PROPOSAL FOR A NEW DRAFT REGULATION

UNIFORM PROVISIONS CONCERNING THE APPROVAL OF:

1. SPECIFIC COMPONENTS OF MOTOR VEHICLES USING COMPRESSED GASEOUS HYDROGEN;

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

Prepared by the Partners of the European Integrated Hydrogen Project – Phase II (EIHP2)

Notes:

1. Originally Annex 7 of this proposal was based on a draft ISO standard and was excessively design orientated for use in a regulation. The annex was to be redrafted to define the appropriate performance requirements necessary for the type approval of compressed gaseous hydrogen containers.
2. Most of the text in Annex 8G to this Regulation (Provisions Regarding The Approval Of Flexible Fuel Lines) is based on ECE R110 for compressed natural gas systems. Following homologation experience for flexible fuel lines according to ECE R110, EIHP2 now believes that the provisions have to be revised. It is understood that TÜV Süddeutschland is working on alternative test methods for flexible fuel lines for ECE R110. Furthermore, it appears necessary to have more involvement from flexible fuel lines manufacturers before the final provisions for flexible fuel lines for hydrogen systems can be agreed. Annex 8G is indicated by red text.
3. For editing purposes the following colour codes have been adopted:
   i) Green highlighting identifies reference to standards, etc.
   ii) Yellow highlighting identifies references to other parts of this document.

CONTENTS

REGULATION

ANNEXES

1 SCOPE

This regulation applies to:

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

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

1.3 Vehicles of categories M and N with regard to the installation of *Specific Components* for the use of compressed gaseous hydrogen (Part II of this Regulation).

2 DEFINITIONS, CONTAINER TYPES, PRESSURE CLASSIFICATIONS AND SERVICE CONDITIONS

2.1 DEFINITIONS

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

2.1.1 "*Approval Of A Vehicle Type*": The approval of a *Vehicle Type* with regard to its *Hydrogen System* installed as original equipment.

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

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

2.1.4 "*Auto-frettage Pressure*": The pressure within the *Over-wrapped Container* at which the required distribution of stresses between the *Liner* and the *Over-wra*p is established.

2.1.5 "*Batch*": A "batch" shall be a group of *Containers* or *Liners* successively produced having the same nominal dimensions, design, specified materials of construction, process of manufacture, equipment for manufacture and heat treatment, and conditions of time, temperature and atmosphere during heat treatment.

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

2.1.7 "*Burst Pressure*": The *Pressure* at which the *Container* ruptures.

2.1.8 "*CGH_2*": Compressed gaseous hydrogen.

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

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

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

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

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

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

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

2.1.16 "*Flexible Fuel Line*": A flexible tubing or hose through which hydrogen flows.

2.1.17 "*Fuel Supply Line*": The line that supplies the *Hydrogen Conversion System(s)* with hydrogen.

2.1.18 "*Fully Wrapped*": An *Over-wrap* having a filament wound reinforcement both in the circumferential and axial direction of the *Container*.

2.1.19 "*Hoop Wrapped*": An *Over-wrap* having a filament wound reinforcement in a substantially circumferential pattern over the cylindrical portion of the *Liner* so that the filament does not carry any significant load in a direction parallel to the *Container* longitudinal axis.

2.1.20 "*Hydrogen Component*": A component that is in direct contact with hydrogen or which forms part of a system installed because of the use of hydrogen.

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

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

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

2.1.24 "*Hydrogen System*": An assembly of *Hydrogen Components* and connecting parts fitted on motor vehicles using hydrogen, excluding *the Hydrogen Conversion System(s)*. The boundary between the *Hydrogen System* and the *Hydrogen Conversion System(s)* is defined as the point(s) at which the *Working Pressure* is higher than the:

i) Maximum operating *Pressure* of fuel cell system(s),

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

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

2.1.26 "*Manual Valve*": A manually operated valve.

2.1.27 "*Manufacturer*": The person or organisation responsible for the design, fabrication and testing of a *Hydrogen Component*.

2.1.28 "*Multifunctional Component*": *Specific Components* combined or fitted together and which may include *Hydrogen Components*.

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

2.1.30 "*Over-wrap*": The reinforcement system of filament and resin applied over the *Liner*.

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

2.1.32 "*Pressure Regulator*": A device used to control the delivery *Pressure* of gaseous fuel to the *Hydrogen Conversion System*.

2.1.33 "*Pressure Relief Device*": A device that prevents a *Hydrogen Component* from bursting due to excessive pressure or temperature.

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

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

2.1.36 "*Receptacle*": A device fitted in the vehicle used to permit refilling of the *Container(s)*.

2.1.37 "*Rigid Fuel Line*": Tubing that has not been designed to flex in normal operation and through which hydrogen flows.

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

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

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

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

2.1.42 "*Specific Component*": A *Hydrogen Component* that is subjected to type approval in accordance with this Regulation.

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

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

2.1.45 "*Usage Monitoring And Control System*": A system that counts the filling cycles and prevents further use of the vehicle when a predetermined number of cycles is exceeded.

2.1.46 "*Vehicle Type*": A vehicle fitted with *Specific Components* for the use of hydrogen that do not differ with respect to the following conditions:

i) The *Manufacturer(s)*,
ii) The installation of the *Hydrogen Components*,
iii) Type(s) of *Specific Components*.

2.1.47 "*Working Pressure*": The gas *Pressure* at a uniform temperature of 15°C that a component is subjected to.

2.2 CONTAINER TYPES

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

Type 1 (Metal)	All metal construction.

Type 2 (*Hoop Wrapped*)	Metal *Liner* reinforced with resin impregnated continuous filament wrapped in discrete circumferential bands.
Type 3 (*Fully Wrapped*)	Metal *Liner* reinforced with resin impregnated continuous filament fully wrapped around the *Liner*.
Type 4 (Non-metallic)	Resin impregnated continuous filament with a non-metallic *Liner*.
Type 5 (Other)	Type of construction not covered by Types 1 to 4 above.

2.3 PRESSURE CLASSIFICATIONS

2.3.1 *Hydrogen Components* and *Hydrogen Systems* for use in vehicles shall be classified with regard to their *Working Pressure* and function as defined below:

Class 0 High pressure components/systems including tubes and *Fittings* containing hydrogen at a *Working Pressure* greater than 3 MPa.

Class 1 Medium pressure components/systems including tubes and *Fittings* containing hydrogen at a *Working Pressure* greater than 0.45 MPa and up to and including 3.0 MPa.

Class 2 Low pressure components/systems including tubes and *Fittings* containing hydrogen at a *Working Pressure* up to and including 0.45 MPa.

2.3.2 A *Hydrogen Component* or *Hydrogen System* can consist of several parts, each part classified in its own class with regard to *Working Pressure* and function.

2.4 SERVICE CONDITIONS

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

2.4.1 *Service Life*

The *Service Life* of *Hydrogen Components* shall be specified by the vehicle manufacturer and may vary with different applications, however, it shall not exceed 20 years.

2.4.2 *Working Pressure*

The *Working Pressure(s)* of the *Hydrogen System* shall be specified by the vehicle manufacturer.

2.4.3 External Surfaces

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

i) Water, either by intermittent immersion or road spray,
ii) Salt, due to the operation of the vehicle near the ocean or where ice melting salt is used,
iii) Ultra-violet radiation from sunlight,
iv) Impact of gravel,
v) Solvents, acids and alkalis, fertilisers,
vi) Automotive fluids, including gasoline, hydraulic fluids, battery acid, glycol and oils,
vii) Exhaust gases.

2.4.4 Gas Permeation

Permeation of gas through the walls of *Hydrogen Components* shall be considered in the design of the *Hydrogen Components*.

2.4.5 Gas Composition

Compressed hydrogen gas shall comply with gas compositions specified in ISO 14687:1999 inc. Cor 1:2001 Hydrogen Fuel – Product Specification.

2.4.6 Temperatures

2.4.6.1 Material Temperatures

The normal operating temperature range for materials used in *Hydrogen Components* shall be -40°C to +85°C, except for internal combustion engine compartments where the temperature range shall be -40°C to +120°C.

2.4.6.2 Gas Temperatures

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

2.4.7 Filling & Pressure Cycles

This section is only applicable to Class O *Hydrogen Components*. Pressure cycles for Class 1 and Class 2 *Hydrogen Components* are stated in Annexes 8 and 9 to this Regulation.

The number of filling cycles for the *Hydrogen Components* approved in accordance with this Regulation and its Annexes shall be 5000 cycles except as allowed below in this Paragraph. The number of filling cycles is

based on the design lifetime mileage of the vehicle and range with maximum fuel capacity, for example:

Design lifetime mileage of the vehicle, L = 1 000 000 km
Range with maximum fuel capacity, R = 200 km
Number of filling cycles, L/R = 5 000

The number of pressure cycles for the *Hydrogen Components* approved in accordance with this Regulation and its Annexes shall be calculated from the number of filling cycles multiplied by a safety factor (γ) of 3.

Calculation example:

Number of pressure cycles	=	γL/R but where L/R is not less than 5000 cycles
	=	3 x 1 000 000/200 but where L/R is not less than 5000 cycles
	=	15 000 pressure cycles

Alternatively the number of filling cycles for *Hydrogen Components* approved in accordance with this Regulation and its Annexes shall be specified by the vehicle manufacturer and may be less than 5000 cycles and may vary with different applications based on the design lifetime mileage of the vehicle and range with maximum fuel capacity, provided that a *Usage Monitoring And Control System* is installed as part of the *Hydrogen System*. The *Usage Monitoring And Control System* shall prevent any further use of the vehicle when the maximum number of filling cycles is exceeded, until the *Hydrogen Components* that have exceeded that value are replaced with new *Hydrogen Components*. The vehicle manufacturer shall specify the maximum number of filling cycles for the *Hydrogen Components*. In case this alternative method is used the number of pressure cycles shall be calculated from the maximum number of filling cycles specified by the vehicle manufacturer in accordance with this Paragraph multiplied by a safety factor of 3. The *Safety Concept* of the *Usage Monitoring And Control System* shall be approved in accordance with Annex 10 to this Regulation.

PART I

SPECIFIC COMPONENTS OF MOTOR VEHICLES USING COMPRESSED GASEOUS HYDROGEN

3 APPLICATION FOR APPROVAL

3.1 The application for approval of a *Specific Component* or *Multifunctional Component* shall be submitted by the holder of the trade name or mark or by his duly accredited representative.

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

i) A detailed description of the type of the *Specific Component* according to Annex 1 to this Regulation,
ii) A drawing of the *Specific Component* sufficiently detailed and on an appropriate scale with a list of parts including material data and intended operating mode,
iii) 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 *Container* and its *Pressure Relief Device(s)* and valves acting as shut-off devices in accordance with Paragraph 14.3.1, shall be provided unless otherwise stated in the Annexes to this Regulation. Supplementary samples shall be supplied upon request.

3.4 If the Technical Service responsible for the type approval tests carries out the tests for *Specific Components* other than those stated in Paragraph 3.3 of this Regulation, then at least two samples of the *Specific Component* shall be provided unless otherwise stated in the Annexes to this Regulation. Supplementary samples shall be supplied upon request.

3.5 The Competent Authority shall verify the existence of satisfactory arrangements for ensuring effective control of conformity of production before type approval is granted.

4 MARKINGS

4.1 The samples of the *Specific Component* submitted for approval shall bear the trade name or mark of the *Manufacturer* and the type; and in addition for *Flexible Fuel Lines* the manufacturing month and year. The marking shall be legible and indelible.

4.2 All *Specific Components* shall have a space large enough to accommodate the approval mark. This space shall be shown on the drawings referred to in Paragraph 3.2 ii) of this Regulation.

5 APPROVAL

5.1 If the *Specific Component* samples submitted for approval meet the relevant requirements of Paragraph 6 of this Regulation, approval of the type of *Specific Component* shall be granted.

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

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

5.4 In addition to the markings prescribed in Paragraph 4.1 and for *Containers* in Annex 7 to this Regulation, there shall be affixed conspicuously in the space referred to in Paragraph 4.2 of this Regulation, to all *Specific Components* conforming to a type approved under this Regulation, an international approval mark consisting of:

i) A circle surrounding the letter "E“ followed by the distinguishing number of the country that has granted approval (see Note *[1] below).

ii) 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 i) above. This approval number consists of the *Specific Component* type approval number that appears on the certificate completed for this type (see Paragraph 5.2 and Annex 4 of this Regulation) preceded by 2 figures indicating the sequence of the latest series of amendments to this Regulation.

5.5 The approval mark shall be clearly legible and indelible.

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

—

Note *[1]:
1 for Germany, 2 for France, 3 for Italy, 4 for 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 Ireland, 25 for Croatia, 26 for Slovenia, 27 for Slovakia, 28 for Belarus, 29 for Estonia, 30 (vacant), 31 for Bosnia and Herzegovina, 32-36 (vacant), 37 for Turkey,38-39 (vacant) and 40 for the former Yugoslav Republic of Macedonia, 43 Japan.
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 or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted

on the Basis of these Prescriptions, and the numbers thus assigned shall be communicated by the Secretary-General of the United Nations to the Contracting Parties to the Agreement.

6 SPECIFICATIONS FOR HYDROGEN COMPONENTS

6.1 GENERAL PROVISIONS

6.1.1 The *Hydrogen Components* shall function in a correct and safe way as specified in this Regulation. They shall reliably withstand the mechanical, thermal and chemical service conditions specified in Paragraph 2.4 of this Regulation without leaking or visibly deforming.

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

6.1.3 Those parts of a component whose correct and safe functioning is liable to be influenced by hydrogen, high pressure or vibrations shall be submitted to the relevant test procedures described in the Annexes to this Regulation.

6.1.4 All *Hydrogen Components* designed to allow uni-directional flow only, shall have the flow direction clearly indicated.

6.1.5 All *Hydrogen Components* shall have the *Working Pressure* for which they have been designed or in the case of *Specific Components* type approved, clearly indicated.

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

6.1.7 If a test method is used other than those referred to in this Chapter and the relevant annexes, its equivalence shall be demonstrated.

6.1.8 *Specific Components* where used in the *Hydrogen System* include:

Automatic Valve,
Container,
Fittings,
Flexible Fuel Line,
Heat exchanger,
Hydrogen Filter,
Manual Valve,
Non-return Valve,
Pressure Regulator,
Pressure Relief Device,
Receptacle.
Sensors (pressure or temperature or hydrogen or flow sensors) if used as a *Safety Device*,

6.1.9 The functions of *Specific Components* may be combined or fitted together with other *Specific Components* or *Hydrogen Components* as *a Multifunctional Component*, but for the purposes of this Regulation will be classified as a *Specific Component*. A *Multifunctional Component* shall be type approved in accordance with the requirements for the *Specific Components* that it combines.

6.1.10 Welded fittings or connections shall be described in a production process for each individual type of welding. Welded connections shall be designed for at least 3 times *Working Pressure* or alternatively tested to a *Pressure* of at least 3 times *Working Pressure* without rupturing.

6.2 PROVISIONS REGARDING HYDROGEN CONTAINERS

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

6.2.2 *Containers* of which the type and method of construction (including *Containers* of welded construction) is not covered by Types 1 to 4 shall be type approved according to proven equivalent methods to those referred to in Annex 7 to this Regulation.

6.2.3 At the request of the *Manufacturer*, an assembly of several *Containers* including their interconnecting fuel lines shall be type approved as one *Container* if the assembly including interconnecting fuel lines fulfils the requirements of Annex 7 to this Regulation.

6.3 PROVISIONS REGARDING PRESSURE RELIEF DEVICES

Pressure Relief Device(s) shall be type approved according to Annex 8A to this Regulation.

6.4 PROVISIONS REGARDING HYDROGEN VALVES

Hydrogen valves shall be type approved pursuant to the provisions laid down in Annex 8B to this Regulation.

6.5 PROVISIONS REGARDING HEAT EXCHANGERS

Heat exchangers shall be type approved pursuant to the provisions laid down in Annex 8C to this Regulation.

6.6 PROVISIONS REGARDING RECEPTACLES

Receptacles shall be type approved pursuant to the provisions laid down in Annex 8D to this Regulation.

6.7 PROVISIONS REGARDING PRESSURE REGULATORS

Pressure Regulators shall be type-approved pursuant to the provisions laid down in Annex 8E to this Regulation.

6.8 PROVISIONS REGARDING SENSORS FOR HYDROGEN SYSTEMS

Sensors for *Hydrogen Systems* shall be type approved pursuant to the provisions laid down in Annex 8F to this Regulation.

6.9 PROVISIONS REGARDING FLEXIBLE FUEL LINES

Flexible Fuel Lines shall be type approved pursuant to the provisions laid down in Annex 8G to this Regulation.

6.10 PROVISIONS REGARDING FITTINGS

Fittings shall be type approved pursuant to the provisions laid down in Annex 8H to this Regulation.

6.11 PROVISIONS REGARDING HYDROGEN FILTERS

Hydrogen Filters shall be type approved pursuant to the provisions laid down in Annex 8J to this Regulation.

6.12 PROVISIONS REGARDING RIGID FUEL LINES

Rigid Fuel Lines shall be designed for a *Burst Pressure* of at least 3 times *Working Pressure* when bent through 180 degrees at the minimum bending radius specified by the *Manufacturer*. Alternatively, the *Rigid Fuel Lines*, when bent through 180 degrees at the minimum bending radius specified by the *Manufacturer* can be tested to a *Pressure* of at least 3 times *Working Pressure* without rupturing.

6.13 PROVISIONS REGARDING ELECTRICAL COMPONENTS

Electrical components of equipment in contact with hydrogen shall:

i) Be insulated in such a manner that no current passes through hydrogen containing parts,

ii) Have the electrical system of the device insulated from:
   a) the body of the component,
   b) the *Container*.

iii) Have an electric circuit insulation resistance, except for power sources, e.g. batteries and fuel cells, that shall exceed 1 kΩ for each volt of the nominal voltage.

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 that granted the type approval. The Administrative Department may then either:

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

or

ii) Require a further report from the Technical Service responsible for carrying out the tests. Modifications of *Containers* require approval testing as specified in Paragraph A7 of Annex 7 to this Regulation.

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

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

8 CONFORMITY OF PRODUCTION

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

i) A *Hydrogen Component* type approved according to this Regulation shall be manufactured so as to conform to the type approved by meeting the requirements specified in Paragraph 6 of this Regulation.

