d"

EN 50019:2000 *Electrical apparatus for potentially explosive atmospheres — Increased safety "e"*

EN 50020:1994 *Electrical apparatus for potentially explosive atmospheres — Intrinsic safety "i"*

EN 50021:1998 *Electrical apparatus for potentially explosive atmospheres — Type of protection "n"*

IEC 60068-2-52:1996 *Environmental testing – Part 2: Tests — Test Kb: Salt mist, cyclic (sodium, chloride solution)*

IEC 60079-10:2002 *Electrical apparatus for explosive gas atmospheres — Part 10 Classification of hazardous areas*

IEC 60529:2001 *Degrees of protection provided by enclosures (IP Code)*
ISO 188:1998 *Rubber, vulcanized or thermoplastic — Accelerated ageing and heat-resistance tests*

ISO 1431-1:1989 *Rubber, vulcanized or thermoplastic — Resistance to ozone cracking — Part 1: Static strain test*

ISO 2768-1:1989 *General tolerances — Part 1 Tolerances for linear and angular dimensions without individual tolerance indications*

ISO 6957:1988 *Copper alloys — Ammonia test for stress corrosion resistance*

ISO 9227:1990 *Corrosion tests in artificial atmospheres — Salt spray tests*

ISO/DIS 11114-4 3/ *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 4: Test method for hydrogen compatibility with metals*

R 77/CEOC/ CP 90 Def – *Appraisal of Materials for Pressure Equipment (and following numbers of the specifications)*

R 80/CEOC/CP 91 def – *Quality Systems for Pressure Vessel Manufacturers*

3/ To be published.

R 81/CEOC/CP 91 def – *Quality requirements for Pressure Vessel manufacturers not possessing a certificated quality system*

R 97/CEOC/CP 96 def – *Supplementary Quality Management System Requirements for Manufacturers of Metallic Materials for Pressure Equipment*
E/ECE/324-E/ECE/TRANS/505/Rev.2 – Agreement concerning the Adoption of Uniform Technical Prescriptions

96/27/EC – Directive of the European Parliament and of the Council on the protection of motor vehicles in the event of a side impact

96/79/EC – Directive of the European Parliament and of the Council on the protection of motor vehicles in the event of a frontal impact

97/23/EC – Directive of the European Parliament and of the Council on the approximation of the laws of the member states concerning pressure equipment

UNECE Regulation No. 94 – Uniform provisions concerning the approval of vehicles with regard to the protection of the occupants in the event of a frontal collision

UNECE Regulation No. 95 – Uniform provisions concerning the approval of vehicles with regard to the protection of the occupants in the event of a lateral collision

Annex 1

ESSENTIAL CHARACTERISTICS OF THE SPECIFIC COMPONENT

1. Automatic valve(s): yes/no 1/
1.1. Make(s): .....
1.2. Type(s): .....
1.3. Description and drawings: .....
1.4. Maximum Allowable Working Pressure (MAWP) 2/**:** .....MPa
1.5. Operating temperature: .....
1.6. Material(s): .....

2. Check valve(s) or non-return valve(s): yes/no 1/
2.1. Make(s): .....
2.2. Type(s): .....
2.3. Description and drawings: .....
2.4. Maximum Allowable Working Pressure (MAWP): 2/.....MPa
2.5. Operating temperature: .....
2.6. Material(s): .....

3. Container(s): yes/no 1/
3.1. Make(s): .....
3.2. Type(s): .....
3.3. Description: .....
3.4. Maximum Allowable Working Pressure (MAWP): 2/.....MPa
3.5. Operating temperature: .....
3.6. Capacity: .....litres (water)
3.7. Dimensions: .....
3.8. Material(s): .....
3.9. Drawings of the container(s) and installation in the vehicle: .....

4. Flexible fuel line(s): yes/no 1/
4.1. Make(s): .....
4.2. Type(s): .....
4.3. Description and drawings: .....
4.4. Maximum Allowable Working Pressure (MAWP): 2/.....MPa
4.5. Operating temperature: .....
4.6. Material(s): .....

5. Heat exchanger(s): yes/no 1/
5.1. Make(s): .....
5.2. Type(s): .....
5.3. Description and drawings: .....
5.4. Maximum Allowable Working Pressure (MAWP): 2/.....MPa
5.5. Operating temperature: .....

5.6. Material(s):.....

6. Manual valve(s): yes/no 1/
6.1. Make(s):.....
6.2. Type(s):.....
6.3. Description and drawings:.....
6.4. Maximum Allowable Working Pressure (MAWP): 2/.....MPa
6.5. Operating temperature:.....
6.6. Material(s):.....

7. Pressure and/or temperature and/or flow sensor(s): yes/no 1/
7.1. Make(s):.....
7.2. Type(s):.....
7.3. Operating principles including description and drawings:.....
7.4. Maximum Allowable Working Pressure (MAWP): 2/.....MPa
7.5. Operating temperature:.....
7.6. Set values:.....
7.7. Material(s):.....

8. Pressure regulator(s): yes/no 1/
8.1. Make(s):.....
8.2. Type(s):.....
8.3. Drawings:.....
8.4. Number of main adjustment points:.....
8.5. Description of principle of adjustment through main adjustment points:.....
8.6. Number of idle adjustment points:.....
8.7. Description of principles of adjustment through idle adjustment points:.....
8.8. Other adjustment possibilities: if so and which (description and drawings):.....
8.9. Maximum Allowable Working Pressure (MAWP): 2/.....MPa
8.10. Operating temperature:.....
8.11. Input and output pressure:.....

9. Pressure relief device: yes/no 1/
9.1. Make(s):.....
9.2. Type(s):.....
9.3. Description and drawings:.....
9.4. Maximum Allowable Working Pressure (MAWP): 2/.....MPa
9.5. Operating temperature:.....
9.6. Set pressure:.....
9.7. Blow off capacity:.....
9.8. Material:.....

10. Refuelling connection or receptacle: yes/no 1/
10.1. Make(s):.....

10.2. Type(s): .....
10.3. Operating principles including description and drawings: .....
10.4. Maximum Allowable Working Pressure (MAWP): 2/ ..... MPa
10.5. Operating temperature: .....
10.6. Material(s): .....

_____

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

Annex 2

ESSENTIAL CHARACTERISTICS OF THE VEHICLE, ENGINE AND HYDROGEN-RELATED SYSTEM

0. Description of the vehicle type
0.1. Make: .....
0.2. Type(s): .....
0.3. Name and address of the 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 of the propulsion system: .....
1.3. Manufacturer's propulsion system code(s) (as marked on the propulsion system, or other means of identification): .....

1.4. Automatic valve(s): yes/no 1/
1.4.1. Make(s): .....
1.4.2. Type(s): .....
1.4.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
1.4.4. Operating temperature: .....
1.4.5. Approval number: .....

1.5. Check valve(s) or non-return valve(s): yes/no 1/
1.5.1. Make(s): .....
1.5.2. Type(s): .....
1.5.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
1.5.4. Operating temperature: .....
1.5.5. Approval number: .....

1.6. Container(s): yes/no 1/
1.6.1. Make(s): .....
1.6.2. Type(s): .....
1.6.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
1.6.4. Operating temperature: .....
1.6.5. Capacity: .....litres (water)
1.6.6. Approval number: .....

1.7. Flexible fuel line(s): yes/no 1/
1.7.1. Make(s): .....
1.7.2. Type(s): .....
1.7.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
1.7.4. Operating temperature: .....
1.7.5. Approval number: .....

1.8. Heat exchanger(s): yes/no 1/
1.8.1. Make(s): .....
1.8.2. Type(s): .....
1.8.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
1.8.4. Operating temperature: .....
1.8.5. Approval number: .....

1.9. Manual valve(s): yes/no 1/
1.9.1. Make(s): .....
1.9.2. Type(s): .....
1.9.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
1.9.4. Operating temperature: .....
1.9.5. Approval number: .....

1.10. Pressure and/or temperature and/or flow sensor(s): yes/no 1/
1.10.1. Make(s): .....
1.10.2. Type(s): .....
1.10.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
1.10.4. Operating temperature: .....
1.10.5. Set values: .....
1.10.6. Approval number: .....