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

9 PENALTIES FOR NON-CONFORMITY OF PRODUCTION

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

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

10 PRODUCTION DEFINITELY DISCONTINUED

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

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

The Parties to the Agreement applying this Regulation shall communicate to the United Nations Secretariat the names and addresses of the Technical Services responsible for conducting approval tests and of the Administrative Departments

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

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

12 APPLICATION FOR APPROVAL

12.1 The application for *Approval Of A Vehicle Type* with regard to the installation of *Specific Components* for the use of compressed gaseous hydrogen shall be submitted by the vehicle manufacturer or by his duly accredited representative.

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

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

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

13 APPROVAL

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

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

13.3 Notice of approval or of refusal or of extension of *Approval Of A Vehicle Type* in accordance with this Regulation shall be communicated to the Parties to the Agreement applying this Regulation by means of a form conforming to the model in Annex 6 to this Regulation.

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

i) A circle surrounding the letter "E“ followed by the distinguishing number of the country that has granted approval (see Note *[1] below).

ii) 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 i) above. This approval number consists of the *Vehicle Type* approval number that appears on

the certificate completed for this type (see Paragraph 13.2 and 13.3 and Annex 6 of this Regulation).

13.5 If the vehicle conforms to a *Vehicle Type* approved under one or more other Regulations annexed to the Agreement in the country which has granted approval under this Regulation, the symbol prescribed in Paragraph 13.4 i) of this Regulation need not to be repeated. In such a case, the Regulation and approval numbers and the additional symbols of all the Regulations under which approval has been granted in the country that has granted approval under this Regulation shall be placed in vertical columns to the right of the symbol prescribed in Paragraph 13.4 i) of this Regulation.

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

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

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

Note *[1]:
1 for Germany, 2 for France, 3 for Italy, 4 for 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 Ireland, 25 for Croatia, 26 for Slovenia, 27 for Slovakia, 28 for Belarus, 29 for Estonia, 30 (vacant), 31 for Bosnia and Herzegovina, 32-36 (vacant), 37 for Turkey,38-39 (vacant) and 40 for the former Yugoslav Republic of Macedonia, 43 Japan.
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 or be Used on Wheeled Vehicles and the Conditions for Reciprocal Recognition of Approvals Granted on the Basis of these Prescriptions, and the numbers thus assigned shall be communicated by the Secretary-General of the United Nations to the Contracting Parties to the Agreement.

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

14.1 GENERAL

14.1.1 The *Hydrogen System* of a vehicle shall function in a safe and proper manner. It shall reliably withstand the chemical, electrical, mechanical and thermal service conditions specified in Paragraph 2.4 of this Regulation without leaking or visibly deforming. The number of *Hydrogen Components*, connections and the length of lines shall be kept to the minimum compatible with safety and the correct functioning of the *Hydrogen System*.

14.1.2 *Specific Components* of *Hydrogen Systems* shall be type approved pursuant to Part I of this Regulation.

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

14.1.4 The temperature range shall be in accordance with Paragraph 2.4.6 of this regulation.

14.1.5 No component of the *Hydrogen System*, including any protective materials that form part of such components, shall project beyond the outline of the vehicle or protective structure. This shall not apply if a *Hydrogen Component* is adequately protected and no part of the *Hydrogen Component* is located outside this protective structure.

14.1.6 The *Hydrogen System* shall be installed such that it is protected against damage so far as is reasonably practical, such as damage due to moving vehicle components, collision, grit or due to the loading or unloading of the vehicle or the shifting of loads.

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

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

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

14.1.10 When pressurised to the *Working Pressure* with hydrogen, helium or a gas mixture containing at least 5% hydrogen or 10% helium, the *Hydrogen System* shall be tested for leakage with a surface active agent without formation of bubbles for three minutes.

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

Components that can leak hydrogen and that are mounted within the passenger or luggage compartment or other non-ventilated compartment shall be enclosed by a gas tight housing in accordance with Paragraph 14.7 of this Regulation or by an equivalent solution.

14.1.12 The location of the *Container(s)* shall take into account possible sources of corrosion, e.g. due to road de-icing salt, leakage of acid batteries.

14.1.13 A minimum overpressure of 0.2 MPa shall be maintained in the *Container* at ambient temperature.

14.1.14 All *Pressure Relief Devices*, other safety components and vent lines shall be protected against unauthorised interference so far as is reasonably practicable.

14.1.15 An *Excess Flow System* shall be part of the *Hydrogen System* and shall fulfil the requirements of Annex 8I to this Regulation.

14.1.16 *Automatic Valves* shall fail to the safest mode of operation for the particular application, i.e. fail safe.

14.1.17 The *Hydrogen System* downstream of a *Pressure Regulator* shall be protected against overpressure due to the possible failure of the *Pressure Regulator*. The opening pressure of a pressure triggered *Pressure Relief Device* shall be 1.5 times the *Working Pressure* for the appropriate section of the *Hydrogen System.*

14.1.18 The *Working Pressure* of *Pressure Regulators* shall be the highest to which they may be subjected.

14.1.19 The *Working Pressure* of the heat exchanger interface between the different circuits of the heat exchanger shall be based on the highest *Working Pressure* of the different circuits in the heat exchanger and not the differential pressure.

14.1.20 A safety system shall be provided to detect failure of the heat exchanger or prevent any hydrogen from entering the other circuit(s), if the circuits(s) has not been designed for this.

14.2 INSTALLATION OF A HYDROGEN CONTAINER ON-BOARD A VEHICLE

14.2.1 *Container(s)* shall be permanently installed on-board the vehicle and may only be removed for maintenance. *Container(s)* shall not be installed in the internal combustion engine compartment.

14.2.2 *Container(s)* can fulfil integrated functions of the vehicle. *Container(s)* shall be designed to fulfil the integrated function requirements plus the *Container* requirements.

14.2.3 *Container(s)* including *Safety Devices* must be mounted and fixed so that the following accelerations can be absorbed (without damage of the safety

related parts) when the *Container(s)* are full. No uncontrolled release of hydrogen is permitted.

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

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

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

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

14.2.4 The provision of Paragraph 14.2.3 shall not apply if the vehicle is approved according to ECE R 94 and ECE R 95.

14.2.5 *Pressure Relief Device(s)* in accordance with Paragraph 14.3.2 of this Regulation shall form the fire protection system for a *Container* to prevent rupture. Thermal insulation or other protective measures shall not influence the response and performance of the *Pressure Relief Device(s).*

14.2.6 *Containers* with non-metallic *Liners* shall not be installed inside the vehicle unless integrated into a system which ensures that permeated hydrogen will be vented outside the vehicle, e.g. it is installed inside a gas tight housing in accordance with Paragraph 14.7 of this Regulation.

14.3 ACCESSORIES FITTED TO A CONTAINER

14.3.1 *Automatic Valves* Or *Non-return Valves*

14.3.1.1 All hydrogen *Fuel Supply Lines* shall be secured with an *Automatic Valve* (idle closed). These valves shall be mounted directly on or within every *Container* or assembly referred to in Paragraph 6.2.3 of this Regulation.

14.3.1.2 The *Receptacle* shall be integrated with a *Non-return Valve*. If the *Receptacle* is not mounted directly on or within the *Container* or assembly referred to in Paragraph 6.2.3 of this Regulation, a *Non-return Valve* or an *Automatic Valve* integrating the function of a *Non-return Valve* shall be mounted directly on or within the *Container* or assembly referred to in Paragraph 6.2.3 of this Regulation, to secure the refilling line.

14.3.1.3 In the event of breakage of the refilling lines or *Fuel Supply Line(s)*, the isolating valves referred to in Paragraphs 14.3.1.1

and 14.3.1.2 of this Regulation shall not be separated from the *Container*.

14.3.1.4 *Automatic Valves* isolating each *Container* or assembly referred to in Paragraph 6.2.3 of this Regulation, shall close in the event of either a malfunction of the *Hydrogen System* that results in the release of hydrogen or severe leakage between the *Container(s)* and the *Hydrogen Conversion System(s)*.

14.3.1.5 The *Automatic Valve* for the *Fuel Supply Line* of the *Propulsion System* shall be operated such that the hydrogen supply is cut off when the *Propulsion System* is switched off, irrespective of the position of the activation switch, and shall remain closed until the *Propulsion System* is required to operate.

14.3.1.6 The *Automatic Valve* for the *Fuel Supply Line* of other *Hydrogen Conversion System(s)* shall be operated such that the hydrogen supply is cut off when the respective *Hydrogen Conversion System* is switched off, irrespective of the position of the activation switch, and shall remain closed until the *Hydrogen Conversion System* is required to operate.

14.3.2 *Pressure Relief Devices*

14.3.2.1 A *Pressure Relief Device* shall be directly installed into the opening of a *Container* or assembly referred to in Paragraph 6.2.3 of this Regulation, in such a manner that it shall discharge the hydrogen into an atmospheric outlet line that vents to the outside of the vehicle.

14.3.2.2 It shall not be possible to isolate the *Pressure Relief Devices* from the *Hydrogen Components* or section of the *Hydrogen System* protected by the *Pressure Relief Device*, by the normal operation or failure of another component.

14.3.2.3 The vent lines of *Pressure Relief Devices* shall not discharge into a wheel arch, nor shall they be aimed at a heat source such as the exhaust or at other *Containers* if fitted. Additionally they shall discharge such that hydrogen cannot enter the inside of the vehicle.

14.3.2.4 The internal dimensions of the *Pressure Relief Device* and the lines both before and after the *Pressure Relief Devices* shall not impede the function of the *Pressure Relief Devices*.

14.3.2.5 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.

14.3.2.6 The vent line of the *Pressure Relief Device* shall be protected against blockage, e.g. by dirt, ice, and ingress of water etc., so far as is reasonably practicable.

14.3.2.7 The outlet of the *Pressure Relief Device* shall be orientated such that if the vent line becomes detached from the *Pressure Relief Device*, the resulting gas flow does not impinge directly on other *Containers* unless they are protected.

14.3.2.8 *Pressure Relief Devices* shall not close once they have opened.

14.4 RIGID AND FLEXIBLE FUEL LINES

14.4.1 *Rigid Fuel Lines* shall be secured such that they shall not be subjected to critical vibration or other stresses.

14.4.2 *Flexible Fuel Lines* shall be secured such that they shall not be subjected to torsional stresses and abrasion is avoided.

14.4.3 *Rigid Fuel Lines* and *Flexible Fuel Lines* shall be mounted to reasonably minimise stresses in the lines during removal or installation of adjoining *Hydrogen Components*.

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

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

14.4.6 At passages through the vehicle body or other *Hydrogen Components*, the fuel lines shall be fitted with grommets or other protective material.

14.4.7 In the passenger or enclosed luggage compartment the fuel lines shall be enclosed in a sleeve which meets the same requirements as specified for a gas tight housing in Paragraphs 14.7of this Regulation.

14.4.8 Metallic *Rigid Fuel Lines* shall be seamless if used in Class 0 *Hydrogen Systems*, and shall elongate by at least 14% before rupture.

14.5 FITTINGS BETWEEN HYDROGEN COMPONENTS

14.5.1 *Fittings* for stainless steel tubes shall only be stainless steel *Fittings*.

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

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

14.6 REFILLING SYSTEM

14.6.1 The *Receptacle* shall be secured against maladjustment and rotation. The *Receptacle* shall also be protected from unauthorised interference, and the ingress of dirt and water so far as is reasonably practicable, e.g. a locked hatch. It shall be safe against reasonably foreseeable handling errors.

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

14.6.3 The refilling line shall be secured at the *Container* as described in Paragraph 14.3.1.2 of this Regulation.

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

14.6.5 The *Working Pressure* of the *Receptacle* shall be equal to the *Working Pressure* of the Class 0 *Hydrogen Components* upstream of and including the first *Pressure Regulator*.

14.6.6 It shall be ensured that, where fitted, the *Propulsion System* or *Hydrogen Conversion System(s)* excluding *Safety Devices* are not operating and that the vehicle is immobilised while the *Receptacle* is connected to the refilling infrastructure.

14.7 GAS TIGHT HOUSING ON THE CONTAINER(S)

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

14.7.2 The ventilation opening of the gas tight housing shall be at the highest point of the housing when installed in the vehicle. It shall not ventilate into a wheel arch, nor shall it be aimed at a heat source such as the exhaust. Additionally it shall vent such that hydrogen cannot enter the inside of the vehicle.

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

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

14.7.5 Any connecting system shall be secured by clamps, or other means, to the gas tight housing or sleeve and the lead-through to ensure that a joint is formed meeting the leakage requirements of Paragraph 14.7.4 of this Regulation.

14.8 ELECTRICAL INSTALLATION

14.8.1 The electrical components of the *Hydrogen System* shall be protected against overloads.

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

14.8.3 The metallic components of the *Hydrogen System* shall have electrical continuity with the vehicle's earth.

14.8.4 During the refilling process the *Hydrogen System* shall have electrical continuity with the refilling facilities before hydrogen transfer is permitted.

14.8.5 Where *Hydrogen Components* are present or hydrogen leaks are possible, electrical connections for power supply bushing shall not permit the ingress of the test gas when pressurised with hydrogen, helium or a gas mixture containing at least 5% hydrogen or 10% helium, at an external over pressure of 0.01 Mpa.

14.9 SAFETY INSTRUMENTED SYSTEMS

14.9.1 *Safety Instrumented Systems* shall be fail-safe or redundant.

14.9.2 If *Safety Instrumented Systems* are fail-safe or self-monitoring electronic systems, the special requirements according to Annex 10 to this Regulation are to be applied.

14.10 REQUALIFICATION

14.10.1 Periodic Requalification

Recommendations for periodic requalification by visual inspection or testing during the *Service Life* of the *Container* shall be provided by the *Manufacturer* of the *Container* on the basis of use under the service conditions specified in Paragraph 2.4 of this Regulation. Every *Container* shall be visually inspected at a frequency in accordance with national requirements, and at the time of any re-installation, for external damage and deterioration, including at the edge of the support straps if used. The inspection procedure should avoid the need of disassembling the *Container(s)*. The visual inspection shall be performed by a Technical Service approved by a Competent Authority, in accordance with the *Manufacturer's* specifications: *Containers* without a marking containing mandatory information, or with labels containing mandatory information that are illegible in any way shall be removed from service. If the *Container* can be positively identified by *Manufacturer* and serial number, a replacement label may be applied, allowing the *Container* to remain in service.

14.10.2 *Containers* Involved In Collisions

Containers which have been subject to direct impact damage during vehicle collisions or other accidents, e.g. during maintenance, shall be condemned and removed from service.

Containers which have been subjected to indirect impact damage that may have affected the *Container*, e.g. mechanical stresses transferred from the vehicle structure, shall be subjected to requalification inspection or testing before the *Container* may be returned to service, or condemned and removed from service

14.10.3 *Container*s Involved In Fires

Containers that have been subject to the action of fire shall be condemned and removed from service.

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

15.1 Every modification of the *Vehicle Type* or of its installation of *Specific Components* for the use of hydrogen shall be notified to the Administrative Department which granted approval of the *Vehicle Type*. The Administrative Department may then either:

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

or

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

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

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

16 CONFORMITY OF PRODUCTION

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

i) A *Vehicle Type* approved according to this Regulation shall be manufactured so as to conform to the type approved by meeting the requirements specified in Paragraph 14 of this regulation.

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

17 PENALTIES FOR NON-CONFORMITY OF PRODUCTION

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

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

18 PRODUCTION DEFINITELY DISCONTINUED

If the holder of the approval permanently ceases to manufacture a type of *Vehicle Type* approved in accordance with this Regulation, he shall immediately inform the authority that granted the approval. Upon receiving the relevant communication, that authority shall inform the other 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 Parties to the Agreement applying this Regulation shall communicate to the United Nations Secretariat the names and addresses of the Technical Services responsible for conducting approval tests and of the Administrative Departments which grant approval and to which forms certifying approval or extension or refusal or withdrawal of approval issued in other countries, are to be sent.

Annex 1

ESSENTIAL CHARACTERISTICS OF SPECIFIC COMPONENTS

1 *Automatic Valve*:

1.1 Make:

1.2 Type:

1.3 Description and drawings:

1.4 *Working Pressure(s)* *[2]: MPa

1.5 Material(s):

1.6 Number of filling cycles (Class O only):

2 *Non-return Valve:*

2.1 Make:

2.2 Type:

2.3 Description and drawings:

2.4 *Working Pressure(s)* *[2]: MPa

2.5 Material(s):

2.6 Number of filling cycles (Class O only):

3 *Container:*

A statement of service shall be provided in accordance with the requirements of Annex 7 to this Regulation.

4 *Excess Flow System*:

4.1 Make:

4.2 Type:

4.3 Description and drawings:

4.4 *Working Pressure(s)* *[2]: MPa

4.5 Material(s):

4.6 Number of filling cycles (Class O only):

5 *Fittings*:

5.1 Make:

5.2 Type:

5.3 Description and drawings:

5.4 *Working Pressure(s)* *[2]: MPa

5.5 Material(s):

5.6 Number of filling cycles (Class O only):

6 *Flexible Fuel Lines:* yes/no [1/]

6.1 Make:

6.2 Type:

6.3 Description and drawings:

6.4 *Working Pressure(s)* *[2]: MPa

6.5 Material(s):

6.6 Number of filling cycles (Class O only):

7 Heat exchanger: yes/no *[1]

7.1 Make:

7.2 Type:

7.3 Description and drawings:

7.4 *Working Pressure(s)* *[2]: MPa

7.5 Material(s):

7.6 Number of filling cycles (Class O only):

8 *Hydrogen Filter:* yes/no *[1]

8.1 Make:

8.2 Type:

8.3 Description and drawings:

8.4 *Working Pressure(s)* *[2]: MPa

8.5 Material(s):

8.6 Number of filling cycles (Class O only):

9 *Manual Valve:* yes/no *[1]

9.1 Make:

9.2 Type:

9.3 Description and drawings:

9.4 *Working Pressure(s)* *[2]: MPa

9.5 Material(s):

9.6 Number of filling cycles (Class O only):

10 Pressure or temperature or flow sensor*[1]: yes/no *[1]

10.1 Make:

10.2 Type:

10.3 Operating principles including description and drawings:

10.4 *Working Pressure(s):* *[2]: MPa

10.5 Material(s):

10.6 Number of filling cycles (Class O only):

11 *Pressure Regulator:* yes/no *[1]

11.1. Make:

11.2 Type:

11.3 Drawings:

11.4 Number of main adjustment points:

11.5 Description of principle of adjustment through main adjustment points:

11.6 Number of idle adjustment points:

11.7 Description of principles of adjustment through idle adjustment points:

11.8 Other adjustment possibilities: if so and which (description and drawings):

11.9 *Working Pressure(s)* *[2]: Mpa

11.10 Number of filling cycles (Class O only):

12 *Pressure Relief Device* (temperature triggered):

12.1 Make:

12.2 Type:

12.3 Description and drawings:

12.4 Normal maximum operating temperature : *[2] °C
(in accordance with Paragraph 2.4.6.1 of this Regulation)

12.5 *Working Pressure(s)* *[2]: MPa

12.6 Material:

12.7 Set (trigger) temperature: *[2]

12.8 Number of filling cycles (Class O only):

13 *Pressure Relief Device* (pressure triggered): yes/no *[1]

13.1 Make:

13.2 Type:

13.3 Description and drawings:

13.4 *Working Pressure(s)* *[2]: MPa

13.5 Material:

13.6 Set pressure: *[2]

13.7 Number of filling cycles (Class O only):

14 *Receptacle*:

14.1 Make:

14.2 Type:

14.3 Operating principles including description and drawings:

14.4 *Working Pressure(s)* *[2]: MPa

14.5 Material:

14.6 Number of filling cycles (Class O only):

Notes:

*[1] - Strike out what does not apply.

*[2] - Specify the tolerance.

Annex 2

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

0 Description Of The *Vehicle Type*

0.1 Make:

0.2 Type(s):

0.3 Name and address of the vehicle manufacturer:

1 Description Of The *Hydrogen System* Used For The propulsion Of The Vehicle *[1]

1.1 Description of the *Propulsion System*:

1.2 Name and address of the *Manufacturer*:

1.3 *Manufacturer's Propulsion System* code(s) (as marked on the *Propulsion System*, or other means of identification):

1.4 *Automatic Valve(s):*

1.4.1 Make(s):

1.4.2 Type(s):

1.4.3 *Working Pressure(s)* *[2]: MPa

1.4.4 Approval number:

1.4.5 Number of filling cycles (Class O only):

1.5 *Non-return Valve(s):*

1.5.1 Make(s):

1.5.2 Type(s):

1.5.3 *Working Pressure(s)* *[2]: MPa

1.5.4 Approval number:

1.5.5 Number of filling cycles (Class O only):

1.6 *Container(s):*

1.6.1 Make(s):

1.6.2 Type(s):

1.6.3 Capacity: litres (water)

1.6.4 Approval number

1.6.5 *Working Pressure*: MPa

1.6.6 Number of filling cycles:

1.7 *Excess Flow System*:

1.7.1 Make(s):

1.7.2 Type(s):

1.7.3 *Working Pressure(s)* *[2]: MPa

1.7.4 Approval number:

1.7.5 Number of filling cycles (Class O only):

1.8 *Fittings:*

1.8.1 Make(s):

1.8.2 Type(s):

1.8.3 *Working Pressure(s)* *[2]: MPa

1.8.4 Approval number:

1.8.5 Number of filling cycles (Class O only):

1.9 *Flexible Fuel Lines(s):* yes/no *[1]

1.9.1 Make(s):

1.9.2 Type(s):

1.9.3 *Working Pressure(s)* *[2]: MPa

1.9.4 Approval number:

1.9.5 Number of filling cycles (Class O only):

1.10 Heat exchanger(s): yes/no *[1]

1.10.1 Make(s):

1.10.2 Type(s):

1.10.3 *Working Pressure(s)* *[2]: MPa

1.10.4 Approval number:

1.10.5 Number of filling cycles (Class O only):

1.11 *Hydrogen Filter(s):* yes/no *[1]

1.11.1 Make(s):

1.11.2 Type(s):

1.11.3 *Working Pressure(s)* *[2]: MPa

1.11.4 Approval number:

1.11.5 Number of filling cycles (Class O only):

1.12 *Manual Valve(s):* yes/no *[1]

1.12.1 Make(s):

1.12.2 Type(s):

1.12.3 *Working Pressure(s)* *[2]: MPa

1.12.4 Approval number:

1.12.5 Number of filling cycles (Class O only):

1.13 Pressure or temperature or flow sensor(s) *[1]: yes/no *[1]

1.13.1 Make(s):

1.13.2 Type(s):

1.13.3 *Working Pressure(s)* *[2]: MPa

1.13.4 Approval number:

1.13.5 Number of filling cycles (Class O only):

1.14 *Pressure Regulator(s):* yes/no *[1]

1.14.1 Make(s):

1.14.2 Type(s):

1.14.3 *Working Pressure(s)* *[2]*:* MPa

1.14.4 Approval number:

1.14.5 Number of filling cycles (Class O only):

1.15 *Pressure Relief Device* (temperature triggered):

1.15.1 Make(s):

1.15.2 Type(s):

1.15.3 Normal maximum operating temperature : *[2] °C
(in accordance with Paragraph 2.4.6.1 of this Regulation)

1.15.4 Approval number:

1.15.5 *Working Pressure(s)* *[2]: MPa

1.15.6 Number of filling cycles (Class O only):

1.16 *Pressure Relief Device* (pressure triggered): yes/no *[1]

1.16.1 Make(s):

1.16.2 Type(s):

1.16.3 *Working Pressure(s):* *[2] MPa

1.16.4 Approval number:

1.16.5 Number of filling cycles (Class O only):

1.17 *Receptacle*:

1.17.1 Make(s):

1.17.2 Type(s):

1.17.3 *Working Pressure(s):* *[2] MPa

1.17.4 Approval number:

1.17.5 Number of filling cycles (Class O only):

2 Description Of The *Hydrogen System(s)* Used For Purposes Other Than The Propulsion Of The Vehicle *[1]

2.1 Description of the *Hydrogen System(s):*

2.2 Name and address of the *Manufacturer(s):*

2.3 *Manufacturer's* system code(s) (as marked on the system, or other means of identification):

2.4 *Automatic Valve(s):* yes/ same component as used in *Propulsion System* *[1]

2.4.1 Make(s):

2.4.2 Type(s):

2.4.3 *Working Pressure(s)* *[2]: MPa

2.4.4 Approval number:

2.4.5 Number of filling cycles (Class O only):

2.5 *Non-return Valve(s):* yes/ same component as used in *Propulsion System* *[1]

2.5.1 Make(s):

2.5.2 Type(s):

2.5.3 *Working Pressure(s)* *[2]: MPa

2.5.4 Approval number:

2.5.5 Number of filling cycles (Class O only):

2.6 *Container(s):* yes/ same component as used in *Propulsion System* *[1]

2.6.1 Make(s):

2.6.2 Type(s):

2.6.3 Capacity: litres (water)

2.6.4 Approval number

2.6.5 *Working Pressure(s)* *[2]: MPa

2.6.6 Number of filling cycles:

2.7 *Excess Flow System*: yes/ same component as used in *Propulsion System* *[1]

2.7.1 Make(s):

2.7.2 Type(s):

2.7.3 *Working Pressure(s)* *[2]: MPa

2.7.4 Approval number:

2.7.5 Number of filling cycles (Class O only):

2.8 *Fittings*: yes/ same component as used in *Propulsion System* *[1]

2.8.1 Make(s):

2.8.2 Type(s):

2.8.3 *Working Pressure(s)* *[2]: MPa

2.8.4 Approval number:

2.8.5 Number of filling cycles (Class O only):

2.9 *Flexible Fuel Lines(s):* yes/no/same component as used in *Propulsion System**[1]

2.9.1 Make(s):

2.9.2 Type(s):

2.9.3 *Working Pressure(s)* *[2]: MPa

2.9.4 Approval number:

2.9.5 Number of filling cycles (Class O only):

2.10 Heat exchanger(s): yes/no/same component as used in *Propulsion System* *[1]

2.10.1 Make(s):

2.10.2 Type(s):

2.10.3 *Working Pressure(s)* *[2]: MPa

2.10.4 Approval number:

2.10.5 Number of filling cycles (Class O only):

2.11 *Hydrogen Filter(s):* yes/no/same component as used in *Propulsion System* *[1]

2.11.1 Make(s):

2.11.2 Type(s):

2.11.3 *Working Pressure(s)* *[2]: MPa

2.11.4 Approval number:

2.11.5 Number of filling cycles (Class O only):

2.12 *Manual Valve(s):* yes/no/same component as used in *Propulsion System* *[1]

2.12.1 Make(s):

2.12.2 Type(s):

2.12.3 *Working Pressure(s)* *[2]: MPa

2.12.4 Approval number:

2.12.5 Number of filling cycles (Class O only):

2.13 Pressure or temperature or flow sensor(s) *[1]: yes/no/same component as used in *Propulsion System* *[1]

2.13.1 Make(s):

2.13.2 Type(s):

2.13.3 *Working Pressure(s)* *[2]: MPa

2.13.4 Approval number:

2.13.5 Number of filling cycles (Class O only):

2.14 *Pressure Regulator(s):* yes/no/same component as used in *Propulsion System* *[1]

2.14.1 Make(s):

2.14.2 Type(s):

2.14.3 *Working Pressure(s)* *[2]: MPa

2.14.4 Approval number:

2.14.5 Number of filling cycles (Class O only):

2.15 *Pressure Relief Device* (temperature triggered): yes/ same component as used in *Propulsion System* *[1]

2.15.1 Make(s):

2.15.2 Type(s):

2.15.3 Normal maximum operating temperature : *[2] °C
(in accordance with Paragraph 2.4.6.1 of this Regulation)

2.15.4 Approval number:

2.15.5 *Working Pressure(s)* *[2]: MPa

2.15.6 Number of filling cycles (Class O only):

2.16 *Pressure Relief Device* (pressure triggered): yes/no/same component as used in *Propulsion System* *[1]

2.16.1 Make(s):

2.16.2 Type(s):

2.16.3 *Working Pressure(s)* *[2]: MPa

2.16.4 Approval number:

2.16.5 Number of filling cycles (Class O only):

2.17 *Receptacle*: yes/ same component as used in *Propulsion System* *[1]

2.17.1 Make(s):

2.17.2 Type(s):

2.17.4 *Working Pressure(s)* *[2]: MPa

2.17.4 Approval number:

2.17.5 Number of filling cycles (Class O only):

3 Further documentation:

3.1 Process diagram (flow chart) for the *Hydrogen System*

3.2 System lay-out including electrical connections, and other external system inputs or outputs, etc.

3.3 Key to symbols used in documentation:

3.4 Adjustment data:

3.5 Cooling/ heating system(s) including *Working Pressures* and normal operating temperatures

3.6 Drawings showing requirements for installation and operation.

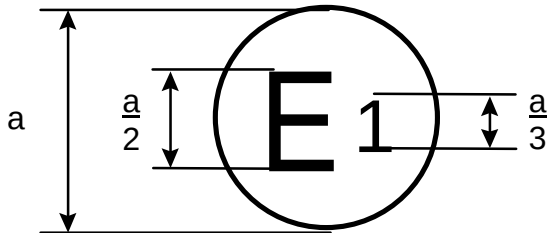
Notes:

*[1] - Strike out what does not apply.

*[2] - Specify the tolerance.

Annex 3

ARRANGEMENT OF THE SPECIFIC COMPONENT APPROVAL MARKS
(See Paragraph 5.4 of this Regulation)



xx R-002439

Where: $a \geq 8$ mm

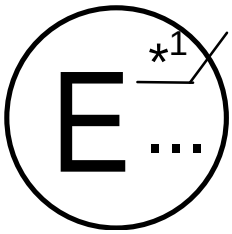
The above approval mark affixed to the *Hydrogen Component* shows that this component has been type approved in Germany (E1), pursuant to the Regulation No. xx under approval number 002439. The first two digits of the approval number indicate that the approval was granted in accordance with the requirements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

Annex 4

COMMUNICATION CONCERNING THE APPROVAL, OR REFUSAL, OR EXTENSION, OR WITHDRAWAL, OR PRODUCTION DEFINITELY DISCONTINUED OF A SPECIFIC COMPONENT PURSUANT TO REGULATION NO. XX

(Maximum format: A4 (210 x 297 mm)

Issued by: Name of administration:



Concerning: APPROVAL GRANTED *2
APPROVAL EXTENDED *2
APPROVAL REFUSED *2
APPROVAL WITHDRAWN *2
PRODUCTION DEFINITELY DISCONTINUED *2

of a type of *Specific Component* pursuant to Regulation No. xx

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

.....……

1. *Specific Component* considered:

Automatic Valve *2

Non-return Valve *2

Container *2

Excess Flow System *2

Fittings *2

Flexible Fuel Line *2

Heat exchanger *2

Hydrogen Filter

Hydrogen Sensor

Manual Valve *2

Pressure sensor *2

Temperature sensor *2

Flow sensor *2

Pressure or hydrogen remaining indicator

Pressure Regulator *2

Pressure Relief Device (temperature triggered) *[2]

Pressure Relief Device (pressure triggered) *[2]

Receptacle *[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. No. 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.

Notes:

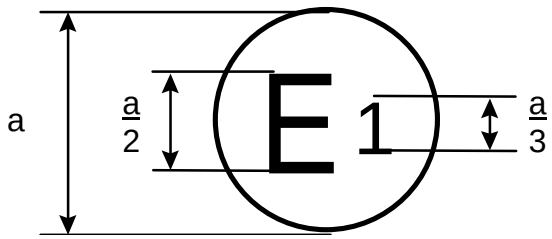
*[1] Distinguishing number of the country that has granted/extended/refused/withdrawn approval (see approval provisions in the Regulation).

*[2] Strike out what does not apply

Annex 5

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

Model A
(See Paragraph 13.4 of this Regulation)

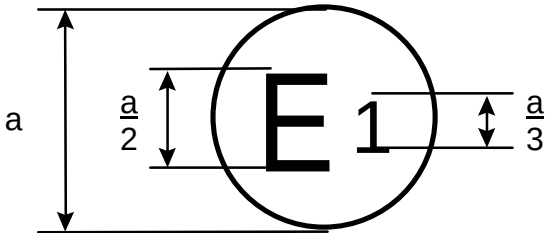


xx R-002439

Where: a ≥ 8 mm

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

Model B
(See Paragraph 13.4 of this Regulation)



xx 002439
83 021628

Where: a ≥ 8 mm

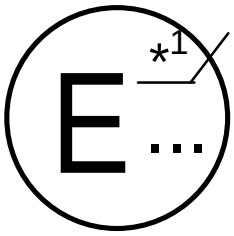
The above approval mark affixed to a vehicle shows that the vehicle has been type approved in Germany (E1), pursuant to the Regulation Nos. xx and 83. The approval numbers indicate that, at the dates when the respective approvals were given, Regulation No. xx was in its original form and Regulation No.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

Annex 6

COMMUNICATION CONCERNING THE APPROVAL, OR REFUSAL, OR EXTENSION, OR WITHDRAWAL, OR PRODUCTION DEFINITELY DISCONTINUED OF A VEHICLE TYPE WITH REGARD TO THE INSTALLATION OF A HYDROGEN SYSTEM PURSUANT TO REGULATION NO. XX

(Maximum format: A4 (210 x 297 mm)

Issued by: Name of administration:



Concerning: APPROVAL GRANTED *2

APPROVAL EXTENDED *2

APPROVAL REFUSED *2

APPROVAL WITHDRAWN *2

PRODUCTION DEFINITELY DISCONTINUED *2

of a *Vehicle Type* with regard to the installation of a *Hydrogen System* pursuant to Regulation No. xx

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

.....

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

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

7.1.1 *Container*: . . . . . .

7.1.2 Other components: . . . . . .

. . . . . .

8. Submitted for approval on: . . . . . .

9. Technical Service responsible for conducting approval tests . . . . . .

. . . . . .

10. Date of report issued by that service . . . . . .

11. No. of report issued by that service . . . . . .

12. Approval granted/refused/extended/withdrawn 2/

13. Reason(s) of extension (if applicable) . . . . . .

14. Place . . . . . .

15. Date . . . . . .

16. Signature . . . . . .

17. The documents filed with the application or extension of approval can be obtained upon request.

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

. . . . . .
. . . . . .

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

. . . . . .
. . . . . .

Notes:

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

*2 Strike out what does not apply

Annex 7

REQUIREMENTS AND APPROVAL TEST PROCEDURES FOR CONTAINERS

Contents **Page**

Annex 7: Part A

PROVISIONS REGARDING THE APPROVAL OF CONTAINERS

A1 REFERENCES

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

International Organisation for Standardization (ISO) Standards

ISO 148:1983	Steel - Charpy Impact Test (V-notch)
ISO 306:1994	Plastics - Thermoplastic Materials - Determination Of Vicat Softening Temperature (VST)
ISO 527-2:1993	Plastics - Determination of Tensile Properties – Part 2: Test Conditions For Moulding And Extrusion Plastics (Incorporating Technical Corrigendum 1:1994)
ISO 2808:1997	Paints And Varnishes - Determination Of Film Thickness
ISO 3146:2000	Plastics - Determination of melting behaviour (melting temperature or melting range) of semi-crystalline polymers by capillary tube and polarizing-microscope methods
ISO 4624:2002	Plastics And Varnishes - Pull-off Test For Adhesion
ISO 6506-1:1999	Metallic Materials - Brinell Hardness Test - Part1: Test Method
ISO 6892:1998	Metallic Materials - Tensile Testing At Ambient Temperature
ISO 7225:1994	Gas cylinders - Precautionary labels
ISO 7866:1999	Gas Cylinders - Refillable Seamless Aluminium Alloy Gas Cylinders - Design, Construction And Testing
ISO 9809-1:1999	Gas Cylinders - Refillable Seamless Steel Gas Cylinders - Design, Construction And Testing - Part 1: Quenched And Tempered Steel Cylinders With Tensile Strength Less Than 1100 MPa
PrEN ISO 11114-4 (??/??)	Transportable Gas Cylinders – Compatibility Of Cylinders And Valve Materials With Gas Contents – Part 4: Test Methods For Selecting Metallic Materials Resistant To Hydrogen Embrittlement

American Society for Testing and Materials (ASTM) Standards

ASTM B117-97	Standard Practice For Operating Salt Spray (Fog) Apparatus
ASTM D522-93a (2001)	Standard Test Method For Mandrel Bend Test Of Attached Organic Coatings
ASTM D1308-87 (1998)	Standard Test Method For Effect of Household Chemicals on Clear and Pigmented Organic Finishes

ASTM D2343-95	Standard Test Methods For Tensile Properties Of Glass Fibre Strands, Yarns And Rovings Used In Reinforced Plastics
ASTM D2344-84(1995)	Standard Test Method For Apparent Interlaminar Shear Strength of Parallel Fibre Composites By Short Beam Method ???Replaced by D2344M-00e1 Standard Test Method for Short-Beam Strength of Polymer Matrix Composite Materials and Their Laminates???
ASTM D2794-93(1999)e1	Standard Test Method For Resistance of Organic Coatings To The Effects of Rapid Deformation (Impact)
ASTM D3170-01	Standard Test Method For Chipping Resistance Of Coatings
ASTM D3359-97	Standard Test Methods For Measuring Adhesion By Tape Test
ASTM D3418-99	Standard Test Method For Transition Temperatures Of Polymers by Differential Scanning Calorimetry
ASTM D4018-99	Standard Test Methods For Properties Of Continuous Filament Carbon And Graphite Fiber Tows
ASTM G53-96	Standard Practice for Operating Light and Water - Exposure Apparatus (Fluorescent UV-Condensation Type) For Exposure Of Non-metallic Materials ???Replaced by G154-00ae1 Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials???