1.11. Pressure regulator(s): yes/no 1/
1.11.1. Make(s): .....
1.11.2. Type(s): .....
1.11.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
1.11.4. Operating temperature: .....
1.11.5. Input and output pressure:.....
1.11.6. Approval number: .....

1.12. Pressure relief device: yes/no 1/
1.12.1. Make(s): .....
1.12.2. Type(s): .....
1.12.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
1.12.4. Operating temperature: .....
1.12.5. Set pressure: .....
1.12.6. Blow off capacity:.....
1.12.7. Approval number: .....
1.13. Refuelling connection or receptacle: yes/no 1/
1.13.1. Make(s): .....
1.13.2. Type(s): .....
1.13.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
1.13.4. Operating temperature: .....
1.13.5. Approval number: .....

2. Description of the hydrogen system(s) used for other purposes 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/no/same component as used in propulsion system 1/
2.4.1. Make(s): .....
2.4.2. Type(s): .....
2.4.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
2.4.4. Operating temperature: .....
2.4.5. Approval number: .....

2.5. Check valve(s) or non-return valve(s): yes/no/same component as used in propulsion system 1/
2.5.1. Make(s): .....
2.5.2. Type(s): .....
2.5.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
2.5.4. Operating temperature: .....
2.5.5. Approval number: .....

2.6. Container(s): yes/no/same component as used in propulsion system 1/
2.6.1. Make(s): .....
2.6.2. Type(s): .....
2.6.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
2.6.4. Operating temperature: .....
2.6.5. Capacity: .....litres (water)
2.6.6. Approval number: .....

2.7. Flexible fuel line(s): yes/no/same component as used in propulsion system 1/
2.7.1. Make(s): .....
2.7.2. Type(s): .....
2.7.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
2.7.4. Operating temperature: .....
2.7.5. Approval number: .....

2.8. Heat exchanger(s): yes/no/same component as used in propulsion system 1/
2.8.1. Make(s): .....
2.8.2. Type(s): .....
2.8.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
2.8.4. Operating temperature: .....
2.8.5. Approval number: .....

2.9. Manual valve(s): yes/no/same component as used in propulsion system 1/
2.9.1. Make(s): .....

2.9.2. Type(s): .....
2.9.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
2.9.4. Operating temperature: .....
2.9.5. Approval number: .....

2.10. Pressure and/or temperature and/or flow sensor(s): yes/no/same component as used in propulsion system 1/
2.10.1. Make(s): .....
2.10.2. Type(s): .....
2.10.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
2.10.4. Operating temperature: .....
2.10.5. Set values: .....
2.10.6. Approval number: .....

2.11. Pressure regulator(s): yes/no/same component as used in propulsion system 1/
2.11.1. Make(s): .....
2.11.2. Type(s): .....
2.11.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
2.11.4. Operating temperature: .....
2.11.5. Input and output pressure:.....
2.11.6. Approval number: .....

2.12. Pressure relief device: yes/no/same component as used in propulsion system 1/
2.12.1. Make(s): .....
2.12.2. Type(s): .....
2.12.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
2.12.4. Operating temperature: .....
2.12.5. Set pressure: .....
2.12.6. Blow off capacity:.....
2.12.7. Approval number: .....

2.13. Refuelling connection or receptacle: yes/no/same component as used in propulsion system 1/
2.13.1. Make(s): .....
2.13.2. Type(s): .....
2.13.3. Maximum Allowable Working Pressure (MAWP) 2/ .....MPa
2.13.4. Operating temperature: .....
2.13.5. Approval number: .....

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

3.5. Layout of cooling/heating system(s) including Maximum Allowable Working Pressure (MAWP) and operating temperature

3.6. Requalification plan according to paragraph 14.15. of this Regulation

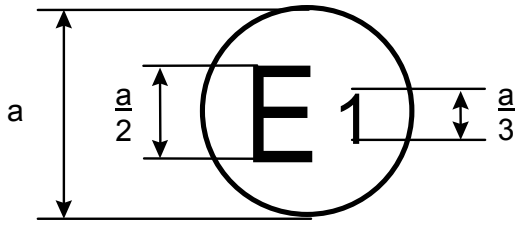
---

1/ Strike out what does not apply

2/ Specify the tolerance

Annex 3

ARRANGEMENT OF THE SPECIFIC COMPONENT APPROVAL MARKS
(see paragraph 5.2. of this Regulation)



xxx R-002439

a ≥ 5 mm

The above approval mark affixed to the hydrogen component shows that this component has been approved in Germany (E1), pursuant to the Regulation No. xxx 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. xxx in its original form.

Annex 4

COMMUNICATION
(maximum format : A4 (210 x 297 mm))

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

concerning: 2/ APPROVAL GRANTED
APPROVAL EXTENDED
APPROVAL REFUSED
APPROVAL WITHDRAWN
PRODUCTION DEFINITELY DISCONTINUED
of a type of hydrogen component pursuant to Regulation No. xxx

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

1. Hydrogen component considered:
   Container 2/
   Pressure relief valve 2/
   Automatic valve 2/
   Manual valve 2/
   Refuelling connection or receptacle 2/
   Check valve or non-return valve 2/
   Pressure regulator 2/
   Flexible fuel line 2/
   Heat exchanger 2/
   Pressure sensor 2/
   Temperature sensor 2/
   Flow sensor 2/
2. Trade name or mark:.....
3. Manufacturer's name and address: .....
4. If applicable, name and address of manufacturer's representative:.....
   .....
5. Submitted for approval on: .....
6. Technical service responsible for conducting approval tests: .....
   .....
7. Date of report issued by that service:.....

8. Number of report issued by that service: .....
9. Approval granted/refused/extended/withdrawn 2/
10. Reason(s) of extension (if applicable): .....
11. Place:.....
12. Date:.....
13. Signature: .....
14. The documents filed with the application or extension of approval can be obtained upon request

---

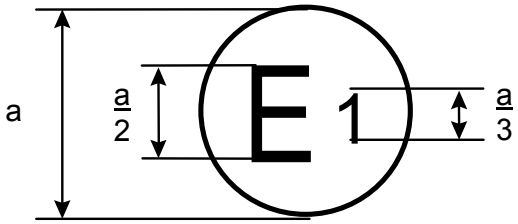
1/ Distinguishing number of the country which has granted/extended/refused/withdrawn approval (see approval provisions in the Regulation)

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

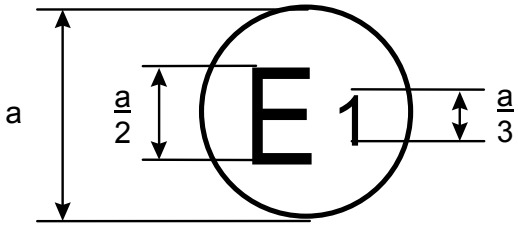


xxx R-002439

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 liquid hydrogen, been approved in Germany (E1), pursuant to the Regulation No. xxx 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. xxx in its original form.

MODEL B
(See paragraph 14.2. of this Regulation)



xxx 002439
83 021628

a ≥ 8 mm

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

Annex 6

COMMUNICATION
(maximum format : A4 (210 x 297 mm))

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

concerning: 2/ APPROVAL GRANTED
APPROVAL EXTENDED
APPROVAL REFUSED
APPROVAL WITHDRAWN
PRODUCTION DEFINITELY DISCONTINUED
of a vehicle type with regard to the installation of a hydrogen system pursuant to Regulation No. xxx

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

1. Trade name or mark:.....
2. Vehicle type:.....
3. Vehicle category:.....
4. Manufacturer's name and address: .....
5. If applicable, name and address of 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
7.1.1. Container:.....
7.1.2. etc. .....
8. Submitted for approval on: .....
9. Technical service responsible for conducting approval tests: .....
.....
10. Date of report issued by that service:.....
11. Number 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 equipment considered to be of importance for the purpose of this Regulation; Where applicable drawings of the various equipments and their position in the vehicle.

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

2/ Strike out what does not apply

Annex 7A

PROVISIONS REGARDING THE APPROVAL OF THE CONTAINER(S)

1. SCOPE

This annex applies to the container for the storage of liquid hydrogen in a motor vehicle and the equipment of the container.