A2 CONTAINER TYPE APPROVAL REQUIREMENTS

A2.1 GENERAL

In addition to the requirements given in Paragraph 3 of this Regulation, the *Manufacturer* shall complete all documents referred to in Table 7A.1 and submit them to the Competent Authority when applying for approval.

Table 7A.1 – *Container* Type Approval Documents

Document	Annex 7 Reference
Statement Of Service	A2.2
Container Drawings	A2.3
Material Specifications and Test Data	A2.4
Container Specifications and Test Data	A2.5
Manufacturing Data	A2.6

A2.2 STATEMENT OF SERVICE

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

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

A2.3 CONTAINER DRAWINGS

Drawings shall show the following information as a minimum:

i) Title, reference number, date of issue and revision number,
ii) Reference to this Regulation and the *Container* Type,
iii) Principal geometrical dimensions including tolerances,
iv) *Container* materials,
v) *Container* mass and internal volume including tolerances,
vi) Details of the exterior protective coating,
vii) *Container* fire protection system.

A2.4 MATERIAL SPECIFICATIONS AND TEST DATA

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

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

A2.5 CONTAINER SPECIFICATIONS AND TEST DATA

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

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

If more *Containers* or *Liners* than required are tested, all results shall be documented.

A2.6 MANUFACTURING DATA

The tolerances of all principal manufacturing processes shall be provided, such as:

i) Tube extrusion, cold deformation, tube drawing, end forming, heat treatment and cleaning processes for the metal manufacturing of *Container* Types 1, 2 and 3,
ii) Acceptance criteria for non-destructive examination (NDE),
iii) Composite manufacturing processes and *Auto-frettage* according to Paragraph A4.2 of this Annex for the manufacturing of *Container* Types 2, 3 and 4,
iv) Hydrostatic pressure test and leak test according to Paragraph A6 of this Annex,

v) Final manufacturing inspection of surface finish, thread details and principal dimensions,
vi) Definition of maximum lot sizes for batch tests.

Table 7A.2 – Statement Of Service

Manufacturer Identification	*Manufacturer* Name: *Manufacturer* Address:
Container Identification	*Container* Identification: *Working Pressure*: MPa Type: Diameter *[1]: mm Length *[1]: mm Internal Volume: litres Empty Weight: kg *Container* Threads:
Container *Service Life*	Maximum *Service Life*: years Maximum Number Of Filling Cycles: cycles
Container Fire Protection System	PRD *Manufacturer*: PRD Identification: PRD Drawing Number(s):
Container Support Method	Support Method: Neck/Cylinder Mounting *[2] Support Drawing Number(s):
Container Protective Coatings	Purpose Of Protection: Protective Coating Drawing Number(s):
Container Design Description	*Container* Drawing Numbers:
Container Corrosion Inhibitor	*Container* Corrosion Inhibitor used: Yes/No *[2] Corrosion Inhibitor Manufacturer: Corrosion Inhibitor Identification:
Additional Information	
Container Statement Of Service	The *Manufacturer* hereby states that the *Container* design is suitable for use during the specified *Service Life* in the service conditions defined in Paragraph 2.4 of this Regulation. *Manufacturer*: Name, position and signature: Place, Date:

Notes: *[1] - May be replaced by other dimensions defining the shape of the *Container*
*[2] – Delete as appropriate

Table 7A.3 - Material Specifications And Test Data

Test and Annex 7 Reference		Applicable To Material					Material Specification	
		teel	**luminium**	**lastic *Liner***	**ibre**	**esin**		
	Material Manufacturer	X	X	X	X	X		
	Type of Material	X	X	X	X	X		
	Material Identification	X	X	X	X	X		
	Heat Treatment Definition	X	X					
	Chemical Composition	X	X					
	Test Data						**Specified Material Value**	**Test Value**
B1	Tensile Test	X	X	X	X			
B3	Charpy Impact Test	X						
B4	Corrosion Test		X					
B5	Sustained Load Cracking Test		X					
B6	Softening/Melting Temperature			X				
B7	Glass Transition Temperature, TG					X		
B8	Resin Shear Strength, ILSS					X		
B9	Coating Test							
B11	Hydrogen Compatibility Test	X	X	X	X	X		

Manufacturer:

Name, position and signature:

Place, Date:

Technical Service:

Inspector's signature:

Place, Date:

Table 7A.4 - *Container* Specifications And Test Data

Test and Annex 7 Reference		Applicable To *Container* Type				Specified Design Value	Test Value
		1	2	3	4		
B12	LBB Performance Test	X	X	X	X		
B13	Extreme Temperature Pressure Cycling Test		X	X	X		
B14	Leak Test				X		
B16	Burst Test	X	X	X	X		
B17	Ambient Temperature Pressure Cycling Test	X	X	X	X		
B18	Acid Environment Test		X	X	X		
B19	Bonfire Test	X	X	X	X		
B20	Penetration Test	X	X	X	X		
B21	Composite Flaw Tolerance Test		X	X	X		
B22	High Temperature Creep Test		X	X	X		
B23	Accelerated Stress Rupture Test		X	X	X		
B24	Impact Damage Test			X	X		
B25	Permeation Test				X		
B26	Boss Torque Test				X		
B27	Hydrogen Gas Cycling Test				X		

Container Identification:

Manufacturer:

Name, position and signature:

Place, Date:

Technical Service:

Inspector's signature:

Place, Date:

A2.7 CONTAINER MARKINGS

On each *Container,* and where applicable the outer surface of a group of permanently encapsulated *Containers*, the *Manufacturer* shall provide clear permanent markings with a font not less than 6 mm high. Marking shall be made either by labels incorporated into resin coatings, labels attached by adhesive, low

stress stamps used on the thickened ends of *Container* Types 1 and 2, or any combination of the above. Adhesive labels and their application shall be in accordance with ISO 7225, or an equivalent standard. Multiple labels are allowed and should be located such that mounting brackets do not obscure them. Every *Container* type approved in accordance with this Regulation shall bear a marking place with the following data clearly legible:

i) Name of the *Manufacturer*,
ii) A unique serial number for every *Container*,
iii) The marking "CGH_2",
iv) *Working Pressure* (MPa) at 15^0C,
v) Year and month of manufacture, e.g. 2000/01,
vi) Approval mark in accordance with Paragraph 5.4 of this Regulation,
vii) The marking "DO NOT USE AFTER yyyy/mm" where yyyy/mm is the year and month of manufacture plus the approved *Service Life* of the *Container*,
viii) The marking "Number of filling cycles xxxxx" where xxxxx is the number of filling cycles from Section 2.4.7 of this Regulation.

A3 CONTAINER DESIGN REQUIREMENTS

A3.1 GENERAL

The *Container* design shall cover all relevant aspects needed to ensure that every *Container* produced to the design is fit for its purpose throughout its specified *Service Life*. The service conditions do not include external loads that may arise from vehicle collisions, or integration of the *Container* into the vehicle, etc. *Containers* need not be designed for continuous exposure to mechanical or chemical attack, e.g. leakage from cargo that may be carried on vehicles or severe abrasion damage from road conditions.

A3.1.1 Leak Before Break

The design shall ensure a leak before break (LBB) failure mode under feasible degradation of pressure parts during normal service. If failure of the *Container* occurs, it shall be only by the growth of a fatigue crack, thus preventing rupture of the *Container*.

A3.1.2 Maximum Defect Size

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

A3.1.3 Fire Protection

The *Container*, *Pressure Relief Devices* and any added insulation or protective material shall be designed collectively to protect the *Container* from rupture when exposed to the fire conditions specified in Paragraph B19 of this Annex. The arrangement of the fire protection system shall be specified.

A3.1.4 Opening Thread(s)

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

A3.1.5 Exterior Environmental Protection

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

A3.2 MATERIALS

A3.2.1 General

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

A3.2.2 Steel

Steels shall conform to the material requirements of ISO 9809.

A3.2.3 Aluminium

Aluminium alloys shall conform to the material requirements of ISO 7866.

A3.2.4 Plastic *Liner* Materials

The polymeric material shall be compatible with the service conditions specified in Paragraph 2.4 of this Regulation.

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

A3.2.5 Fibres

The fibre manufacturer shall certify that the fibre material properties conform to the *Manufacturer*'s specifications for the product.

A3.2.6 Resins

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

A3.3 *BURST PRESSURE* RATIOS

The minimum *Burst Pressure* ratios, i.e. the minimum actual *Burst Pressure* of the *Container* divided by its *Working Pressure*, shall not be less than the values given in Table 7A.5.

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

Over-wrapping	Type 1	Type 2	Type 3	Type 4
All metal	2.25			
Glass		2.75 (2.50*[1])	3.65 (3.50*[1])	3.65
Aramid		2.35	3.10 (3.00*[1])	3.10
Carbon		2.35*[2]	2.35*[2]	2.35*[2]
Hybrid		*[3]		

Notes:

*[1] The minimum *Burst Pressure* ratios may be reduced to the bracketed values, if the calculated stress ratios, i.e. stress in the fibre at the minimum *Burst Pressure* Ratio times *Working Pressure* divided by the stress in the fibre at *Working Pressure*, conform to the un-bracketed values. The stress ratio calculations shall:

i) Be based on an analysis method with capability for non-linear materials (special purpose computer program or finite element analysis program),
ii) Include correct modelling of the Elastic-plastic stress-strain curve for the *Liner* material,
iii) Include correct modelling of mechanical properties of the composite,
iv) Include calculations made at *Auto-frettage Pressure*, zero pressure after *Auto-frettage*, *Working Pressure* and minimum *Burst Pressure*,
v) Take into account the prestress from winding tension.

*[2] A reduced *Burst Pressure* ratio of 1.8 may be used for carbon fibre designs if an integrity monitoring system is an integral component of the *Container* design. The integrity monitoring system shall prevent further use of the *Container* when damage occurs that could adversely affect *Container* safety.

*[3] For *Container* designs using hybrid reinforcement, i.e. two or more different fibre types, consideration shall be given to the load share between the different fibres based on the different elastic modulii of the fibres. The calculated stress ratios for each individual fibre type shall conform to the un-bracketed values. Verification of the stress ratios may also be performed using strain gauges. The minimum *Burst*

Pressure Ratio must be chosen such that the calculated stress in the fibres at the minimum *Burst Pressure* Ratio times *Working Pressure* divided by the calculated stress in the fibre at *Working Pressure* meets the stress ratio requirements for the fibres used.

A4 CONTAINER MANUFACTURING REQUIREMENTS

A4.1 METAL CONTAINERS AND LINERS

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

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

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

A4.2 COMPOSITE CONTAINERS

A4.2.1 Composite Filament Winding

Composite Containers shall be fabricated from a *Liner Over-wrapped* with continuous filament windings. Filament winding operations shall be computer or mechanically controlled. During winding the principal parameters shall be monitored and kept within specified tolerances, and documented in a winding record. These parameters shall include, but are not limited to:

i) Fibre type including tex value and sizing,
ii) Number of fibre tows per bandwidth,
iii) Type of resin and resin components mix ratio,
iv) Manner of impregnation, weight or volume fraction of resin or fibre,
v) Winding program reference and winding angle,
vi) Number of winding rotations hoop,
vii) Number of windings cycles helical (Type 3 and 4 only),
viii) Band width,
ix) Winding tension,
x) Winding speed,
xi) Temperature of the resin,
xii) Temperature of the *Liner*.

A4.2.2 Curing Of Thermosetting Resins

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

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

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

A4.2.3 *Auto-frettage*

Auto-frettage, if used, shall be carried out before the hydrostatic pressure test. The *Auto-frettage Pressure* shall be within the limits established by the *Manufacturer*.

A5 BATCH TEST REQUIREMENTS

A5.1 BATCH TEST

A5.1.1 General

The *Manufacturer* shall conduct batch testing on *Finished Containers* or *Liners* that are representative of normal production. The *Finished Containers* or *Liners* to be tested shall be randomly selected from each *Batch*. In no case shall a *Batch* be permitted to exceed 200 *Finished Containers* or *Liners* (not including *Finished Containers* or *Liners* used in destructive tests), or one shift of successive production, whichever is greater.

With reference to Table 7A.6, the following batch tests are required:

i) One *Finished Container* shall be subjected to the ambient temperature pressure cycle test at the frequency given in Paragraph A5.1.2 of this Annex,

ii) One *Finished Container* shall be subjected to the burst test. If a *Finished Container* passes the ambient temperature pressure cycle test the same *Container* may be subjected to the burst test,

iii) One *Finished Container*, *Liner* or heat-treated test sample that is representative of *Finished Containers* or *Liners*, shall be subjected to the other tests.

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

All *Containers* represented by a batch test that fail to meet the specified requirements shall follow the procedures specified in Paragraph A5.2 of this Annex.

Table 7A.6 - Batch Tests

Test and Annex Reference		Applicable To *Container* Type				Specified Design Value	Test Value
		1	2	3	4		
	Verification of Principal Dimensions	X	X	X	X		
B1	Tensile Test	X	X*[1]	X*[1]	X*[1]		
B3	Charpy Impact Test	X	X*[1]	X*[1]			
B6	Softening/Melting Temp. Test				X*[1]		
B10	Coating Batch Test	X	X	X	X		
B16	Burst Test	X	X	X	X		
B17	Ambient Temperature Pressure Cycle Test	X	X	X	X*[2]		

Notes:
*[1] - Test on *Liner* material
*[2] - Test to be performed between a Boss Torque Test (B26) and a Leak Test (B14)

A5.1.2 Frequency Of Ambient Temperature Pressure Cycling Test

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

i) One *Container* from each *Batch* shall be pressure cycled for the number of pressure cycles in accordance with Paragraph 2.4.7 of this Regulation,

ii) If on 10 sequential production *Batches* of a design family, i.e. similar materials and processes, none of the pressure cycled *Containers* in i) above should leak or rupture within 1.5 times the number of pressure cycles in accordance with Paragraph 2.4.7 of this Regulation, then the pressure cycle test can be reduced to one *Container* from every 5 *Batches* of production,

iii) If on 10 sequential production *Batches* of a design family, none of the pressure cycled *Containers* in i) above should leak or rupture within 2.0 times the number of pressure cycles in accordance with Paragraph 2.4.7 of this Regulation, then the pressure cycle test can be reduced to one *Container* from every 10 *Batches* of production,

iv) Should more than 3 months have expired since the last *Batch* of production, then a *Container* from the next *Batch* of production shall be pressure cycle tested in order to maintain the reduced frequency of batch testing in ii) or iii) above,

v) Should any reduced frequency pressure cycle test *Container* in ii) or iii) above fail to meet the number of pressure cycles in accordance with Paragraph 2.4.7 of this Regulation, then the batch pressure cycle test frequency in i) shall be reintroduced for at least 10 production *Batches* in order to re-establish the reduced frequency of batch pressure cycle testing in ii) or iii) above,

vi) Should any *Container* in i), ii) or iii) above fail within the number of pressure cycles in accordance with Paragraph 2.4.7 of this Regulation, then the cause of failure shall be determined and corrected following the procedures in Paragraph A5.2 of this Annex. The pressure cycle test shall then be repeated on an additional three *Containers* from that *Batch*. Should any of the three additional *Containers* fail to meet the number of pressure cycles, the *Batch* shall be rejected.

A5.2 FAILURE TO MEET TEST REQUIREMENTS

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

i) If there is evidence of a fault in carrying out a test, or an error of measurement, a further test shall be performed. If the result of this test is satisfactory, the first test shall be ignored,

ii) If the test has been carried out in a satisfactory manner, the cause of the test failure shall be identified.

If the failure is considered to be due to the heat treatment applied, the *Manufacturer* may subject all the *Containers* of that *Batch* to a further heat treatment.

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

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

A6 PRODUCTION EXAMINATION AND TEST REQUIREMENTS

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

i) Verification that the principal dimensions and mass of the *Finished Container* and of any *Liner* and *Over-wrapping* are within design tolerances,

ii) Verification of compliance with principal manufacturing parameters, in accordance with Paragraph A2.6 of this Annex, including examination of any specified surface finish with special attention to deep drawn surfaces and folds or laps in the neck or shoulder of forged or spun end enclosures or openings,

iii) For metallic *Container(s)* and *Liner(s)*, NDE in accordance with Annex B of ISO 9809, or demonstrated equivalent method capable of detecting the maximum defect size allowed, to verify that the maximum defect size does not exceed the size specified in the design as determined in accordance with Paragraph A3.1.2 of this Annex,

iv) Brinell hardness test for metallic *Container(s)* and *Liner(s)* in accordance with Paragraph B2 of this Annex and fulfil the requirements therein,

v) Hydrostatic test, in accordance with Paragraph B15 of this Annex and fulfil the requirements therein,

vi) Leak test for *Container* Type 4, in accordance with Paragraph B14 of this Annex and fulfil the requirements therein,

vii) Verification of markings, in accordance with Paragraph A2.7 of this Annex.

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

Table 7A.7 - Production Examination And Tests

Production Examination And Tests & Annex 7 Reference		**Applicable To *Container* Type**			
		1	**2**	**3**	**4**
	Principal Design Dimensions	X	X	X	X
A2.6	Principal Manufacturing Parameters	X	X	X	X
	NDE	X	X*[1]	X*[1]	
B2	Brinell Hardness Test	X	X*[1]	X*[1]	
B14	Leak Test				X
B15	Hydrostatic Test	X	X	X	X
A2.7	Markings	X	X	X	X

Note:
*[1] - Test on metallic *Liner*

A7 MODIFICATIONS

Approval testing of modifications should be based on Table 7A.8 where appropriate.