2. GENERAL PROVISIONS

2.1. The container and its equipment shall function in a correct and safe way. It shall reliably withstand the electrical, mechanical, thermal and chemical operating conditions and it shall stay gas tight. These requirements are fulfilled if this annex 7A is fulfilled. The design validation of the container by calculation shall be done in accordance with EN 1251-2:2000. Other regulations may be applied in agreement with the technical service if they are at least equivalent.

2.2. Mechanical stresses

The following mechanical stresses shall be considered:

2.2.1. Inner tank.

2.2.1.1. The test pressure:
The inner tank shall resist the test pressure P_{test}:

$$P_{test} = 1.3 \text{ (MAWP} + 0.1 \text{ MPa)}$$

with MAWP: Maximum Allowable Working Pressure of the inner tank in MPa

2.2.1.2. Outer pressure:
If an operating mode of the inner tank and its equipment under vacuum is possible, the inner tank and its equipment shall resist an outer pressure of 0.1 MPa.

2.2.2. Outer jacket.

2.2.2.1. The outer jacket shall resist the Maximum Allowable Working Pressure (MAWP), which is the set pressure of its safety device.

2.2.2.2. The outer jacket shall resist an outer pressure of 0.1 MPa.

2.2.3. Outer supports:
The outer supports of the full container shall resist the accelerations named in Part II, paragraph 14.3.4. of this Regulation without rupture, in which case the allowable stress in the support elements shall not exceed (calculated according linear stress model):

$$\sigma \leq 0.5 \, R_m$$

2.2.4. Inner supports:
The inner supports of the full container shall resist the accelerations named in Part II, paragraph 14.3.4. of this Regulation without rupture, in which case the allowable stress in the support elements shall not exceed (calculated according linear stress model):

$$\sigma \leq 0.5\ R_m\ .$$

2.2.5. The requirements of paragraphs 2.2.3. and 2.2.4. do not apply if it can be demonstrated that the tank may support the accelerations named in Part II, paragraph 14.3.4. of this Regulation without any leak on the inner tank and all the different pipes upstream automatic safety devices, shut off valves and/or non return valves.

2.2.6. The proof of the dimensioning of the supports of the container can be done either by calculation or by experiment, e.g. crash tests.

2.3. Design temperature

2.3.1. Inner tank and outer jacket
The design temperature of the inner tank and the outer jacket shall be 20 °C.

2.3.2. Other equipment
For all other equipment which is not mentioned under paragraph 2.3.1. the design temperature is the lowest respectively the highest possible operating temperature.

2.3.3. The thermal stresses by operating conditions like filling or withdrawal or during the cooling down processes shall be considered.

2.4. Chemical compatibility

2.4.1. The materials of the container and its equipment shall be compatible with:
- hydrogen, if the parts are in contact with
- the atmosphere, if the parts are in contact with
- other media if the parts are in contact with (i.e. coolant, etc.)

2.4.2. All components used for the insulation system and the container's) shall be compatible with an atmosphere enriched with oxygen according to EN 1797:2001.

3. MATERIALS

3.1. The manufacturer of the materials shall provide:
- the appropriate equipment for manufacturing and testing
- the appropriate procedures for manufacturing
- the competent personnel for manufacturing and testing

– the appropriate quality assurance and documentation to ensure the quality and the traceability of the material

3.2. The materials shall be composed, manufactured and further treated in a manner that:
– the finished products show the required mechanical properties
– the finished products which are used for pressurised components and are in contact with hydrogen resist the thermal, chemical and mechanical stresses that they may be subjected to.

3.3. For manufacturers of parent and filler materials which are used for the inner tank and those parts of the container which are pressurised and in contact with hydrogen (except sealing materials) the technical service shall once perform a quality conformance inspection to prove and certify that the conditions of paragraphs 3.1. and 3.2. of this annex are fulfilled. The inspection shall be performed according to CEOC-Specification, e.g. R 97/CEOC/CP 96 def "Existing certificates of notified bodies according to pressure equipment Directive 97/23/EC or equivalent shall be accepted.

3.4. Characteristics

3.4.1. Materials used at low temperatures shall follow the toughness requirements of EN 1252-1:1998/AC1998. For non-metallic materials low temperature suitability shall be validated by an experimental method, taking into account service conditions.

3.4.2. The materials used for the outer jacket shall ensure the integrity of the insulation system, and their elongation at fracture in a tensile test shall be at least 12 per cent at liquid nitrogen temperature.

3.4.3. A corrosion allowance is not required for the inner tank. A corrosion allowance is not required on other surfaces if they are adequately protected against corrosion.

3.5. Certificates and proofs of the material characteristics

3.5.1. For parent and filler materials which are used for the inner tank and those parts of the container which are pressurised and in contact with hydrogen (except sealing materials) the technical service shall issue a certificate for the materials. The inspection shall be performed according to CEOC-Specifications R 77/CEOC/CP 90 def (and following numbers of the specifications). Existing certificates of notified bodies according to the pressure equipment Directive 97/23/EC or equivalent shall be accepted.

3.5.2. The filler materials shall be compatible with the parent material so as to form welds with properties equivalent to those specified for the parent material for all temperatures that the material may encounter.

3.5.3. The container manufacturer shall obtain and provide chemical cast analysis and mechanical properties certificates of the material in respect of the steels or

other materials used in the construction of the parts subject to pressure. In case of metallic materials the certificate must be at least type 3.1.B according to EN 10204:1991/A1:1995 or equivalent. In case of non-metallic materials the certificate must be of equivalent type.

3.5.4. The technical service shall have the opportunity to make independent analyses and examinations. These examinations shall be carried out either on specimens taken from the materials as supplied to the container manufacturer or on the finished containers.

3.5.5. The manufacturer shall make available to the technical service the results of metallurgical and mechanical tests and analyses of parent and filler materials carried out on welds.

3.5.6. Material sheets shall be marked at least with:
- sign of the manufacturer
- material identification number
- batch number
- sign of the inspecting person

3.6. Design calculation

3.6.1. Provisions regarding the inner tank:
The design of the inner tank shall be done according to the design rules of EN 1251 2:2000.

3.6.2. Provisions regarding the outer jacket:
The design of the outer jacket shall be done according to the design rules of EN 1251-2:2000.

3.6.3. Unless indicated otherwise the general tolerances of ISO 2768-1:1989 shall apply.

4. MANUFACTURING AND MOUNTING OF THE CONTAINER

4.1. The manufacturer of the containers or parts of it shall provide:
- the appropriate equipment for manufacturing and testing
- the appropriate procedures for manufacturing
- the competent personnel for manufacturing and testing
- a manufacturing and inspection plan
- the appropriate quality assurance and documentation to ensure the quality and the traceability of the parts and materials

4.2. For the manufacturer of the container the technical service shall once perform a quality conformance inspection to proof and certify that the conditions of paragraph 4.1. of this annex are fulfilled. The inspection shall be performed analogously according to CEOC-

Specification, e.g. R 80/CEOC/CP 91 def, R 81/CEOC/CP 91 def. Existing certificates of notified bodies according to the pressure equipment Directive 97/23/EC or equivalent shall be accepted.

4.3. Manufacturers of welded containers shall have a welding quality system in operation, taking into account the quality requirements for welding in accordance with EN 729-2:1994 or EN 729-3:1994.

4.4. The welding process shall be approved by the technical service in accordance with EN 288-3:1992/A1:1997, EN 288-4:1992/A1:1997 and EN 288-8:1995.

4.5. Welders shall be approved by the technical service according to EN 287-1:1992/A1:1997, EN 287-2:1992/A1:1997 and for automatic welding operators in accordance with EN 1418:1998.

4.6. Manufacturing operations (e.g. forming and heat treatment, welding) shall be carried out according to EN 1251-2:2000.

4.7. The inspections and the testing of the internal pipe work between the inner tank and the outer jacket: all welded joints of the pipe work shall be subject to 100 per cent non destructive inspection, where ever possible by radiographic inspection, alternatively ultrasonic test, penetration test, helium leakage test etc.

4.8. The number of joints should be minimized. Joints shall not be permitted within the void between the inner tank and the outer jacket unless they are welded or glued.