Table 7A.8 - Change Of Design Design Change	Type Of Test											
	Materials B1 - B9, as applicable	LBB Performance B12	Burst B16	Ambient Temp. pressure Cycling B17	Acid Environment B18	Bonfire B19	Penetration B20	Composite Flaw Tolerance B21	High. Temp. Creep - B22 Acc. Stress Rupture - B23	Impact Damage Test B24	Permeation B25 Boss torque B26 Hydrogen Cycling B27	Hydrogen Compatibility B11
Fibre Manufacturer			2, 3, 4	2, 3, 4					2, 3, 4	2, 3, 4	4	2, 3, 4
Metallic *Container* Or *Liner* Material	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	1, 2, 3	2, 3	2, 3		1, 2, 3
Plastic *Liner* Material	4	4		4	4	4			4	4	4	4
Fibre Material	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4	4	2, 3, 4
Resin Material					2, 3, 4		2, 3, 4	2, 3, 4	2, 3, 4	2, 3, 4		2, 3, 4
Diameter Change ≤20%			1, 2, 3, 4	1, 2, 3, 4								
Diameter Change >20%		1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4		1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4		2, 3, 4		
Length Change ≤ 50%			1, 2, 3, 4									
Length Change> 50%			1, 2, 3, 4	1, 2, 3, 4		1, 2, 3, 4				3, 4		
Working Pressure Change ≤20% *[1]			1, 2, 3, 4	1, 2, 3, 4								
Dome Shape or Opening Size			1, 2, 3, 4	1, 2, 3, 4							4*[2]	
Coating Change	2, 3, 4				2, 3, 4							
End Boss Design											4*[2]	
Change In Manufacturing Process			1, 2, 3, 4	1, 2, 3, 4								
Fire Protection System						1, 2, 3, 4						

Notes: 2,3 indicates that a test is required for *Container* Types 2 and 3 only

*[1] - Only when thickness change proportional to diameter or pressure change

*[2] - A hydrogen cycle test is not required if only the opening size of the boss end is reduced, the *Liner* to boss interface is not affected and the original materials are used for boss, *Liner* and seals.

Annex 7: Part B

APPROVAL TEST PROCEDURES FOR CONTAINERS

TESTS OF CONTAINER MATERIALS

B1 TENSILE TEST

B1.1 Sampling

The test applies to all *Container* Types.
The test applies to metallic and non-metallic materials and fibres.
Number of *Containers* or *Liners* to be tested for type approval: 2 *[1]
Number of *Containers* or *Liners* to be tested per *Batch*: In accordance with Paragraph A5.1 of this Annex.

Note: *[1] - The same *Containers* or *Liners* may be used for the Charpy Impact Test in Paragraph B3 of this Annex.

B1.2 Procedure

B1.2.1 Steel And Aluminium

A tensile test shall be carried out on the material taken from the cylindrical part of the *Finished Container* or *Liner* using a rectangular test piece shaped in accordance with the methods described in ISO 9809 for steel and ISO 7866 for aluminium. The two faces of the test piece representing the inside and outside surface of the *Container* or *Liner* shall not be machined. The tensile test shall be carried out in accordance with ISO 6892.

B1.2.2 Plastic *Liner* Materials

Mechanical properties for plastic *Liner* materials shall be carried out in accordance with ISO 527. The tensile yield strength and ultimate elongation of plastic *Liner* materials shall be determined at -50 °C using ISO 527.

B1.2.3 Fibres

A tensile strand test shall be carried out in accordance with ASTM D4018, ASTM D2343 or equivalent standards. Strand test samples shall be manufactured with the identical materials (fibre and resin) and composite cure cycle as given by the *Container* design. Only the mechanical properties of the fibres shall be tested and presented.

B1.3 Requirements

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

B1.4 Results

For type approval, the following mechanical properties shall be presented in a test certificate, e.g. Table 7A.3 of this Annex:

i) Elastic Modulus
ii) Plastic Tensile Modulus
iii) Minimum Tensile Yield Stress
iv) Ultimate Tensile Stress
v) Minimum Elongation At Break

The *Manufacturer* shall keep the results on file throughout the *Service Life* of the *Container*.

B2 BRINELL HARDNESS TEST

B2.1 Sampling

The test applies to all *Containers* and *Liners* of *Container* Types 1, 2 and 3.
The test applies to metallic materials only.
Minimum number of samples to be tested: All *Containers* produced.

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

B2.2 Procedure

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

B2.3 Requirement

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

B2.4 Results

The hardness value shall be presented in a test certificate, e.g. Table 7A.3 of this Annex.

The *Manufacturer* shall keep the results on file throughout the *Service Life* of the *Container*.

B3 CHARPY IMPACT TEST

B3.1 Sampling

The test applies to *Finished Containers* of *Container* Types 1, 2 and 3.
The test applies to steel materials only.
Number of *Containers* or *Liners* to be tested for type approval: 2 *[1].
Number of *Containers* or *Liners* to be tested per *Batch*: In accordance with Paragraph A5.1 of this Annex.

Note: *[1] - The same *Containers* or *Liners* may be used for the Tensile Test in Paragraph B1 of this Annex

B3.2 Procedure

The test shall be carried out on three test pieces of material taken from the cylindrical part of the *Container* in accordance with ISO 148. The test pieces shall be taken from the wall of the *Container* in the direction specified in Table 7B.1. The notch shall be perpendicular to the face of the *Container* wall. For longitudinal tests the test piece shall be machined all over (on six faces). If the wall thickness does not permit a final test piece width of 10 mm, the width shall be as close to the nominal thickness of the *Container* wall as practicable. The test pieces taken in transverse direction shall be machined on four faces only; the inner and outer face of the *Container* wall shall not be machined.

B3.3 Requirement

Impact values shall not be less than that indicated in Table 7B.1.

Table 7B.1 – Charpy Impact Test Acceptable Values

Cylinder diameter D, mm	>140			≤140
Direction of testing	Transverse			Longitudinal
Width of test piece, mm	3 - 5	>5 - 7.5	>7.5 - 10	3 to 5
Test temperature, °C	-50			-50
Min. required Impact strength, J/cm²				
Mean of 3 samples	30	35	40	60
Individual sample	24	28	32	48

B3.4 Results

The impact values shall be presented in a test certificate, e.g. Table 7A.3 of this Annex, and shall include the individual sample results and the mean value of all samples.

The *Manufacturer* shall keep the impact values on file throughout the *Service Life* of the *Container*.

B4 CORROSION TEST

B4.1 Sampling

The test applies to *Container* Types 1, 2 and 3.
The test applies to aluminium materials only.
Minimum number of samples to be tested: As specified in ISO 7866 Annex A.

B4.2 Procedure and Requirement

Aluminium alloys shall be tested in accordance with ISO 7866 Annex A, and meet the corrosion requirements therein.

B4.3 Results

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

B5 SUSTAINED LOAD CRACKING TEST

B5.1 Sampling

The test applies to *Container* Types 1, 2 and 3.
The test applies to aluminium materials only.
Minimum number of samples to be tested: As specified in ISO 7866 Annex B.

B5.2 Procedure and Requirement

The resistance of aluminium alloys to sustained load cracking shall be tested in accordance with ISO 7866 Annex B, and meet the requirements therein.

B5.2.3 Results

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

B6 SOFTENING TEMPERATURE TEST

B6.1 Sampling

The test applies to *Container* Type 4.
The test applies to plastic materials only.
Number of *Liners* to be tested for type approval: 1.
Number of *Liners* to be tested per *Batch*: In accordance with Paragraph A5.1 of this Annex.

B6.2 Procedure

The softening temperature of thermoplastic materials from finished *Liners* shall be determined based on the A50 method in ISO 306, and the melting temperature shall be determined in accordance with ISO 3146.

B6.3 Requirement

The following requirements shall be met:
i) The softening temperature shall be ≥ 100 °C,
ii) The melting temperature shall be ≥ 130 °C.

B6.4 Results

The softening and melting temperature values shall be presented in a test certificate, e.g. Table 7A.3 of this Annex.

The *Manufacturer* shall keep the softening and melting temperature values on file throughout the *Service Life* of the *Container*.

B7 GLASS TRANSITION TEMPERATURE TEST

B7.1 Sampling

The test applies to *Container* Types 2, 3 and 4.
The test applies to composite resin materials only.
Minimum number of samples to be tested: 3.

B7.2 Procedure

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

B7.3 Requirements

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

B7.4 Results

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

B8 RESIN SHEAR STRENGTH TEST

B8.1 Sampling

The test applies to *Container* Type 2, 3 and 4.
The test applies to composite resin materials only.
Minimum number of samples to be tested: 3.

B8.2 Procedure

Resin materials shall be tested on a sample coupon representative of the composite *Over-wrap* in accordance with ASTM D2344, or an equivalent National Standard.

B8.3 Requirement

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

B8.4 Results

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

B9 COATING TEST

B9.1 Sampling

The test applies to all *Container* Types where exterior environmental protective coating is used, e.g. organic coating/paint.
Minimum number of samples to be tested: As specified in the appropriate standards.

B9.2 Procedure and Requirement

Coatings shall be evaluated using the following test methods:

i) Adhesion strength in accordance with ISO 4624, using Method A or B as appropriate. The coating shall exhibit an adhesion rating of 4.
ii) Flexibility in accordance with ASTM D522, using Method B with a 12.7 mm mandrel at the specified thickness at -20 °C. Test samples shall be prepared in accordance with ASTM D522. There shall not be any visually apparent cracks.
iii) Impact resistance in accordance with ASTM D2794. The coating at room temperature shall pass a forward impact test of 18 J.
iv) Chemical resistance in general accordance with ASTM D1308. The test shall be conducted using the Open Spot Test Method and 100 hours exposure to a 30% sulphuric acid solution (battery acid with a specific gravity of 1.219) and 24 hours exposure to a polyalkalene glycol, e.g. brake fluid. There shall be no evidence of lifting, blistering or softening of the coating. The adhesion shall meet a rating of 3 when tested in accordance with ASTM D3359.
v) Light and water exposure in accordance with ASTM G53, using an exposure of 1000 hours. There shall be no evidence of blistering. The adhesion shall meet a rating of 3 when tested in accordance with ISO 4624. The maximum gloss loss allowed is 20%.
vi) Salt spray exposure in accordance with ASTM B117, using an exposure of 500 hours. Undercutting shall not exceed 3 mm at the scribe mark. There shall be no evidence of blistering. The adhesion shall meet a rating of 3 when tested in accordance with ASTM D3359.
vii) Resistance to chipping at room temperature using the ASTM D3170. The coating shall have a rating of 7A or better, and there shall not be any exposure of the substrate.

B9.3 Results

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

B10 COATING BATCH TEST

B10.1 Sampling

The test applies to all *Container* Types where exterior environmental protective coating is used, e.g. organic coating/paint.
Number of *Containers* to be tested per *Batch*: In accordance with Paragraph A5.1 of this Annex.

B10.2 Procedure and Requirement

Coatings shall be evaluated using the following test methods:

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

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

B10.3 Results

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

The *Manufacturer* shall keep the coating thickness and adhesion strength values on file throughout the *Service Life* of the *Container*.

B11 HYDROGEN COMPATIBILITY TEST

B11.1 Sampling

The test applies to all *Container* Types.
The test applies to all materials that are in contact with hydrogen.
Number of samples to be tested: In accordance with prEN/ISO 11114 - 4.

B11.2 Procedure and Requirement

Hydrogen compatibility shall be tested in accordance with prEN/ISO 11114 - 4 and meet the requirements therein.

B11.4 Results

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

TESTS OF FINISHED CONTAINERS

B12 LEAK-BEFORE-BREAK (LBB) PERFORMANCE TEST

B12.1 Sampling

The test applies to all *Container* Types. The test is not required if the *Container* design is already proven to exceed 3 times the number of pressure cycles calculated in accordance with Paragraph 2.4.7 of this Regulation, when tested in accordance with Paragraph B17 of this Annex.
Number of *Finished Containers* to be tested: 3.

B12.2 Procedure

The *Container* shall be tested using the following procedure:
i) Fill the *Container* to be tested with a non-corrosive fluid such as oil, inhibited water or glycol,
ii) Pressure cycle the *Container* between ≤ 2.0 MPa and ≥ 1.5 times *Working Pressure* at a rate of ≤ 10 cycles per minute to the number of pressure cycles calculated in accordance with Paragraph 2.4.7 of this Regulation.

B12.3 Requirement

The *Containers* tested shall fail by leakage and not by rupture.

B12.4 Results

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

B13 EXTREME TEMPERATURE PRESSURE CYCLING TEST

B13.1 Sampling

The test applies to all *Container* Types.
Number of *Finished Containers* to be tested: 2.

B13.2 Procedure

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

i) Condition for 48 hours with a temperature ≥ 85 °C and a relative humidity ≥ 95%,
ii) Pressure cycle between ≤ 2.0 MPa and ≥ 1.25 times *Working Pressure* at a temperature ≥ 85 °C and a relative humidity ≥ 95%, for 1.5 times the number of filling cycles calculated in accordance with Paragraph 2.4.7 of this Regulation,
iii) Stabilise at ambient conditions,
iv) Condition for 48 hours at a temperature ≤ -40 °C
v) Pressure cycle between ≤ 2.0 MPa and ≥ *Working Pressure* at ≤ -40 °C, for 1.5 times the number of filling cycles,
vi) Leak Test*[1] in accordance with Paragraph B14 of this Annex,
vii) Burst Test in accordance with Paragraph B16 of this Annex.

Note: *[1] - Applies to *Container* Type 4 only.

Adequate recording instrumentation shall be provided to ensure the minimum temperature and pressure of the fluid within the *Container* is maintained during the low temperature cycling.

B13.3 Requirement

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

Containers of Type 4 shall meet the leak test requirements.

All *Containers* shall not burst at less than 85% of the *Working Pressure* times the *Burst Pressure* ratio given in Paragraph A3.3 of this Annex.

B13.4 Results

The *Burst Pressure* shall be presented in a test certificate, e.g. Table 7A.4 of this Annex.

B14 LEAK TEST

B14.1 Sampling

The test applies to *Container* Type 4.
Number of *Finished Containers* to be tested: All *[1].
Number of *Finished Containers* to be tested for type approval: 1.

Note: *[1] - This test shall follow the boss torque and ambient temperature cycle tests when performing a batch test in accordance with Paragraph A5.1 of this Annex.

B14.2 Procedure

The *Container* shall be thoroughly dried and pressurised to 1.25 times *Working Pressure* with hydrogen, helium or a gas mixture containing at least 5% hydrogen or 10% helium.

B14.3 Requirement

Any leakage detected through cracks, pores, unbonds or similar defects shall cause the *Container* to be rejected. Permeation through the wall in accordance with Paragraph B25 of this Annex is not considered to be leakage.

B14.4 Results

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

The *Manufacturer* shall keep the total leakage value on file throughout the *Service Life* of the *Container*.

B15 HYDROSTATIC TEST

B15.1 Sampling

The test applies to all *Container* Types.
Number of *Finished Containers* to be tested: All.

B15.2 Procedure and Requirement

One of the following two options shall be used for the hydrostatic test:

Option 1 - Volumetric Expansion Test (Water Jacket Test)

i) The *Container* shall be pressurised to ≥ 1.5 times *Working Pressure*. Under no circumstance may the pressure exceed the *Auto-frettage Pressure*.
ii) The pressure shall be maintained for at least 30 seconds to ensure complete expansion. If the pressure cannot be maintained due to failure of the test apparatus, it is permissible to repeat the test at a pressure increased by 0.7 MPa. Not more than 2 such repeat tests are permitted.

iii) For *Containers* of Type 2 or 3, the *Manufacturer* shall define the appropriate limit of permanent volumetric expansion for the test pressure used, but in no case shall the permanent expansion exceed 5% of the total volumetric expansion measured under the test pressure.

iv) For *Containers* of Type 4, the *Manufacturer* shall define the appropriate limit of elastic expansion for the test pressure used, but in no case shall the elastic expansion of any *Container* exceed the average *Batch* value by more than 10%.

v) Any *Container* that does not meet the defined expansion limit shall be rejected, but may still be used for batch test purposes.

Option 2- Proof Pressure Test

i) The *Container* shall be pressurised gradually and regularly to 1.5 times *Working Pressure*,

ii) The pressure shall be maintained for at least 30 seconds to ascertain that there is no tendency for the pressure to decrease.

B15.3 Results

The results shall be presented in a test certificate, e.g. Table 7A.4 of this Annex.

The *Manufacturer* shall keep the results on file throughout the *Service Life* of the *Container*.

B16 BURST TEST

B16.1 Sampling

The test applies to all *Container* Types.
Number of *Finished Containers* to be tested for type approval: 3.
Number of *Liners* to be tested: 1 (*Container* Type 2 only)
Number of *Containers* to be tested per *Batch*: In accordance with Paragraph A5.1 of this Annex.

B16.2 Procedure

The *Container* shall be hydrostatically burst tested at ambient temperature using the following procedure:

The rate of pressurisation shall be ≤ 1.4 MPa/s for pressures higher than 80% of the *Working Pressure* times the *Burst Pressure* ratio given in Paragraph A3.3 of this Annex. If the rate exceeds 0.35 MPa/s at pressures higher than 80% of the *Working Pressure* times the *Burst Pressure* ratio, then either the *Container* must be placed in series between the pressure source and the pressure measurement device, or there must be a 5 second hold at the *Working Pressure* times the *Burst Pressure* ratio.

B16.3 Requirement

The *Container Burst Pressure* shall exceed the *Working Pressure* times the *Burst Pressure* ratio given in Paragraph A3.3 of this Annex.

The *Burst Pressure* of the *Liner* shall exceed the minimum *Burst Pressure* specified for the *Liner* design.

B16.4 Results

The *Burst Pressure* shall be presented in a test certificate, e.g. Table 7A.4 of this Annex.

The *Manufacturer* shall keep the *Burst Pressure* value on file throughout the *Service Life* of the *Container*.

B17 AMBIENT TEMPERATURE PRESSURE CYCLING TEST

B17.1 Sampling

The test applies to all *Container* Types.
Number of *Finished Containers* to be tested for type approval: 2.
Number of *Containers* to be tested per *Batch*: In accordance with Paragraph A5.1 of this Annex.

B17.2 Procedure

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

i) Fill the *Container* to be tested with a non-corrosive fluid such as oil, inhibited water or glycol.
ii) Pressure cycle between ≤ 2.0 MPa and ≥ 1.25 times *Working Pressure* at a rate not exceeding 10 cycles per minute.

The *Containers* shall be pressure cycled to failure, or to the number of pressure cycles calculated in accordance with Paragraph 2.4.7 of this Regulation.

Containers that do not fail within the number of pressure cycles shall be destroyed either by continuing the cycling until failure occurs, or by hydrostatically pressurising to burst.

B17.3 Requirement

The *Containers* shall not fail before reaching the number of pressure cycles calculated in accordance with Paragraph 2.4.7 of this Regulation. *Containers* exceeding the number of pressure cycles shall fail by leakage and not by rupture.

B17.4 Results

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

The *Manufacturer* shall keep the results on file throughout the *Service Life* of the *Container*.

B18 ACID ENVIRONMENT TEST

B18.1 Sampling

The test applies to all *Container* Types.
Number of *Finished Containers* to be tested: 1.

B18.2 Procedure

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

i) The upper section of the *Container* shall be divided into five distinct areas and marked for pendulum impact preconditioning and fluid exposure. The five areas shall each be nominally 150 mm in diameter. The five areas do not need to be oriented along a single line, but shall not overlap,

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

iii) Each of the 5 preconditioned areas shall be exposed to one of five solutions. The five solutions are:

   a) Sulphuric acid - 30% solution (battery acid with a specific gravity of 1.219),
   b) Sodium hydroxide - 25% solution by weight in water,
   c) Methanol/gasoline - 5/95 % concentration,
   d) Ammonium nitrate - 28% solution by weight in water,
   e) Windshield washer fluid (50% by volume solution of methyl alcohol and water).
   f) During the exposure, orientate the *Container* with the fluid exposure areas uppermost. Place a pad of glass wool approximately 0.5 mm thick and 150 mm in diameter on each of the five preconditioned exposure areas. Apply an amount of the test fluid to the glass wool sufficient to ensure that the pad is wetted evenly across its surface and through its thickness for the duration of the test,

iv) Pressure cycle between ≤ 10% of *Working Pressure* and ≥ 1.25 times *Working Pressure* for the number of filling cycles calculated in accordance with Paragraph 2.4.7 of this Regulation, at a maximum pressurisation rate of 2.75 MPa/s,

v) Pressurise to 1.25 times *Working Pressure* until the elapsed exposure time (pressure cycling and pressure hold) to the environmental fluids equals 48 hours,

vi) Burst Test in accordance with Paragraph B16 of this Annex.

B18.3 Requirement

The *Container* shall achieve a *Burst Pressure* of ≥ 1.8 times *Working Pressure*.

B18.4 Results

The *Burst Pressure* shall be presented in a test certificate, e.g. Table 7A.4 of this Annex.

B19 BONFIRE TEST

B19.1 Sampling

The test applies to all *Container* Types.
Number of *Finished Containers* to be tested: Minimum 1.

B19.2 Procedure

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

The *Container* shall be pressurised with hydrogen or nitrogen to *Working Pressure*. The pressurised *Container* shall be tested as follows:

i) Place the *Container* in a horizontal position approximately 100 mm above a uniform fire source with a length of 1.65 m. The arrangement of the fire shall be recorded in sufficient detail to ensure the rate of heat input to the *Container* is reproducible. Any failure or inconsistency of the fire source during a test shall invalidate the result,
ii) If the *Container* is ≤ 1.65 m, it shall be positioned centrically above the fire source,
iii) If the *Container* is > 1.65 m and it is fitted with a *Pressure Relief Device* at only one end, the fire source shall commence at the opposite end,
iv) If the *Container* is > 1.65 m and it is fitted with *Pressure Relief Devices* at more than one location along its length, the centre of the fire source shall be centred midway between those *Pressure Relief Devices* that are separated by the greatest horizontal distance,
v) If the *Container* is > 1.65 m and it is additionally protected by thermal insulation, 2 fire tests shall be performed at *Working Pressure*. The *Container* shall be positioned centrically above the fire source in one test, while the fire shall commence at one of the *Container* ends in the other,
vi) Metallic shielding shall be used to prevent direct flame impingement on *Container* valves, *Fittings*, or *Pressure Relief Devices*. The metallic shielding shall not be in direct contact with the *Pressure Relief Devices*. Any failure during the test of a valve, *Fitting* or tubing that is not part of the intended protection system for the design shall invalidate the result,
vii) Surface temperatures shall be monitored by at least three thermocouples located along the bottom of the *Container* and spaced not more than 0.75 m apart. Metallic shielding shall be used to prevent direct flame impingement on the thermocouples. Alternatively, thermocouples may be inserted into blocks of metal measuring less than 25 mm x 25 mm x 25 mm,
viii) The fire source shall provide direct flame impingement on the *Container* surface across its entire diameter immediately following ignition,
ix) Thermocouple temperatures and the *Container* pressure shall be recorded at intervals of ≤ 10 seconds during the test,

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

If a thermally activated *Pressure Relief Device* is not used an additional test shall be performed with a *Container* at an initial pressure of 50bar at 15^0C.

B19.3 Requirement

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

B19.4 Results

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

i) The elapsed time from ignition of the fire to the start of venting through the *Pressure Relief Device(s),*
ii) The maximum pressure and time of evacuation until a pressure ≤ 1.0 MPa is reached.

B20 PENETRATION TEST

B20.1 Sampling

The test applies to all *Container* Types.
Number of *Finished Containers* to be tested: 1.

B20.2 Procedure

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

i) Pressurise with compressed gas to *Working Pressure* ± 1.0 MPa,
ii) Penetrate at least one sidewall of the *Container* by an armour piercing bullet with a diameter of 7.62 mm or greater. The projectile shall impact the sidewall at an approximate angle of 45°.

B20.3 Requirement

The *Container* shall show no evidence of fragmentation failure. Small pieces of material may be lost provided that each piece weighs less than 45 grams.

B20.4 Results

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

B21 COMPOSITE FLAW TOLERANCE TEST

B21.1 Sampling

The test applies to *Container* Types 2, 3 and 4.
Number of *Finished Containers* to be tested: 1.

B21.2 Procedure

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

i) Flaws in the longitudinal direction shall be cut into the composite *Over-wrap*. The flaws shall be greater than the visual inspection limits as specified by the *Manufacturer*,

ii) Pressure cycle the flawed *Container* between ≤ 2.0 MPa and ≥ 1.25 times *Working Pressure* at ambient temperature for the number of pressure cycles calculated in accordance with Paragraph 2.4.7 of this Regulation.

B21.3 Requirement

The *Container* shall not leak or rupture within the number of filling cycles calculated in accordance with Paragraph 2.4.7 of this Regulation, but may fail by leakage during the remaining test cycles.

B21.4 Results

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

B22 HIGH TEMPERATURE CREEP TEST

B22.1 Sampling

The test applies to *Container* Types 2, 3 and 4, except as indicated in Note *[1] below. Number of *Finished Containers* to be tested: 1.

Note *[1] - The test is not required for *Container* Types 2 and 3 if the glass transition temperature of the resin matrix is greater than or equal to the maximum material temperature given in Paragraph 2.4.6 of this Regulation plus 20 °C.

B22.2 Procedure

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

i) Pressurise to 1.25 times *Working Pressure* at 95 °C for ≥ 1000 hours,

ii) Hydrostatic Test in accordance with Paragraph B15 of this Annex,

iii) Leak Test in accordance with Paragraph B14 of this Annex (*Container* Type 4 only),

iv) Burst Test in accordance with Paragraph B16 of this Annex.

B22.3 Requirement

The *Container* shall meet the hydrostatic, leak and burst test requirements.

B22.4 Results

The hydrostatic, leak and burst test results shall be presented in a test certificate, e.g. Table 7A.4 of this Annex.

B23 ACCELERATED STRESS RUPTURE TEST

B23.1 Sampling

The test applies to *Container* Types 2, 3 and 4.
Number of *Finished Containers* to be tested: 1.

B23.2 Procedure

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

i) Expose the *Container* to a relative humidity ≥ 95% at 85 °C for the full test period,
ii) Pressurise to 1.25 times *Working Pressure* for 1000 hours,
iii) Burst Test in accordance with Paragraph B16 of this Annex.

B23.3 Requirement

The *Container* shall achieve a *Burst Pressure* of ≥ 85% of the *Working Pressure* times the *Burst Pressure* ratio given in Paragraph A3.3 of this Annex.

B23.4 Results

The *Burst Pressure* shall be presented in a test certificate, e.g. Table 7A.4 of this Annex.

B24 IMPACT DAMAGE TEST

B24.1 Sampling

The test applies to *Container* Types 2, 3 and 4.
Number of *Finished Containers* to be tested: Minimum 1 (All drop tests may be performed on the same *Container*).

B24.2 Procedure

The drop tests shall be performed at ambient temperature without internal pressurisation or attached valves.

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

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

i) Drop twice from a horizontal position with the bottom 1.8 m above the ground,
ii) Drop twice onto one end from a vertical position with a potential energy ≥ 488 J, but in no case shall the bottom be more than 1.8 m above the ground,
iii) Drop twice onto the other end from a vertical position with a potential energy ≥ 488 J, but in no case shall the bottom be more than 1.8 m above the ground,
iv) Drop twice onto the same dome position at a 45° angle, with its centre of gravity 1.8 m above the ground. However, if the bottom is closer to the ground

than 0.6 m, the drop angle shall be changed to maintain a minimum height of 0.6 m and the centre of gravity 1.8 m above the ground.

v) Pressure cycle between ≤ 2.0 MPa and ≥ 1.25 times *Working Pressure* for the number of pressure cycles calculated in accordance with Paragraph 2.4.7 of this Regulation.

B24.3 Requirement

The *Container* shall not leak or rupture within the number of filling cycles calculated in accordance with Paragraph 2.4.7 of this Regulation, but may fail by leakage during the remaining test cycles.

B24.4 Results

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

B25 PERMEATION TEST

B25.1 Sampling

The test applies to *Container* Type 4.
Number of *Finished Containers* to be tested: 1.

B25.2 Procedure

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

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

i) Pressurise with hydrogen gas to *Working Pressure*,

ii) Place in an enclosed sealed chamber at ambient temperature and monitor for leakage for ≥ 500 hours.

B25.3 Requirement

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

B25.4 Results

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

B26 BOSS TORQUE TEST

B26.1 Sampling

The test applies to *Container* Type 4.
Number of *Finished Containers* to be tested for type approval: 1.
Number of *Containers* to be tested per *Batch*: In accordance with Paragraph A5.1 of this Annex.

B26.2 Procedure

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

i) Restrain the body of the *Container* against rotation,
ii) Apply a torque of 2 times the valve or *Pressure Relief Device* installation torque specified by the *Manufacturer* to each end boss of the *Container*; first in the direction to tighten the threaded connection, then in the direction to loosen, and finally again in the direction to tighten,
iii) Leak Test in accordance with Paragraph B14 of this Annex,
iv) Burst Test in accordance with Paragraph B16 of this Annex.

B26.3 Requirement

The *Container* shall meet the leak and burst test requirements.

B26.4 Results

The applied torque, leakage and *Burst Pressure* shall be presented in a test certificate, e.g. Table 7A.4 of this Annex.

The *Manufacturer* shall keep the results on file throughout the *Service Life* of the *Container*.

B27 HYDROGEN GAS CYCLING TEST

B27.1 Sampling

The test applies to *Container* Type 4.
Number of *Finished Containers* to be tested: 1.

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

B27.2 Procedure

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

i) Use hydrogen gas to pressure cycle the *Container* between ≤ 2.0 MPa and ≥ 1.25 times *Working Pressure* for 1000 cycles at a rate not less than 1 cycle of filling and venting per hour,
ii) Leak test in accordance with Paragraph B14 of this Annex,
iii) Section the *Container* and inspect the *Liner*/end boss interface for evidence of any deterioration, such as fatigue cracking or electrostatic discharge.

B27.3 Requirement

The *Container* shall meet the leak test requirements.

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

B27.4 Results

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

Annex 8

REQUIREMENTS FOR SPECIFIC COMPONENTS OTHER THAN HYDROGEN CONTAINERS

Annex 8A

PROVISIONS REGARDING THE APPROVAL OF PRESSURE RELIEF DEVICES

1. Applicable test procedures:

Material hydrogen compatibility	Annex 9
Material temperature compatibility	Annex 9
Pressure test	Annex 9
External leakage test	Annex 9
Seat leakage test	Annex 9
Endurance test (applicable to pressure triggered devices only)	Annex 9 (100 operation cycles)
Corrosion resistance	Annex 9 *[1] *[3]
Pressure cycle test	Annex 9
Temperature cycle test	Annex 9 *[2]

2. Further Requirements For *Pressure Relief Devices* (Temperature Triggered)

2.1 *Pressure Relief Devices* (Temperature Triggered) specified by the *Manufacturer* shall be shown to be compatible with the service conditions listed in Paragraph 2.4 of this Regulation and through the following qualification tests:

2.1.1 One specimen shall be held at a controlled temperature of not less than 95°C and a pressure not less than 1.5 times *Working Pressure* for 120 hours.

At the end of this test there shall be no leakage or visible sign of extrusion of any fusible metal used in the design.

2.1.2 One specimen shall be fatigue tested at a pressure cycling rate not to exceed 4 cycles per minute as follows:

i) Held at 85 °C while pressurised for 1.5 times the number of filling cycles calculated in accordance with Paragraph 2.4.7 of this Regulation between 2.0 MPa and 1.25 times *Working Pressure*.

ii) Held at - 40 °C while pressure for 1.5 times the number of filling cycles calculated in accordance with Paragraph 2.4.7 of this Regulation between 2.0 MPa and *Working Pressure*.

At the end of this test there shall be no leakage, or any visible sign of extrusion of any fusible metal used in the design.

2.1.3 Exposed brass pressure retaining components of *Pressure Relief Devices* shall withstand, without stress corrosion cracking, a mercurous nitrate test as described in ASTM B154-01 Standard Test Method for Mercurous Nitrate Test for Copper and Copper Alloys. The *Pressure Relief Device* shall be immersed for 30 minutes in an aqueous mercurous nitrate solution containing 10 g of mercurous

nitrate and 10 ml of nitric acid per litre of solution. Following the immersion, the *Pressure Relief Device* shall be leak tested with hydrogen, helium or a gas mixture containing at least 5% hydrogen or 10% helium, by applying a pressure of 1.25 times *Working Pressure* for one minute during which time the component shall be checked for external leakage.

Any leakage shall not exceed 10 Ncm^3/hr.

2.2 Exposed stainless steel pressure retaining components of *Pressure Relief Devices* shall be made of an alloy type resistant to chloride induced stress corrosion cracking.

Notes:

*[1] only for metallic parts

*[2] only for non-metallic parts

*[3] only for equipment outside of the gas tight housing.

Annex 8B

PROVISIONS REGARDING THE APPROVAL OF HYDROGEN VALVES

Applicable test procedures:

Material hydrogen compatibility	Annex 9
Material temperature compatibility	Annex 9
Pressure test	Annex 9
External leakage test	Annex 9
Seat leakage test	Annex 9
Endurance test	Annex 9 Manual: 100 operation cycles unless located at the *Receptacle* when the number of operation cycles shall be equal to the number of pressure cycles calculated in accordance with Paragraph 2.4.7 of this Regulation. Automatic: The number of operation cycles shall be equal to four times the number of filling cycles calculated in accordance with Paragraph 2.4.7 of this Regulation.
Corrosion resistance	Annex 9 *[1] *[3]
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 *[2]
Pressure cycle test	Annex 9
Temperature cycle test	Annex 9 *[2]

Notes:

*[1] only for metallic parts

*[2] only for non-metallic part

*[3] only for equipment outside of the gas tight housing.

Annex 8C

PROVISIONS REGARDING THE APPROVAL OF HEAT EXCHANGERS

Applicable test procedures:

Material hydrogen compatibility	Annex 9
Material temperature compatibility	Annex 9
Pressure test	Annex 9
External leakage test	Annex 9
Corrosion resistance	Annex 9 *[1]
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 *[2]
Pressure cycle test	Annex 9
Temperature cycle test	Annex 9 *[2]

Notes:

*[1] only for metallic parts

*[2] only for non-metallic part

Annex 8D

PROVISIONS REGARDING THE APPROVAL OF RECEPTACLES

Applicable test procedures:

Material hydrogen compatibility	Annex 9
Material temperature compatibility	Annex 9
Pressure test	Annex 9
External leakage test	Annex 9
Seat leakage test	Annex 9
Endurance test	Annex 9 The number of operation cycles shall be equal to four times the number of filling cycles calculated in accordance with Paragraph 2.4.7 of this Regulation.
Corrosion resistance	Annex 9 *[1]
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 *[2]
Pressure cycle test	Annex 9
Temperature cycle test	Annex 9 *[2]

Notes:

*[1] only for metallic parts

*[2] only for non-metallic part

Annex 8E

PROVISIONS REGARDING THE APPROVAL OF PRESSURE REGULATORS

Applicable test procedures:

Material hydrogen compatibility	Annex 9
Material temperature compatibility	Annex 9
Pressure test	Annex 9
External leakage test	Annex 9
Seat leakage test	Annex 9
Endurance test	Annex 9 The number of operation cycles shall be equal to four times the number of filling cycles calculated in accordance with Paragraph 2.4.7 of this Regulation.
Corrosion resistance	Annex 9 *1 *3
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 *2
Pressure cycle test	Annex 9
Temperature cycle test	Annex 9 *2

Notes:

*1 only for metallic parts

*2 only for non-metallic parts

*3 only for equipment outside of the gas tight housing.

Annex 8F

PROVISIONS REGARDING THE APPROVAL OF SENSORS FOR HYDROGEN SYSTEMS

1. Applicable test procedures for every sensor except *Hydrogen Sensors*:

Pressure test	Annex 9
External leakage test	Annex 9
Corrosion resistance	Annex 9 *1 *3
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 *2
Pressure cycle test	Annex 9
Temperature cycle test	Annex 9 *2

2. Additional test procedure for pressure sensors only

Pressure cycle test	Annex 9

3. *Hydrogen Sensors* shall be designed and type approved in accordance with:

EN 50054:1999 Electrical apparatus for the detection and measurement of combustible gases. General requirements and test methods,

EN 50057:1999 Electrical apparatus for the detection and measurement of combustible gases. Performance requirements for Group II apparatus indicating up to 100% lower explosive limit,

EN 50058:1999 Electrical apparatus for the detection and measurement of combustible gases. Performance requirements for Group II apparatus indicating up to 100% (V/V) gas.