4.9. The equipment of the container shall be mounted in a way that the system and its components function in a correct and safe way and are gas tight.

4.10. The container shall be cleaned and dried before operation according to EN 12300:1998.

5. EQUIPMENT

5.1. Protection of the outer jacket
The outer jacket shall be protected by means of a device preventing bursting of the outer jacket or collapsing of the inner tank.

5.2. Provisions regarding the insulation

5.2.1. Under no circumstances may ice be allowed to form on the outer wall of the container under normal operating conditions. At the area of pressure relief pipe, local ice formation is allowed on the outside of the pipe.

5.2.2. When exposed to fire the thermal autonomy of the container, equipped with its vacuum insulation and fire protection measures (if present), shall be at least 5 minutes.

5.3. Level gauge

5.3.1. A measuring gauge in the driver's compartment shall indicate the level of liquid in the container with an accuracy of +/- 10 per cent of the container capacity.

5.3.2. If the system comprises a float, the latter shall withstand an outside pressure greater than the Maximum Allowable Working Pressure (MAWP) of the inner tank with a minimum coefficient of safety of 2 with respect to the buckling failure criteria.

5.4. Maximum filling level

5.4.1. A system shall be provided for preventing the container from being overfilled. This system may work in conjunction with the refuelling station.

5.4.2. The device shall bear a permanent marking, indicating the container-type for which it has been designed and if applicable the mounting position and orientation. Under all circumstances and regardless of the fuel condition and the maximum operating pressure of the inner tank, the filling volume of the liquid shall not exceed 95 per cent of the water volume of the inner tank.

5.5. Marking

5.5.1. The marking of the inner tank and of the outer jacket should be according to Part I, paragraph 4.3. of this Regulation.

5.5.2. The marking method shall not cause localised stress peaks in the structure of the inner tank or the outer jacket.

5.6. Inspection openings
Inspection openings are not required in the inner or outer jacket.

6. TESTS AND INSPECTION

6.1. Tests and inspection for the approval

For the approval the technical service shall perform the tests and inspections according to paragraphs 6.3.1. to 6.3.6. of this annex on two samples of containers. The samples shall be provided in the applicable state necessary for the under-mentioned inspections. For the approval samples of the container shall be subjected to the tests according to paragraphs 6.3.7. to 6.3.9. of this annex and shall be witnessed by the technical service. A crash test according to paragraph 6.3.10. shall be witnessed by the technical service if calculations are not sufficient to determine and verify the design criteria of the container jackets or supports.

6.2. Tests and inspection during production

For the serial production the manufacturer shall perform the tests and inspections according to paragraphs 6.3.1. to 6.3.6. of this annex on each container.

6.3. Testing procedures

6.3.1. Pressure test.

6.3.1.1. The inner tank and the pipe work situated between the inner tank and the outer jacket shall withstand an inner pressure test at room temperature any suitable media, according to the following requirements.
The test pressure p_{test} shall be:

$$p_{test} = 1.3 \text{ (MAWP + 0.1 MPa)}$$

with MAWP: Maximum Allowable Working Pressure of the inner tank in MPa.

6.3.1.2. The pressure test is to be performed before the outer jacket is mounted.

6.3.1.3. The pressure in the inner tank shall be increased at an even rate until the test pressure is reached.

6.3.1.4. The inner tank must remain under the test pressure at least for 10 minutes to establish that the pressure is not reducing.

6.3.1.5. After the test the inner tank must not show any signs of visible permanent deformation or visible leaks.

6.3.1.6. Any inner tank tested which does not pass the test because of permanent deformation shall be rejected and shall not be repaired.

6.3.1.7. Any inner tank tested which does not pass the test because of leakage may be accepted after repair and retesting.

6.3.1.8. In case of hydraulic test, upon completion of this test, the container shall be emptied and dried until the dew point inside the container is –40 °C (according to EN 12300:1998).

6.3.1.9. A test report shall be drawn up and the inner tank shall be marked by the inspection departments if accepted.

6.3.2. Leak testing.

After final assembly the hydrogen container shall be leak tested with a gas mixture containing a minimum of 10 per cent of helium

6.3.3. Verification of the dimensions.

The following dimensions shall be verified:
- for cylindrical container(s) roundness of the inner tank (see EN 1251-2:2000, 5.4)
- departure from a straight line of the inner and outer jacket (see EN 1251-2:2000, 5.4)

6.3.4. Destructive and non-destructive tests of welding seams
The tests shall be performed according to EN 1251-2:2000.

6.3.5. Visual inspection.

The welding seams and the inner and outer surfaces of the inner and outer jackets of the container shall be inspected visually. The surfaces shall not show any critical damages or defaults.

6.3.6. Marking.

The marking shall be verified in compliance with Part I, paragraph 4.3. of this Regulation.

6.3.7. Inner tank burst test.

The burst test shall be performed according to annex 8A of this Regulation on one sample of the inner tank.

6.3.8. Thermal autonomy test under fire.

The thermal autonomy test for the container shall be performed according to annex 8A of this Regulation.

6.3.9. Maximum filling level test.

The maximum filling level test for the container shall be performed according to annex 8A of this Regulation.

6.3.10. Crash test.

If a crash test is performed it shall be in accordance with Part II, paragraph 14.3.4. or 14.3.5. of this Regulation.

7. DOCUMENTATION

7.1. Documentation system

The manufacturer shall use a documentation system that can provide the information required to verify during the manufacturing process the following topics:

- the completeness of the documents described in part I, paragraph 3.2. of this Regulation

- the compliance with these specifications, in detail:
  - dimensions
  - construction
  - materials and certifications about material characteristics and compatibility
  - heat treatment
  - manufacturing procedures
  - equipment
  - marking
  - operating conditions
  - calculation of the insulation quality
  - calculation of the minimum flow rate of the pressure relief device
  - test report about the fire test and loss of vacuum
  - test reports about crash test or burst test, if necessary
  - further testing certificates, if necessary.

7.2. Provisions regarding every container

7.2.1. Documentation shall include the manufacturing and the inspection information for every container. This documentation shall be kept by the container manufacturer for 10 years.

7.2.2. The documentation shall contain at least the reference to the manufacturing procedure, the approval number, the list of the welding procedures and reference to the qualification, the batch number of every material used for the inner tank and the internal pipe work with the certificates of conformity of the required level, the date, the pressure and the control certificate of the pneumatic or hydraulic test and the pressure at the end of the pumping.

Annex 7B

PROVISIONS REGARDING THE APPROVAL OF PRESSURE RELIEF DEVICES

1. The design, manufacturing and control of the pressure relief devices shall be in accordance with EN 13648-1:2002 and EN 13648-2:2002.

2. In case of boil off system in parallel of the primary safety device, then the safety valve is a category B safety device otherwise it is a category A safety device according to EN 13648.

3. Maximum Allowable Working Pressure (MAWP): 1.5 x Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the component is subjected to.

4. Set pressure

4.1. Primary devices of the inner tank: according to paragraph 6.4.1.1. of Part I of this Regulation.

4.2. Secondary device of the inner tank: according to paragraph 6.4.1.2. of Part I of this Regulation.

4.3. Pressure relief devices for components other than the tank: according to paragraph 6.4.2. of Part I of this Regulation.

5. Design temperatures

5.1. External temperature: see Part II, paragraph 14.1.7. of this Regulation.

5.2. Internal temperature: -253 °C to +85 °C.

6. Applicable test procedures:

Pressure test	annex 8B
External leakage test	annex 8B
Operational test	according to EN 13648-1:2002 or EN 13648-2:2002
Corrosion resistance	annex 8B */ **/
Temperature cycle test	annex 8B ***/

*/ only for metallic parts
**/ only for equipment outside of the gas tight housing
***/ only for non-metallic parts

Annex 7C

PROVISIONS REGARDING THE APPROVAL OF HYDROGEN VALVES

1. The design, manufacturing and control of the cryogenic hydrogen shall be in accordance with EN 13648-1:2002 and EN 13648-2:2002.

2. Maximum Allowable Working Pressure (MAWP): 1.5 x Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the component is subjected to.

3. Design temperatures

3.1. External temperature: see Part II, paragraph 14.1.7. of this Regulation.

3.2. Internal temperature: -253 °C to +85 °C for valves before the heat exchanger
-40 °C to +85 °C for valves after the heat exchanger

4. Applicable test procedures:

Pressure test	annex 8B
External leakage test	annex 8B
Seat leakage test	annex 8B
Endurance test	annex 8B

(with 6,000 operation cycles for manual valves
with 20,000 operation cycles for automatic valves)

Corrosion resistance	annex 8B */ **/
Resistance to dry-heat	annex 8B ***/
Ozone ageing	annex 8B ***/
Temperature cycle test	annex 8B ***/

*/ only for metallic parts
**/ only for equipment outside of the gas tight housing
***/ only for non-metallic parts

Annex 7D

PROVISIONS REGARDING THE APPROVAL OF HEAT EXCHANGERS

1. Maximum Allowable Working Pressure (MAWP): 1.5 x Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the component is subjected to.

2. Design temperatures

2.1. External temperature: see Part II, paragraph 14.1.7 of this Regulation.

2.2. Internal temperature: -253 °C to +85 °C.

3. Applicable test procedures

Pressure test	annex 8B
External leakage test	annex 8B
Corrosion resistance	annex 8B */
Resistance to dry-heat	annex 8B ***/
Ozone ageing	annex 8B ***/
Temperature cycle test	annex 8B ***/

4. The manufacturing and mounting of the heat exchanger is to be certified according to annex 7A, paragraphs 4.3. to 4.5.

---

*/ only for metallic parts
***/ only for non-metallic parts

Annex 7E

PROVISIONS REGARDING THE APPROVAL OF
REFUELLING CONNECTIONS OR RECEPTACLES

1. The design, manufacturing and control of the connection shall be in accordance with EN 13371:2001.

2. Maximum Allowable Working Pressure (MAWP): 1.5 x Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the component is subjected to.

3. Design temperatures

3.1. External temperature: see Part II, paragraph 14.1.7. of this Regulation.

3.2. Internal temperature: -253 °C to 85 °C

4. Applicable test procedures

Pressure test	annex 8B
External leakage test	annex 8B
Seat leakage test	annex 8B
Endurance test	annex 8B
(with 3,000 operation cycles)	
Corrosion resistance	annex 8B */
Resistance to dry-heat	annex 8B ***/
Ozone ageing	annex 8B ***/
Temperature cycle test	annex 8B ***/

*/ only for metallic parts
***/ only for non-metallic parts

Annex 7F

PROVISIONS REGARDING THE APPROVAL OF PRESSURE REGULATORS

1. Maximum Allowable Working Pressure (MAWP): 1.5 x Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the component is subjected to.

2. Design temperatures

2.1. External temperature: see Part II, paragraph 14.1.7. of this Regulation.

2.2. Internal temperature: at least as given in Part II, paragraph 14.1.7. of this Regulation.

3. Applicable test procedures

Pressure test	annex 8B
External leakage test	annex 8B
Seat leakage test	annex 8B
Endurance test	annex 8B
(with 20,000 operation cycles)	
Corrosion resistance	annex 8B */ **/
Resistance to dry-heat	annex 8B ***/
Ozone ageing	annex 8B ***/
Temperature cycle test	annex 8B ***/

*/ only for metallic parts
**/ only for equipment outside of the gas tight housing
***/ only for non-metallic parts

Annex 7G

PROVISIONS REGARDING THE APPROVAL OF SENSORS

1. Maximum Allowable Working Pressure (MAWP): 1.5 x Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the component is subjected to.

2. Design temperatures

2.1. If operated with ambient temperature: see Part II, paragraph 14.1.7. of this Regulation.

2.2. If operated with cryogenic temperature: lowest operating temperature: -253 °C, maximum temperature: +85 °C or 120 °C as given in Part II, paragraph 14.1.7. of this Regulation.

3. Applicable test procedures for every sensor

Pressure test	annex 8B ****/
External leakage test	annex 8B ****/
Corrosion resistance	annex 8B */ **/
Resistance to dry-heat	annex 8B
Ozone ageing	annex 8B ***/
Temperature cycle test	annex 8B ***/

*/ only for metallic parts
**/ only for equipment outside of the gas tight housing
***/ only for non-metallic parts
****/only for equipment directly in contact with hydrogen

Annex 7H

PROVISIONS REGARDING THE APPROVAL OF FLEXIBLE FUEL LINES

1. The design, manufacturing and control of the cryogenic flexible fuel lines shall be in accordance with EN 12434:2000.

2. Maximum Allowable Working Pressure (MAWP): 1.5 x Maximum Allowable Working Pressure (MAWP) of the inner tank or maximum pressure the component is subjected to.

3. Design temperatures

3.1. If operated with ambient temperature: see Part II, paragraph 14.1.7. of this Regulation.

3.2. If operated with cryogenic temperature: lowest operating temperature: -253 °C, maximum temperature: 85 °C or 120 °C as given in Part II, paragraph 14.1.7. of this Regulation.

4. Applicable test procedures for every flexible fuel line

Pressure test	annex 8B
External leakage test	annex 8B
Corrosion resistance	annex 8B */ **/
Resistance to dry-heat	annex 8B ***/
Ozone ageing	annex 8B ***/
Temperature cycle test	annex 8B ***/
Pressure cycle	annex 8B

*/ only for metallic parts
**/ only for equipment outside of the gas tight housing
***/ only for non-metallic parts

Annex 8A

APPROVAL TEST PROCEDURES FOR THE CONTAINER

1. INNER TANK BURST TEST

1.1. Criteria

1.1.1. An inner tank not integrated in its outer jacket and not insulated shall withstand a burst test.

1.1.2. The burst pressure shall be at least equal to the burst pressure used for the mechanical calculations. For steel tanks that is to say:
- either the Maximum Allowable Working Pressure (MAWP) (in MPa) plus 0.1 MPa multiplied by 3.25;
- or the Maximum Allowable Working Pressure (MAWP) (in MPa) plus 0.1 MPa multiplied by 1.5 and multiplied by R_m / R_p.

1.1.3. At the Maximum Allowable Working Pressure (MAWP), the principal dimensions (perimeter, length, etc.) shall not be modified more than 1 per cent.

1.1.4. Once the test is completed the volume of the tank shall have increased by more than 8 per cent.

1.1.5. The performance of hydrogen containers made from materials other than steel, shall be demonstrated to be equivalent to these requirements according to existing international standards.

1.2. Procedure

1.2.1. The test tank shall be representative of the design and the manufacturing of the type to be homologated.

1.2.2. The test shall be an hydraulic test.

1.2.3. The tube and piping may be modified to enable the test (purge of dead volume, introduction of the liquid, closing of non used pipes, etc.)

1.2.4. The tank shall be filled with water. The pressure will be increased at a constant rate not exceeding 0.5 MPa/min until burst. When the Maximum Allowable Working Pressure (MAWP) is reached there will be a at least ten minute wait period at constant pressure so that the deformation of the tank shall be checked in accordance with paragraph 1.1.3. of this annex.

1.2.5. A system will enable to look at possible deformations.

1.2.6. The pressure shall be recorded or written during the entire test.

1.3. Results

The test conditions and the bursting pressure shall be written in a test certificate signed by the manufacturer and the technical service.

2. THERMAL AUTONOMY UNDER FIRE

2.1. Criteria

2.1.1. The thermal autonomy of the tank shall not be less than 5 minutes under external fire.

2.1.2. The tank shall not burst and the pressure inside the inner tank shall not exceed the permissible fault range of the inner tank In the case of steel inner tanks, the tank pressure shall not exceed 136 per cent of the Maximum Allowable Working Pressure (MAWP) of the inner tank. For other materials, an equivalent level of safety shall be applied.

2.2. Procedure

2.2.1. The test tank shall be representative of the design and the manufacturing of the type to be homologated.

2.2.2. Its manufacturing is completely finished and it is mounted with all its equipment and particularly the level gauge.

2.2.3. The second safety device is replaced by a shut off valve that will open in case of failure of the test at a pressure lower than the hydraulic test pressure.