Notes:

*1 only for metallic parts

*2 only for non-metallic parts

*3 only for equipment outside of the gas tight housing.

Annex 8G

PROVISIONS REGARDING THE APPROVAL OF FLEXIBLE FUEL LINES

1 GENERAL

1.1 Applicable test procedures for all *Flexible Fuel Lines*:

Material hydrogen compatibility	Annex 9
Corrosion resistance	Annex 9 *1 *3
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 *2
Temperature cycle test	Annex 9 *2

Notes:

*1 only for metallic parts

*2 only for non-metallic parts

*3 only for equipment outside of the gas tight housing.

1.2 Specific requirements related to the pressure classification of the *Flexible Fuel Lines* are given in the following paragraphs.

2 CLASS 0 - HIGH PRESSURE FLEXIBLE FUEL LINES

2.1 General Specifications

The inside diameter shall be in compliance with Table 1 of ISO 1307: 1992 Rubber And Plastic Hoses For General purpose Industrial Applications - Bore Diameters And Tolerances, And Tolerances On Length.

2.2 *Flexible Fuel Line* Construction

2.2.1 The *Flexible Fuel Line* shall include integral couplings.

2.2.2 Any reinforcing interlayer(s) shall be protected by a cover against corrosion, unless corrosion-resistant-material, i.e. stainless-steel is used for the reinforcing interlayer(s).

2.2.3 Any cover shall be intentionally perforated to avoid the formation of bubbles between the layers, however, it shall otherwise be free from pores, holes, etc.

2.3 Specifications And Tests For The Lining

2.3.1 Tensile Strength And Elongation

Tensile strength and elongation at break shall be in accordance with ISO 37: 1994 Rubber, vulcanised Or Thermoplastic - Determination Of Tensile Stress-strain Properties. The tensile strength shall be not less than 20 MPa and elongation at break not less than 250 per cent.

2.3.2 Resistance to ageing shall be in accordance with ISO 188: 1998 Rubber, Vulcanised Or Thermoplastic - Accelerated Ageing And Heat Resistance Tests with the following conditions:

i) Temperature: 75°C (test temperature = maximum material temperature - 10°C)
ii) Exposure period: 168 hours

Requirements:

a) Maximum change in tensile strength 25 per cent
b) Maximum change in elongation at break -30 per cent and +10 per cent

2.4 Specifications And Tests For The Cover

2.4.1 Tensile strength and elongation at break shall be in accordance with ISO 37: 1994 Rubber, vulcanised Or Thermoplastic - Determination Of Tensile Stress-strain Properties. The tensile strength shall be not less than 10 MPa and elongation at break not less than 250 per cent.

2.4.2 Resistance to ageing shall be in accordance with ISO 188: 1998 Rubber, Vulcanised Or Thermoplastic - Accelerated Ageing And Heat Resistance Tests with the following conditions:

i) Temperature: 75°C (test temperature = maximum material temperature - 10°C)
ii) Exposure period: 336 hours

Requirements:

a) Maximum change in tensile strength 25 per cent
b) Maximum change in elongation at break -30 per cent and +10 per cent

2.5 Specifications For *Flexible Fuel Line*

2.5.1 Gas-tightness (Permeability)

2.5.1.1 One finished *Flexible Fuel Line* shall be filled with hydrogen, helium or a gas mixture containing at least 5% hydrogen or 10% helium to *Working Pressure*, placed in an enclosed sealed chamber at ambient temperature, and monitored for leakage for a time sufficient to establish a steady state permeation rate.

2.5.1.2 The leakage through the wall of the *Flexible Fuel Line* shall not exceed 25 Ncm^3 of helium or hydrogen per metre of *Flexible Fuel Line* per 24 hours.

2.5.2 Resistance At Low Temperature

2.5.2.1 The test shall be carried out in compliance with the method described in ISO 4672: 1997 Rubber And Plastic Hoses - Sub-ambient Temperature Flexibility Tests, method B.

2.5.2.2 The test temperature shall be the appropriate minimum temperature from Paragraph 2.4.6 of this Regulation ± 3°C.

2.5.2.3 The test piece shall not crack or rupture.

2.5.3 Bending test

2.5.3.1 An empty *Flexible Fuel Line*, with a length of approximately 3.5 m must be able to withstand 3,000 times the following bending-test without breaking. After the test the *Flexible Fuel Line* must be capable of withstanding the test pressure stated in Paragraph 2.5.4.2 of this Annex

2.5.3.2 Bending radius and distance between bending centres shall be as follows:

Inside Diameter of *Flexible Fuel Line* (mm)	Bending Radius (mm)	Distance Between Centres	
		Vertical mm	Horizontal mm
Up to 13	102	241	102
13 to 16	153	356	153
From 16 to 20	178	419	178

2.5.3.3 The testing-machine shall consist of a rigid frame, provided with two wheels, with a rim-width of 130 mm.

The radius of the wheels, measured to the bottom of the groove, shall be as indicated in Paragraph 2.5.3.2 of this Annex. The circumference of the wheels shall be grooved for the guidance of the *Flexible Fuel Line*.

The longitudinal median planes of both wheels shall be in the same vertical plane and the distance between the wheel-centres shall be in accordance with Paragraph 2.5.3.2 of this Annex.

Each wheel shall be able to rotate freely round its pivot-centre.

A propulsion-mechanism shall pull the *Flexible Fuel Line* over the wheels at a speed of four complete motions per minute.

The *Flexible Fuel Line* shall be installed in an S-shape over the wheels. The end that runs over the upper wheel shall be tightened against the wheels. The part that runs over the lower wheel is attached to the propulsion-mechanism.

The mechanism shall be adjusted, so that the *Flexible Fuel Line* travels a total distance of 1.2 m in both directions.

2.5.4 Hydraulic Test Pressure And Minimum *Burst Pressure*

2.5.4.1 The test shall be carried out in compliance with the method described in ISO 1402: 1994 Rubber And Plastic Hoses And Hose Assemblies - Hydrostatic Testing.

2.5.4.2 The test pressure shall be 1.50 x *Working Pressure* and shall be applied for a period of 10 minutes without any leakage.

2.5.4.3 The *Burst Pressure* shall not be less than 2.25 x *Working Pressure*.

2.6 Couplings

The couplings shall be in accordance with Annex 8H to this Regulation.

2.7 Assembly Of *Flexible Fuel Line* And Couplings

2.7.1 The construction of the couplings must be such that it is not necessary to peel the cover unless the reinforcement of the *Flexible Fuel Line* consists of corrosion-resistant material.

2.7.2 The *Flexible Fuel Line* assembly shall be subjected to an impulse test in compliance with ISO 1436: 1991 Rubber Hoses And Hose Assemblies - Wire Reinforced Hydraulic Type - Specification with the following requirements:

i) The test shall be completed with circulating oil having a temperature of 93°C, and a minimum pressure of 3.0 MPa.
ii) The *Flexible Fuel Line* shall be subjected to 150,000 impulses.
iii) After the impulse-test the *Flexible Fuel Line* shall withstand the test pressure stated in Paragraph 2.5.4 of this Annex.

2.7.3 Gas-tightness

The *Flexible Fuel Line* assembly (*Flexible Fuel Line* with couplings) shall withstand for a period of five minutes a gas pressure of 1.5 x *Working Pressure* of the *Container* without any leakage.

2.8 Markings

Every *Flexible Fuel Line* shall be marked at intervals of not greater than 0.5 m, with the following clearly legible and indelible identification markings consisting of characters, figures or symbols:

i) Trade name or mark of the *Manufacturer,*
ii) Year and month of fabrication,
iii) Size and pressure rating,
iv) Identification-marking "CGH_2 - Class 0",
v) The marking “DO NOT USE AFTER yyyy/mm” where yyyy/mm is the year and month of approval plus the approved *Service Life* of the *Container*.

3 CLASS 1 - MEDIUM PRESSURE FLEXIBLE FUEL LINES

3.1 General Specifications

The inside diameter shall be in compliance with Table 1 of ISO 1307: 1992 Rubber And Plastic Hoses For General purpose Industrial Applications - Bore Diameters And Tolerances, And Tolerances On Length.

3.2 *Flexible Fuel Line* Construction

3.2.1 The *Flexible Fuel Line* shall include integral couplings.

3.2.2 Any reinforcing interlayer(s) shall be protected by a cover against corrosion, unless corrosion-resistant-material, i.e. stainless-steel is used for the reinforcing interlayer(s).

3.2.3 Any cover may be intentionally perforated to avoid the formation of bubbles between the layers, however, it shall otherwise be free from pores, holes etc.

3.3 Specifications And Tests For The Lining

3.3.1 Tensile Strength And Elongation

Tensile strength and elongation at break shall be in accordance with ISO 37: 1994 Rubber, vulcanised Or Thermoplastic - Determination Of Tensile Stress-strain Properties. The tensile strength shall be not less than 10 MPa and elongation at break not less than 250 per cent.

3.3.2 Resistance to ageing shall be in accordance with ISO 188: 1998 Rubber, Vulcanised Or Thermoplastic - Accelerated Ageing And Heat Resistance Tests with the following conditions:

i) Temperature: 110°C (test temperature = maximum material temperature - 10°C)
ii) Exposure period: 168 hours

Requirements:

a) Maximum change in tensile strength 25 per cent
b) Maximum change in elongation at break -30 per cent and +10 per cent

3.4 Specifications And Tests For The Cover

3.4.1 Tensile strength and elongation at break shall be in accordance with ISO 37: 1994 Rubber, vulcanised Or Thermoplastic - Determination Of Tensile Stress-strain Properties. Tensile strength not less than 10 MPa and elongation at break not less than 250 per cent.

3.4.2 Resistance to ageing shall be in accordance with ISO 188: 1998 Rubber, Vulcanised Or Thermoplastic - Accelerated Ageing And Heat Resistance Tests with the following conditions:

i) Temperature: 110°C (test temperature = maximum material temperature - 10°C)
ii) Exposure period: 336 hours

Requirements:

a) Maximum change in tensile strength 25 per cent
b) Maximum change in elongation at break -30 per cent and +10 per cent

3.5 Specifications For *Flexible Fuel Line*

3.5.1 Gas-tightness (Permeability)

3.5.1.1 One finished *Flexible Fuel Line* shall be filled with hydrogen, helium or a gas mixture containing at least 5% hydrogen or 10% helium to *Working Pressure*, placed in an enclosed sealed chamber at ambient temperature, and monitored for leakage for a time sufficient to establish a steady state permeation rate.

3.5.1.2 The leakage through the wall of the *Flexible Fuel Line* shall not exceed 25 Ncm^3 of helium or hydrogen per metre of *Flexible Fuel Line* per 24 hours.

3.5.2 Resistance At Low Temperature

3.5.2.1 The test shall be carried out in compliance with the method described in ISO 4672: 1997 Rubber And Plastic Hoses - Sub-ambient Temperature Flexibility Tests method B.

3.5.2.2 The test-temperature shall be the appropriate minimum temperature from Paragraph 2.4.6 of this Regulation ± 3°C.

3.5.2.3 The test piece shall not crack or rupture.

3.5.3 Bending test

3.5.3.1 An empty *Flexible Fuel Line*, with a length of approximately 3.5 m must be able to withstand 3,000 times the following bending-test without breaking. After the test the *Flexible Fuel Line* must be capable of withstanding the test pressure stated in Paragraph 3.5.4.2 of this Annex

3.5.3.2 Bending radius and distance between bending centres shall be as follows:

Inside Diameter of *Flexible Fuel Line* (mm)	Bending Radius (mm)	Distance Between Centres	
		Vertical mm	Horizontal mm
Up to 13	102	241	102
13 to 16	153	356	153
From 16 to 20	178	419	178

3.5.3.3 The testing-machine shall consist of a rigid frame, provided with two wheels, with a rim-width of 130 mm.

The radius of the wheels, measured to the bottom of the groove, shall be as indicated in Paragraph 3.5.3.2 of this Annex. The circumference of the wheels shall be grooved for the guidance of the *Flexible Fuel Line*.

The longitudinal median planes of both wheels shall be in the same vertical plane and the distance between the wheel-centres shall be in accordance with Paragraph 3.5.3.2 of this Annex.

Each wheel shall be able to rotate freely round its pivot-centre.

A propulsion-mechanism shall pull the *Flexible Fuel Line* over the wheels at a speed of four complete motions per minute.

The *Flexible Fuel Line* shall be installed in an S-shape over the wheels. The end that runs over the upper wheel shall be tightened against the wheels. The part that runs over the lower wheel is attached to the propulsion-mechanism.

The mechanism shall be adjusted, so that the *Flexible Fuel Line* travels a total distance of 1.2 m in both directions.

3.5.4 Hydraulic-Test Pressure And Minimum *Burst Pressure*

3.5.4.1 The test shall be carried out in compliance with the method described in ISO 1402: 1994 Rubber And Plastic Hoses And Hose Assemblies - Hydrostatic Testing.

3.5.4.2 The test pressure shall be 1.50 x *Working Pressure* (outlet) of the first upstream *Pressure Regulator*, and shall be applied for a period of 10 minutes without any leakage.

3.5.4.3 The *Burst Pressure* shall not be less than 2.25 x *Working Pressure*.

3.6 Couplings

The couplings shall be in accordance with Annex 8H to this Regulation.

3.7 Assembly Of *Flexible Fuel Line* And Couplings

3.7.1 The construction of the couplings must be such, that it is not necessary to peel the cover unless the reinforcement of the *Flexible Fuel Line* consists of corrosion-resistant material.

3.7.2 The *Flexible Fuel Line* assembly shall be subjected to an impulse test in compliance with ISO 1436: 1991 Rubber Hoses And Hose Assemblies - Wire Reinforced Hydraulic Type - Specification with the following requirements:

i) The test shall be completed with circulating oil having a temperature of 93°C, and a minimum pressure of 3.0 MPa.
ii) The *Flexible Fuel Line* shall be subjected to 150,000 impulses.
iii) After the impulse-test the *Flexible Fuel Line* shall withstand the test pressure stated in Paragraph 3.5.4 of this Annex.

3.7.3 Gas-tightness

The *Flexible Fuel Line* assembly (*Flexible Fuel Line* with couplings) shall withstand for a period of five minutes a gas pressure of 1.5 x *Working*

Pressure (outlet) of the first upstream *Pressure Regulator* without any leakage.

3.8 Markings

Every *Flexible Fuel Line* shall be marked at intervals of not greater than 0.5 m, with the following clearly legible and indelible identification markings consisting of characters, figures or symbols:

i) Trade name or mark of the *Manufacturer,*
ii) Year and month of fabrication,
iii) Size and pressure rating,
iv) Identification marking "CGH_2 - Class 1",
v) The marking “DO NOT USE AFTER yyyy/mm” where yyyy/mm is the year and month of approval plus the approved *Service Life* of the *Container*.

4 CLASS 2 - LOW PRESSURE FLEXIBLE FUEL LINES

4.1 General Specifications

The inside diameter shall be in compliance with Table 1 of ISO 1307: 1992 Rubber And Plastic Hoses For General purpose Industrial Applications - Bore Diameters And Tolerances, And Tolerances On Length.

4.2 *Flexible Fuel Line* Construction

If the *Flexible Fuel Line* is constructed from a lining and cover, the cover may be intentionally perforated to avoid the formation of bubbles between the layers, however, it shall otherwise be free from pores, holes etc.

4.3 Specifications And Tests For The Lining

4.3.1 Tensile Strength And Elongation

Tensile strength and elongation at break shall be in accordance with ISO 37: 1994 Rubber, vulcanised Or Thermoplastic - Determination Of Tensile Stress-strain Properties. The tensile strength shall be not less than 10 MPa and elongation at break not less than 250 per cent.

4.3.2

Resistance to ageing shall be in accordance with ISO 188: 1998 Rubber, Vulcanised Or Thermoplastic - Accelerated Ageing And Heat Resistance Tests with the following conditions:

i) Temperature: 120°C (test temperature = maximum material temperature)
ii) Exposure period: 168 hours

Requirements:

a) Maximum change in tensile strength 35 per cent
b) Maximum change in elongation at break -30 per cent and +10 per cent

4.4 Specifications And Tests For The Cover

4.4.1 Tensile strength and elongation at break shall be in accordance with ISO 37: 1994 Rubber, vulcanised Or Thermoplastic - Determination Of Tensile Stress-strain Properties. Tensile strength not less than 10 MPa and elongation at break not less than 250 per cent.

4.4.2 Resistance to ageing shall be in accordance with ISO 188: 1998 Rubber, Vulcanised Or Thermoplastic - Accelerated Ageing And Heat Resistance Tests with the following conditions:
i) Temperature: 120°C (test temperature = maximum material temperature),
ii) Exposure period: 336 hours.

Requirements:
a) Maximum change in tensile strength 25 per cent,
b) Maximum change in elongation at break -30 per cent and +10 per cent.

4.5 Specifications For *Flexible Fuel Line*

4.5.1 Gas-tightness (Permeability)

4.5.1.1 One finished *Flexible Fuel Line* shall be filled with hydrogen, helium or a gas mixture containing at least 5% hydrogen or 10% helium to *Working Pressure*, placed in an enclosed sealed chamber at ambient temperature, and monitored for leakage for a time sufficient to establish a steady state permeation rate.

4.5.1.2 The leakage through the wall of the *Flexible Fuel Line* shall not exceed 25 Ncm^3 of helium or hydrogen per metre of *Flexible Fuel Line* per 24 hours.

4.5.2 Resistance At Low Temperature

4.5.2.1 The test shall be carried out in compliance with the method described in ISO 4672: 1997 Rubber And Plastic Hoses – Sub-ambient Temperature Flexibility Tests method B.

4.5.2.2 The test-temperature shall be the appropriate minimum temperature from Paragraph 2.4.6 of this Regulation ± 3°C.

4.5.2.3 The test piece shall not crack or rupture.

4.5.3 Bending test

4.5.3.1 An empty *Flexible Fuel Line*, with a length of approximately 3.5m must be able to withstand 3,000 times the following bending-test without breaking. After the test the *Flexible Fuel Line* must be capable of withstanding the test pressure stated in Paragraph 4.5.4.2 of this Annex

4.5.3.2 Bending radius and distance between bending centres shall be as follows:

Inside Diameter of *Flexible Fuel Line*	Bending Radius (mm)	Distance Between Centres

(mm)		Vertical mm	Horizontal mm
Up to 13	102	241	102
13 to 16	153	356	153
From 16 to 20	178	419	178

4.5.3.3 The testing-machine shall consist of a rigid frame, provided with two wheels, with a rim-width of 130 mm.

The radius of the wheels, measured to the bottom of the groove, shall be as indicated in Paragraph 4.5.3.2 of this Annex. The circumference of the wheels shall be grooved for the guidance of the *Flexible Fuel Line*.