2.2.4. The tank has already been cooled down and the inner tank is at the same temperature as the liquid hydrogen. The tank has contained during the previous 24 hours a volume of liquid hydrogen at least equal to half of the water volume of the inner tank.

2.2.4.1. The tank is filled with liquid hydrogen so that the quantity of liquid hydrogen measured by the mass measurement system shall be half of the maximum allowed quantity that may be contained in the inner tank.

2.2.4.2. A fire shall burn 0.1 meter underneath the tank. The length and the width of the fire shall exceed the plan dimensions of the container by 0.1 m. The temperature of the fire shall be at least 590 °C. The fire shall continue to burn for the duration of the test.

2.2.4.3. The pressure of the tank at the beginning of the test shall be between 0 MPa and 0.01 MPa at the boiling point of hydrogen in the inner tank.

2.2.4.4. The lapse of time before the opening of the safety device will be measured. It shall not be less than 5 minutes.

2.2.4.5. Once the safety device opens, the test shall continue until the blow off of the safety device has finished. During the test the tank shall not burst and the pressure inside the inner tank shall not exceed the permissible fault range of the inner tank. In the case of steel inner tanks, the tank pressure shall not exceed 136 per cent of the Maximum Allowable Working Pressure (MAWP) of the inner tank. For other materials, an equivalent level of safety shall be applied.

2.3. Results

The test conditions, the thermal autonomy and the maximum pressure reached within the tank during the test, shall be recorded in a test certificate signed by the manufacturer and the technical service.

3. MAXIMUM FILLING LEVEL

3.1. Criteria

The level of hydrogen shall never exceed 95 per cent of the water volume of the inner tank. During all the tests done for the homologation, the maximum filling level between tests shall not vary by more than 10 per cent of the remaining vapour volume of the tank.

3.2. Procedure

3.2.1. The test tank shall be representative of the design and the manufacturing of the type to be homologated.

3.2.2. Its manufacturing is completely finished and it is fitted with all its equipment and particularly the level gauge.

3.2.3. The tank has already been cooled down and the inner tank is at the same temperature as the liquid hydrogen. The tank has contained during the previous 24 hours a volume of liquid hydrogen at least equal to half of the water volume of the inner tank.

3.2.4. A system measures either the mass of hydrogen or the mass flow rate at the inlet and the outlet of the tank with an accuracy better than 1 per cent of the maximum filling mass of the tested container.

3.2.5. The tank shall be completely filled 10 times with liquid hydrogen at equilibrium with its vapour. Between each filling at least a quater of the liquid hydrogen of the tank is emptied.

3.3. Results

The test conditions and the ten maximum level measured by the added system shall be written in a test certificate signed by the manufacturer and the technical service.

Annex 8B

APPROVAL TEST PROCEDURES FOR OTHER SPECIFIC COMPONENTS

1. GENERAL REQUIREMENTS

1.1. Leakage tests shall be conducted with pressurized gas such as air or nitrogen containing at least 10 per cent helium.

1.2. Water or another fluid may be used to obtain the required pressure for pressure test.

1.3. All test records shall indicate the type of test medium used, if applicable.

1.4. The test period for leakage and pressure tests shall be not less than 3 minutes more than the response time of the sensor.

1.5. All tests shall be performed at a temperature of 20 °C ± 5 °C, unless otherwise stated.

1.6. The different components shall be correctly dried before leak test.

2. PRESSURE TEST

2.1. A hydrogen containing component shall withstand without any visible evidence of leak or deformation a test pressure of 1.5 times its Maximum Allowable Working Pressure (MAWP) with the outlets of the high pressure part plugged. The pressure shall then be increased from 1.5 to 3 times the Maximum Allowable Working Pressure (MAWP). The component shall not show any visible evidence of rupture or cracks.

2.2. The pressure supply system shall be equipped with a positive shut-off valve and a pressure gauge, having a pressure range of not less than 1.5 times nor more than 2 times the test pressure and the accuracy of the gauge shall be 1 per cent of the pressure range.

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

3. EXTERNAL LEAKAGE TEST

3.1. A component shall be free from leakage through stem or body seals or other joints, and shall not show evidence of porosity in casting when tested as described in paragraph 5.3. at any pneumatic pressure between zero and its Maximum Allowable Working Pressure (MAWP).

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

3.2.1. at a temperature of 20 °C ± 5 °C;

3.2.2. at the minimum operating temperature or at liquid nitrogen temperature after 3 hours conditioning at this temperature;

3.2.3. at the maximum operating temperature after 3 hours conditioning at this temperature.

3.3. During this test the equipment under test will be connected to a source of pneumatic pressure. A positive shut-off valve and a pressure gauge having a pressure range of not less than 1.5 times nor more than 2 times the test pressure are to be installed in the pressure supply piping and the accuracy of the gauge shall be 1 per cent of the pressure range. The pressure gauge is to be installed between the positive shut-off valve and the sample under test.

3.4. Throughout the test, the sample will be tested for leakage, with a surface active agent without formation of bubbles or measured with a leakage rate less than 10 cm^3/hour.

4. SEAT LEAKAGE TEST

4.1. The following tests for seat leakage are to be conducted on samples which have previously been subjected to the external leakage test of paragraph 3. above.

4.2. Seat leakage tests shall be conducted with the inlet of the sample valve connected to a source of pneumatic pressure, the valve in the closed position, and with the outlet open. A positive shut-off valve and a pressure gauge having a pressure range of not less than 1.5 times and not more than twice the test pressure are to be installed in the pressure supply piping and the accuracy of the gauge shall be 1 per cent of the pressure range. The pressure gauge is to be installed between the positive shut-off valve and the sample under test. While under the applied test pressure corresponding to the Maximum Allowable Working Pressure (MAWP), observations for leakage are to be made with the open outlet submerged in water or by a flow meter installed on the inlet side of the valve under test. The flow meter shall be capable of indicating, for the test fluid employed, the maximum leakage flow rates permitted within an accuracy of +/-1 per cent .

4.3. The seat of a shut-off valve, when in the closed position, shall not leak at a rate exceeding 10 cm^3/hour at any pneumatic pressure between zero and Maximum Allowable Working Pressure (MAWP).

4.4. A non-return valve when in the closed position, shall not leak when subjected to any aerostatic pressure between 50 kPa and its Maximum Allowable Working Pressure (MAWP).

4.5. A non-return valve in closed position shall not leak with a rate exceeding 500 cm^3/hour of air during the test. In case the filling unit includes a non-return valve then this valve shall not leak at a rate exceeding 10 cm^3 / hour during the test.

4.6. The pressure relief devices shall not leak at a rate exceeding 10 cm^3/hour at any pneumatic pressure between zero and set pressure minus 10 per cent.

5. ENDURANCE TEST (CONTINUED OPERATION)

5.1. A hydrogen carrying component shall be capable of conforming to the applicable leakage test requirements of paragraphs 3. and 4. of this annex, after being subjected to the number of operation cycles specified for that component in annex 7B to 7H to this Regulation.

5.2. The appropriate tests for external leakage and seat leakage, as described in paragraphs 3. and 4. of this annex are to be conducted immediately following the endurance test.

5.3. The component shall be securely connected to a pressurized source of dry air or nitrogen and subjected to the number of cycles specified for that specific component in annex 7 to this Regulation. A cycle shall consist of one opening and one closing of the component within a period of not less than 10 ± 2 seconds.

5.4. The component shall be operated through 96 per cent of the number of specified cycles at a temperature of 20 °C ± 5 °C and at the MAWP of the component. During the off cycle the downstream pressure of the test fixture should be allow to decay to 50 per cent of the MAWP of the component.

5.5. The component shall be operated through 2 per cent of the total cycles at the maximum material temperature (see paragraph 14.1.7. of this Regulation) after 3 hours conditioning a this temperature and at MAWP. The component shall comply with paragraphs 3. and 4. of this annex at the appropriate maximum material temperature (see paragraph 14.1.7. of this Regulation) at the completion of the high temperature cycles.

5.6. The component shall be operated through 2 per cent of the total cycles at the minimum material temperature but not less than the temperature of liquid nitrogen (see paragraph 14.1.7. of this Regulation) after 3 hours conditioning at this temperature and at the MAWP of the component. The component shall comply with paragraphs 3. and 4. of this annex at the appropriate minimum material temperature (see paragraph 14.1.7. of this Regulation) at the completion of the low temperature cycles.

6. OPERATIONAL TESTS

6.1. Operation test of the pressure relief valve

These tests has to be carried out in accordance with EN 13648-1:2002 or EN 13648 2:2002. The specific requirements of the standard are applicable.

7. CORROSION RESISTANCE

7.1. Metallic hydrogen containing components shall comply with the leakage tests mentioned in paragraphs 3. and 4. above, if applicable, after being submitted to 144 hours salt spray test according to DIN 50021:1998, ISO 9227:1990 or IEC 60068-2-52:1996 with all connections closed.

7.2. A copper or brass hydrogen containing component shall comply with the leakage tests mentioned in paragraphs 3. and 4. above and after being submitted to 24 hours immersion in ammonia according to DIN 50916-2:1985 or ISO 6957:1988 with all connections closed.

8. RESISTANCE TO DRY-HEAT

The test has to be done in compliance with ISO 188:1998. The test piece has to be exposed to air at a temperature equal to the maximum operating temperature for 168 hours. The change in tensile strength shall not exceed + 25 per cent. The change in ultimate elongation shall not exceed the following values:

- maximum increase 10 per cent,
- maximum decrease 30 per cent.

9. OZONE AGEING

9.1. The test has to be in compliance with ISO 1431-1:1989. The test piece, which has to be stressed to 20 per cent elongation, shall be exposed to air at 40 °C with an ozone concentration of 50 parts per hundred million during 120 hours.

9.2. No cracking of the test piece is allowed.

10. TEMPERATURE CYCLE TEST

A non-metallic part containing hydrogen shall comply with the leakage tests mentioned in paragraphs 3. and 4. after having been submitted to a 96 hours temperature cycle from the minimum operating temperature up to the maximum operating temperature with a cycle time of 120 minutes, under Maximum Allowable Working Pressure (MAWP).

11. PRESSURE CYCLE

11.1. Any flexible fuel line shall be capable of conforming to the applicable leakage test requirements of paragraphs 3. above, after being subjected to 6,000 pressure cycles.

11.2. The pressure shall change from atmospheric pressure to the Maximum Allowable Working Pressure (MAWP) of the tank within less than five seconds, and after a time of

at least five seconds, shall decrease to atmospheric pressure within less than five seconds.

11.3. The appropriate test for external leakage, as described under external leakage test in paragraph 3. above is to be conducted immediately following the endurance test.

Annex 8C

HYDROGEN COMPATIBILITY TEST

At temperatures close to ambient a number of metallic materials are susceptible to hydrogen embrittlement, particularly those with a body centered cubic lattice structure. This is a particular problem with many ferritic steels if they are subjected to mechanical stresses. Prior to being able to locally embrittle a metallic structure hydrogen must enter the material in atomic form. In the presence of hydrogen gas the hydrogen molecules have to dissociate first. The process preferably takes place on freshly generated metallic surfaces that are likely to form at surface defects or other stress raisers as a result of stress induced local plastic deformation processes. Impurities like hydrogen sulfide dissociate atomic hydrogen even more easily than molecular hydrogen.

In general the susceptibility to hydrogen embrittlement can be lowered by:

- restricting the hardness and, therefore, the strength level of the material used to a safe value;
- lowering the level of applied stress;
- minimizing residual stresses by e.g. stress-relieving weldments and by normalizing or fully annealing cold worked material;
- avoiding or minimizing cold plastic deformation from operations such as cold bending or forming.

In components that are subjected to frequent load cycles all situations shall be avoided that can lead to local fatigue since hydrogen is known to significantly accelerate a possible initiation and propagation of fatigue cracks in a structure.

Austenitic stainless steels in general are not or less susceptible to hydrogen embrittlement and are commonly used as structural materials for hydrogen equipment because of their excellent toughness behaviour at cryogenic temperatures. However some of these austenitic stainless steels are not stable and can form martensite when deform at low temperature. This martensite being very sensitive to H_2 embrittlement, it is not recommended to use such materials especially for equipment that shall be warm up to room temperature under H_2.

The hydrogen compatibility may be proved according to standard ISO/DIS 11114-4.

Annex 9

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

1. GENERAL

This annex defines the special requirements for documentation, fault strategy and verification with respect to the safety aspects of complex electronic vehicle control systems (paragraph 2.3. below) as far as this Regulation is concerned.

This annex may also be called, by special paragraphs in this Regulation, for safety related functions which are controlled by electronic system(s).

This annex does not specify the performance criteria for "The System" but covers the methodology applied to the design process and the information which must be disclosed to the technical service, for type approval purposes.

This information shall show that "The System" respects, under normal and fault conditions, all the appropriate performance requirements specified elsewhere in this Regulation.

2. DEFINITIONS

For the purposes of this annex:

2.1. "Safety concept" is a description of the measures designed into the system, for example within the electronic units, so as to address system integrity and thereby ensure safe operation even in the event of an electrical failure. The possibility of a fall-back to partial operation or even to a back-up system for vital vehicle functions may be a part of the safety concept.

2.2. "Electronic control system" means 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. "The System", referred to herein, is the one for which type approval is being sought.

2.3. "Complex electronic vehicle control systems" are those electronic control systems which are subject to a hierarchy of control in which a controlled function may be over-ridden by a higher level electronic control system/function. A function which is over-ridden becomes part of the complex system.

2.4. "Higher-level control" systems/functions are those which employ additional processing and/or sensing provisions to modify vehicle behaviour by commanding variations in the normal function(s) of the vehicle control system. This allows complex systems to automatically change their objectives with a priority which depends on the sensed circumstances.

2.5. "Units" are the smallest divisions of system components which will be considered in this annex, since these combinations of components will be treated as single entities for purposes of identification, analysis or replacement.

2.6. "Transmission links" are the means used for inter-connecting distributed units for the purpose of conveying signals, operating data or an energy supply. This equipment is generally electrical but may, in some part, be mechanical, pneumatic or hydraulic.

2.7. "Range of control" refers to an output variable and defines the range over which the system is likely to exercise control.

2.8. "Boundary of functional operation" defines the boundaries of the external physical limits within which the system is able to maintain control.

3. DOCUMENTATION

3.1. Requirements

The 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 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 which are involved.

For periodic technical inspections, the documentation shall describe how the current operational status of "The System" can be checked.

3.1.1. Documentation shall be made available in two parts:

(a) The formal documentation package for the approval, containing the material listed in paragraph 3. (with the exception of that of paragraph 3.4.4.) 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 4. of this annex.

(b) Additional material and analysis data of paragraph 3.4.4., which shall be retained by the manufacturer, but made open for inspection at the time of type approval.

3.2. 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.

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

3.2.2. A list of all output variables which 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 (paragraph 2.7.) exercised on each such variable shall be defined.

3.2.3. Limits defining the boundaries of functional operation (paragraph 2.8.) shall be stated where appropriate to system performance.

3.3. System layout and schematics

3.3.1. Inventory of components

A list shall be provided, collating all the units of "The System" and mentioning the other vehicle systems which 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 made clear.

3.3.2. 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.

3.3.3. Interconnections

Interconnections within "The System" shall be shown by a circuit diagram for the electric transmission links, by a piping diagram for pneumatic or hydraulic transmission equipment and by a simplified diagrammatic layout for mechanical linkages.

3.3.4. 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.

3.3.5. Identification of units

Each unit shall be clearly and unambiguously identifiable (e.g. by marking for hardware and marking or software output for software content) 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 hardware identification marking shall be used.

The manufacturer shall, by the use of this identification, affirm that the equipment supplied conforms to the corresponding document.

3.3.5.1. The identification defines the hardware and software version and, where the latter changes such as to alter the function of the unit as far as this Regulation is concerned, this identification shall also be changed.

3.4. Safety concept of the manufacturer

3.4.1. The manufacturer shall provide a statement which 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.

3.4.2. 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.

3.4.3. The manufacturer shall provide the technical authorities 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 for example:

(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

In case of a failure, the driver shall be warned for example by warning signal or message display. When the system is not deactivated by the driver, e.g. by turning the ignition (run) 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.

3.4.3.1. 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.

3.4.3.2. 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.

3.4.3.3. 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.

3.4.4. 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(es) shall be established and maintained by the manufacturer and shall be made open for inspection by the technical service at the time of the type approval.

3.4.4.1. This documentation shall itemise the parameters being monitored and shall set out, for each fault condition of the type defined in paragraph 3.4.4. above, the warning signal to be given to the driver and/or to service/technical inspection personnel.

4. VERIFICATION AND TEST

4.1. The functional operation of "The System", as laid out in the documents required in paragraph 3., shall be tested as follows:

4.1.1. 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.

4.1.2. Verification of the safety concept of paragraph 3.4.

The reaction of "The System" shall, at the discretion of the type approval authority, 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.

4.1.2.1. 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.

Annex 10

PROVISIONS REGARDING HYDROGEN IDENTIFICATION MARKS
FOR PUBLIC SERVICE VEHICLES OF CATEGORIES M2 AND M3

The sign consists of a sticker that shall be weather resistant.

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

Colours:	Background: green (ISO???)	
	Border: white (ISO???)	
	Letters: white (ISO???)	
	Either the borders and letters or the background shall be retroreflective.	
Dimensions:	Border width:	5 mm
	Sticker width:	125 mm (across flat sides)
	Sticker height:	125 mm (across flat sides)
	Font size:	
	"LIQUID"	
	Font height:	14 mm
	Font thickness:	3 mm
	"H_2" (capitalised)	
	Font height:	25 mm
	Font thickness:	5 mm

The words shall be in upper case characters and shall be centred in the middle of the sticker.

Annex 11

LIST OF EN/ISO EQUIVALENT STANDARDS

EN/ISO standard number	Title
EN 287-1:1992/A1:1997 ISO 9606-1:1994/Amd 1:1998	*Approval testing of welders — Fusion welding — Part 1: Steels* Approval testing of welders — Fusion welding — Part 1: Steels
EN 287-2:1992/A1:1997 ISO 9606-2:1994/Amd 1:1998	*Approval testing of welders — Fusion welding — Part 2: Aluminium and aluminium alloys* Approval testing of welders — Fusion welding — Part 2: Aluminium and aluminium alloys
EN 288-3:1992/A1:1997 ISO 9956-3:1995	*Specification and approval of welding procedures for metallic materials — Part 3: Welding procedure tests for the arc welding of steel* Specification and approval of welding procedures for metallic materials — Part 3: Welding procedure tests for arc welding of steels
EN 288-4:1992/A1:1997 ISO 9956-4:1995	*Specification and approval of welding procedures for metallic materials — Part 4: Welding procedure tests for the arc welding of aluminium and its alloys* Specification and approval of welding procedures for metallic materials — Part 4: Welding procedure tests for the arc welding of aluminium and its alloys
EN 288-8:1995 ISO 9956-8:1995	*Specification and approval of welding procedures for metallic materials — Part 8 Approval by a pre-production welding test* Specification and approval of welding procedures for metallic materials — Part 8: Approval by a pre-production welding test
EN 729-2:1994 ISO 3834-2:1994	*Quality requirements for welding — Fusion welding of metallic materials — Part 2: Comprehensive quality requirements* Quality requirements for welding — Fusion welding of metallic materials — Part 2: Comprehensive quality requirements
EN 729-3:1994 ISO 3834-3:1994	*Quality requirements for welding — Fusion welding of metallic materials — Part 3: Standard quality requirements* Quality requirements for welding — Fusion welding of metallic materials — Part 3: Standards quality requirements

EN/ISO standard number	Title
EN 1251-2:2000	*Cryogenic vessels — Transportable vacuum insulated vessels of not more than 1000 litres volume — Part 2: Design, fabrication, inspection and testing*
ISO/CD 21029-1 1/	Cryogenic vessels — Transportable vacuum insulated vessels of no more 1000 l volume — Part 1: Design, fabrication , inspection and testing
EN 1252-1:1998/AC:1998	*Cryogenic vessels — Materials — Part 1: Toughness requirements for temperatures below –80 °C*
ISO/DIS 21028-1 1/	Cryogenic vessels — Toughness requirements for materials at cryogenic temperature — Part 1: Temperature below –80 °C
EN 1418:1998	*Welding personnel — Approval testing of welding operators for fusion welding and resistance weld setters for fully mechanised and automatic welding of metallic materials*
ISO 14732:1998	Welding personnel — Approval testing of welding operators for fusion welding and of resistance weld setters for fully mechanized and automatic welding of metallic materials
EN 1626:1999	*Cryogenic vessels — Valves for cryogenic service*
ISO/WD 21011 1/	Cryogenic vessels —Valves
EN 1797: 2001	*Cryogenic vessels —Gas/material compatibility*
ISO/DIS 21010 1/	Cryogenic vessels — Gas/material compatibility
EN 10204:1991/A1:1995	*Metallic products — Types of inspection documents*
ISO 10474:1991	Steel and steel products — Inspection documents
EN 12300:1998	*Cryogenic vessels — Cleanliness for cryogenic service*
ISO/WD 23208 1/	Cryogenic vessels — Cleanliness for cryogenic service
EN 12434:2000	*Cryogenic vessels — Cryogenic flexible hoses*
ISO/WD 21012 1/	Cryogenic vessels — Hoses
EN 13371:2001	*Cryogenic vessels — Couplings for cryogenic service*
	No equivalent standard was found
EN 13648-1:2002	Cryogenic vessels — Safety devices for protection against excessive pressure — Part 1: Safety valves for cryogenic service
ISO/WD 21013-1 1/	Cryogenic vessels — Safety accessories for cryogenic services — Part 1: Reclosable relief

1/ To be published

EN/ISO standard number	Title
EN 13648-2:2002	*Cryogenic vessels — Safety devices for protection against excessive pressure — Part 2: Bursting discs safety device for cryogenic service*
ISO/WD 21013-2[2]	Cryogenic vessels – safety accessories for cryogenic services — Part 2: Non-reclosable relief
prEN 13648-3: 2000	*Cryogenic vessels — Safety devices for protection against excessive pressure — Part 3: Determination of required discharge — Capacity and sizing*
ISO/WD 21013-3[2]	Cryogenic vessels – Safety accessories for cryogenic services — Part 3: Sizing and capacity determination
EN 50014:1997/AC:1998/ A1:1998/A2:1999	*Electrical apparatus for potentially explosive atmospheres — General requirements*
IEC 60079-0:2000	Electrical apparatus for explosive gas atmospheres — Part 0: General requirements
EN 50015:1998	*Electrical apparatus for potentially explosive atmospheres — Oil-immersion "o"*
IEC 60079-6:1995	Electrical apparatus for explosive gas atmospheres — Part 6: Oil-immersion 'o'
EN 50016:1995	*Electrical apparatus for potentially explosive atmospheres — Pressurized apparatus "p"*
IEC 60079-2:2001	Electrical apparatus for explosive gas atmospheres — Part 2: Pressurized enclosures "p"
EN 50017:1998	*Electrical apparatus for potentially explosive atmospheres — Powder filling "q"*
IEC 60079-5:1997	Electrical apparatus for explosive gas atmospheres — Part 5: Powder filling "q"
EN 50018:2002	*Electrical apparatus for potentially explosive atmospheres — Flameproof enclosure* "d"
IEC 60079-1:2001	Electrical apparatus for explosive gas atmospheres — Part 1: Flameproof enclosures "d"
EN 50019:2000	*Electrical apparatus for potentially explosive atmospheres — Increased safety "e"*
IEC 60079-7:2001	Electrical apparatus for explosive gas atmospheres — Part 7: Increased safety "e"
EN 50020:1994	*Electrical apparatus for potentially explosive atmosphere — Intrinsic safety "i"*
IEC 60079-11:1999	Electrical apparatus for explosive gas atmospheres — Part 11: Intrinsic safety "i"

EN/ISO standard number	Title
EN 50021:1998	*Electrical apparatus for potentially explosive atmospheres — Type of protection "n"*
IEC 60079-15:2001	Electrical apparatus for explosive gas atmospheres — Part 15: Type of protection "n"

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