The longitudinal median planes of both wheels shall be in the same vertical plane and the distance between the wheel-centres shall be in accordance with Paragraph 4.5.3.2 of this Annex.

Each wheel shall be able to rotate freely round its pivot-centre.

A propulsion-mechanism shall pull the *Flexible Fuel Line* over the wheels at a speed of four complete motions per minute.

The *Flexible Fuel Line* shall be installed in an S-shape over the wheels. The end that runs over the upper wheel shall be tightened against the wheels. The part that runs over the lower wheel is attached to the propulsion-mechanism.

The mechanism shall be adjusted, so that the *Flexible Fuel Line* travels a total distance of 1.2 m in both directions.

4.5.4 Hydraulic Test Pressure And Minimum *Burst Pressure*

4.5.4.1 The test shall be carried out in compliance with the method described in ISO 1402: 1994 Rubber And Plastic Hoses And Hose Assemblies – Hydrostatic Testing.

4.5.4.2 The test pressure shall be 1.50 x *Working Pressure* (outlet) of the first upstream *Pressure Regulator*, and shall be applied for a period of 10 minutes without any leakage.

4.5.4.3 The *Burst Pressure* shall not be less than 2.25 x *Working Pressure*.

4.6 Couplings

The couplings shall be in accordance with Annex 8H to this Regulation.

4.7 Assembly Of *Flexible Fuel Line* And Couplings

4.7.1 The construction of the couplings must be such, that it is not necessary to peel the cover unless the reinforcement of the *Flexible Fuel Line* consists of corrosion-resistant material.

4.7.2 The *Flexible Fuel Line* assembly shall be subjected to an impulse test in compliance with ISO 1436: 1991 Rubber Hoses And Hose Assemblies – Wire Reinforced Hydraulic Type – Specification with the following requirements:

i) The test shall be completed with circulating oil having a temperature of 93°C, and a minimum pressure of 3.0 Mpa.
ii) The *Flexible Fuel Line* shall be subjected to 150,000 impulses.
iii) After the impulse-test the *Flexible Fuel Line* shall withstand the test pressure stated in Paragraph 4.5.4 of this Annex.

4.7.3 Gas-tightness

The *Flexible Fuel Line* assembly (*Flexible Fuel Line* with couplings) shall withstand for a period of five minutes a gas pressure of 1.5 x *Working Pressure* (outlet) of the first upstream *Pressure Regulator* without any leakage.

4.8 Markings

Every *Flexible Fuel Line* shall be marked at intervals of not greater than 0.5 m, with the following clearly legible and indelible identification markings consisting of characters, figures or symbols:

i) Trade name or mark of the *Manufacturer,*
ii) Year and month of fabrication,
iii) Size and pressure rating,
iv) Identification marking "CGH_2 – Class 2",
v) The marking "DO NOT USE AFTER yyyy/mm" where yyyy/mm is the year and month of approval plus the approved *Service Life* of the *Container*.

Annex 8H

PROVISIONS REGARDING THE APPROVAL OF FITTINGS

Applicable test procedures:

Material hydrogen compatibility	Annex 9
Pressure test	Annex 9
External leakage test	Annex 9
Corrosion resistance	Annex 9 *[1] *[3]
Resistance to dry-heat	Annex 9
Endurance test	Annex 9 (100 Connection and disconnection cycles)
Pressure cycle test	Annex 9
Temperature cycle test	Annex 9 *[2]
Connection test	Annex 9

Notes:

*[1] only for metallic parts

*[2] only for non-metallic parts

*[3] only for equipment outside of the gas tight housing.

Annex 8I

PROVISIONS REGARDING THE APPROVAL OF EXCESS FLOW SYSTEMS

Applicable test procedures:

Material hydrogen compatibility	Annex 9
Material temperature compatibility	Annex 9
Pressure test	Annex 9
External leakage test	Annex 9
Seat leakage test	Annex 9
Endurance test	Annex 9
	(1000 operation cycles)
Corrosion resistance	Annex 9 *[1] *[3]
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 *[2]
Temperature cycle test	Annex 9 *[2]

Notes:

*[1] only for metallic parts

*[2] only for non-metallic parts

*[3] only for equipment outside of the gas tight housing.

Annex 8J

PROVISIONS REGARDING THE APPROVAL OF HYDROGEN FILTERS

Applicable test procedures:

Material hydrogen compatibility	Annex 9
Material temperature compatibility	Annex 9
Pressure test	Annex 9
External leakage test	Annex 9
Corrosion resistance	Annex 9 *1 *3
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 *2
Pressure cycle test	Annex 9
Temperature cycle test	Annex 9 *2

Notes:

*1 only for metallic parts

*2 only for non-metallic parts

*3 only for equipment outside of the gas tight housing.

Annex 9

APPROVAL TEST PROCEDURES FOR SPECIFIC COMPONENTS OTHER THAN HYDROGEN CONTAINERS

1 CLASSIFICATION

1.1 *Hydrogen Components* for use in vehicles shall be classified with regard to their *Working Pressure* and function, in accordance with Paragraph 2.3 of this Regulation.

1.2 The classification of *Specific Components* determines the tests that have to be performed for approval of the components or parts of the components.

2 APPLICABLE TEST PROCEDURES

Table 9.1 of this Annex states the applicable test procedures that have to be performed for the approval of *Specific Components* according to their pressure classifications as defined by Paragraph 2.3 of this Regulation.

Table 9.1

TEST	Class 0	Class 1	Class 2	Paragraph of this Annex
Pressure	X	X	X	4
External leakage	X	X	X	5
Seat (internal) leakage	A	A	A	6
Endurance (continued operation)	A	A	A	7
Hydrogen compatibility	A	A	A	8
Corrosion resistance	X	X	X	9
Resistance to dry heat	A	A	A	10
Ozone ageing	A	A	A	11
Temperature cycle	A	A	A	12
Pressure cycle	A			13
Vibration resistance	A	A	A	14
Service Temperatures	X	X	X	15
Connection	X	X	X	16

Key:
X Applicable
A If applicable

3 GENERAL REQUIREMENTS

3.1 Leakage tests shall be conducted with hydrogen, helium or a gas mixture containing at least 5% hydrogen or 10% helium.

3.2 Water or another fluid may be used to obtain the required pressure for the hydrostatic strength test.

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

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

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

3.6 The materials used for the components shall have written specifications that fulfill test requirements laid down in this Annex with respect to:

i) Temperature,
ii) Pressure,
iii) Hydrogen compatibility,
iv) Durability.

4 PRESSURE TEST

4.1 A hydrogen containing component previously subjected to the endurance (continued operation) test in Paragraph 7 of this Annex shall withstand a hydraulic pressure test in accordance with Table 9.2 of this Annex. For the test the outlets of the high pressure part shall be plugged. The hydrogen containing component shall not show any visible evidence of rupture or permanent distortion.

Table 9.2

Classification Of Component	Overpressure
Class 0	1.5 x *Working Pressure*
Class 1	1.5 x *Working Pressure*
Class 2	2.0 x *Working Pressure*

4.2 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.

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

5 EXTERNAL LEAKAGE TEST

5.1 The external leakage test shall include external leakage and permeation. 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 below.

5.2 The test shall be performed on the same component at the following conditions:
i) At the minimum required material temperature, in accordance with Paragraph 2.4.6.1 of this Regulation, after 3 hours conditioning at this temperature and at 1, 10 and 100% of *Working Pressure*.
ii) At the maximum required material temperature, in accordance with Paragraph 2.4.6.1 of this Regulation, after 3 hours conditioning at this temperature and at 1, 10 and 125% of *Working Pressure*, except for components with a required material temperature of 120^0C where the higher test pressure shall be 137% of *Working Pressure*.

5.3 During this test, the equipment under test shall be connected to a source of pressure. A positive shut-off valve and a pressure gauge having an upper pressure reading of not less than 1.5 times nor more than 2 times the test pressure shall be installed in the pressure supply piping. The pressure gauge is to be installed between the positive shut-off valve and the sample under test.

5.4 Throughout the test the sample shall be tested for leakage with a surface active agent without formation of bubbles for 3 minutes or measured with a combined leakage and permeation rate less than 10 Ncm^3/hour or tested by using another equivalent test method.

6 SEAT (INTERNAL) LEAKAGE TEST

6.1 The following tests for seat (internal) leakage are to be conducted on samples which have previously been subjected to the external leakage test of Paragraph 5 of this Annex.

6.2 Seat leakage tests shall be conducted with:
i) The inlet of the sample valve connected to a source of pressure,
ii) The valve in the closed position,
iii) The outlet open.

6.3 A positive shut-off valve and a pressure gauge having an upper pressure reading of not less than 1.5 times and not more than twice the test pressure are to be installed in the pressure supply piping. The pressure gauge is to be installed between the positive shut-off valve and the sample under test. While under the applied test pressure, observations for leakage are to be made with the open outlet submerged in water, by a flowmeter installed on the inlet side of the valve under test, the test described in Paragraph 6.7 of this Annex or other equivalent test method. If a flowmeter is used it shall be capable of indicating accurately, for the test fluid being used, the maximum leakage flow rates measured.

6.4 The seat of a shut-off valve shall not leak at a rate exceeding 10 Ncm^3/hour at 1, 10 and 150% of *Working Pressure* when in the closed position.

6.5 A *Non-return Valve* shall not leak at a rate exceeding 10 Ncm^3/hour at 1, 10 and 150% of *Working Pressure* when in the closed position.

6.6 Pressure triggered *Pressure Relief Devices* shall not leak at a rate exceeding 10 cm^3/hour at 1, 10 and 125% of *Working Pressure* when in the closed position, except for components with a required material temperature of 120^0C where the higher test pressure shall be 137% of *Working Pressure*.

6.7 Conformance with Paragraph 6 of this Annex may be determined by connecting a length of tubing to the valve outlet. The open end of this outlet tube is to be located within an inverted graduated cylinder that is calibrated in cubic centimetres. The inverted cylinder is to be closed by a watertight seal. The apparatus is to be adjusted so that:

i) The end of the outlet tube is located approximately 13 mm above the water level within the inverted graduated cylinder,

ii) The water within and exterior to the graduated cylinder is at the same level.

With these adjustments made, the water level within the graduated cylinder is to be recorded. With the valve in the closed position assumed as the result of normal operation, the test gas at the specified test pressure is to be applied to the valve inlet for a test period of not less than 2 minutes. During this time, the vertical position of the graduated cylinder is to be adjusted, if necessary, to maintain the same water level within and exterior to it.

At the end of the test period and with the water within and outside the graduated cylinder at the same level, the level of water within the graduated cylinder is again recorded. From the change of volume within the graduated cylinder, the leakage rate is to be calculated according to the following formula:

$$V_1 = V_t \cdot \frac{60}{t} \cdot \left(\frac{273}{T} \cdot \frac{P}{101.3} \right)$$

Where:

V_1 = leakage rate, cubic centimetres of test gas per hour.

V_t = increase in volume within graduated cylinder during test.

T = time of test, minutes.

P = barometric pressure during test, in kPa.

T = ambient temperature during test, in K.

7 ENDURANCE TEST (CONTINUED OPERATION)

7.1 A hydrogen carrying component shall be capable of conforming to the applicable leakage test requirements of Paragraphs 5 and 6 of this Annex, after being subjected to the number of operation cycles specified for that component in Annex 8 to this Regulation.

7.2 The appropriate tests for external leakage and seat leakage, as described in Paragraphs 5 and 6 of this Annex are to be conducted immediately following the durability tests.

7.3 The component shall be securely connected to a pressurised source of dry air or nitrogen and subjected to the number of cycles specified for that *Specific Component* in Annex 8 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.

7.4 The component shall be operated through the total number of specified cycles at a temperature of 20°C ± 5°C and at the *Working Pressure* of the component. During

the off cycle the downstream pressure of the test fixture should be allowed to decay to 50 per cent of the *Working Pressure* of the component.

7.5 The component shall be operated through 2 per cent of the total cycles at the maximum material temperature (see Paragraph 2.4.6.1 of this Regulation) after 3 hours conditioning at this temperature and at 125% of *Working Pressure*, except for components with a required material temperature of 120^0C where the test pressure shall be 137% of *Working Pressure*. The component shall comply with Paragraph 5 and 6 of this Annex at the appropriate maximum material temperature (see Paragraph 2.4.6.1 of this Regulation) at the completion of the high temperature cycles.

7.6 The component shall be operated through 2 per cent of the total cycles at the minimum material temperature (see Paragraph 2.4.6.1 of this Regulation) after 3 hours conditioning at this temperature and at the *Working Pressure* of the component. The component shall comply with Paragraph 5 and 6 of this Annex at the appropriate minimum material temperature (see Paragraph 2.4.6.1 of this Regulation) at the completion of the low temperature cycles.

7.7 Where appropriate following the durability tests and leakage re-tests specified above, the component shall be capable of completely opening and closing when a torque not greater than that specified in Table 9.3 is applied to the component handle in a direction to open it completely and then in the reverse direction to close it completely.

Table 9.3

Component Inlet Size (mm)	Max. Torque (Nm)
6	1.7
8 or 10	2.3
12	2.8

This test shall be conducted at both the appropriate maximum and minimum material temperatures specified (see Paragraph 2.4.6.1 of this Regulation).

8 HYDROGEN COMPATIBILITY

Hydrogen compatibility testing shall be carried out in accordance with PrEN ISO 11114-4 (??/??) Transportable Gas Cylinders – Compatibility Of Cylinders And Valve Materials With Gas Contents – Part 4: Test Methods For Selecting Metallic Materials Resistant To Hydrogen Embrittlement.

9 CORROSION RESISTANCE

9.1 Metallic hydrogen containing components shall comply with the leakage tests specified in Paragraphs 5 and 6 of this Annex after being submitted to 144 hours salt spray test in accordance with ISO 9227: 1990 Corrosion Tests In Artificial Atmospheres - Salt Spray Tests" with all connections closed.

9.2 A copper or brass hydrogen containing component shall comply with the leakage tests specified in Paragraphs 5 and 6 of this Annex after being submitted to 24 hours immersion in Ammonia in accordance with ISO 6957: 1988 Copper Alloys - Ammonia Test For Stress Corrosion Resistance with all connections closed.

10 RESISTANCE TO DRY-HEAT

10.1 The test shall be undertaken in compliance with ISO 188: 1998 Rubber, Vulcanised Or Thermoplastic - Accelerated Ageing And Heat Resistance Tests. The test piece shall be exposed to air at the maximum material temperature (see Paragraph 2.4.6.1 of this Regulation) for 168 hours.

10.2 The change in tensile strength shall not exceed + 25 per cent.

10.3 The change in ultimate elongation shall not exceed the following values:

Maximum increase	10 per cent
Maximum decrease	30 per cent

11 OZONE AGEING

11.1 The test shall be undertaken in compliance with ISO 1431: 1989 Rubber, Vulcanised Or Thermoplastic - Resistance To Ozone Cracking, Part 1: Static Strain Test. 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 for a period of 120 hours.

11.2 No cracking of the test piece is allowed.

12 TEMPERATURE CYCLE TEST

All non-metallic parts containing hydrogen shall comply with the leakage tests mentioned in Paragraphs 5 and 6 of this Annex after having been submitted to 96 hours temperature cycle from the minimum material temperature at *Working Pressure* up to the maximum material temperature (see Paragraph 2.4.6.1 of this Regulation) with a cycle time of 120 minutes, under 125% of *Working Pressure*, except for components with a required material temperature of 120^0C where the test pressure shall be 137% of *Working Pressure*.

13 PRESSURE CYCLE

13.1 The *Specific Components* to be tested shall be capable of conforming to the applicable leakage test requirements of Paragraph 5 of this Annex after being subjected to the total number of pressure cycles calculated in accordance with Paragraph 2.4.7 of this Regulation. The pressure shall change from atmospheric pressure to 125% of *Working Pressure*, except for components with a required material temperature of 120^0C where the test pressure shall be 137% of *Working Pressure,* within less than five seconds, and after a time of at least five seconds, shall decrease to atmospheric pressure within less than five seconds. The appropriate test for external leakage, as described under external leakage test in Paragraph 5 of this Annex is to be conducted immediately following this test.

13.2 All hydrogen carrying parts of heat exchangers shall be capable of conforming to the applicable leakage test requirements of Paragraph 5 of this Annex after being subjected to the total number of pressure cycles calculated in accordance with Paragraph 2.4.7 of this Regulation. The pressure shall change from atmospheric pressure to 125% of *Working Pressure*, except for components with a required material temperature of 120^0C where the test pressure shall be 137% of *Working Pressure* of the component, within less than five seconds, and after a time of at least five seconds, shall decrease to atmospheric pressure within less than five seconds. The appropriate test for external leakage, as described under external leakage test in Paragraph 5 of this Annex is to be conducted immediately following this test.

14 VIBRATION RESISTANCE TEST

14.1 All components with moving parts shall remain undamaged, continue to operate, and comply with the applicable leakage test requirements of Paragraph 5 and 6 of this Annex after 6 hours of vibration in accordance with the test method described below.

14.2 The component shall be secured in an apparatus and vibrated for 2 hours at 17 Hz with an amplitude of 1.5 mm in each of three orientation axes.

15 SERVICE TEMPERATURES

The component shall remain fully functional within the appropriate temperature ranges specified in Paragraph 2.4.6 of this Regulation

16 CONNECTION TEST

All *Fittings* shall comply with the applicable leakage test requirements of Paragraph 5 of this Annex, after being subjected to 25 cycles of connection and disconnection.

Annex 10

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

1 GENERAL

This Annex defines the special requirements for documentation, verification and test with respect to the safety aspects of *Complex Electronic Vehicle Control Systems* (defined in Paragraph 2 of this Annex) as far as this Regulation is concerned.

2 DEFINITIONS

For the purposes of this Annex the definitions of Paragraph 2.1 of this regulation shall apply.

3 DOCUMENTATION

3.1 Requirements

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

Documentation shall be made available in 2 parts:

i) The formal documentation package for the approval, containing the material listed in Paragraphs 3.2 to 3.4 of this Annex, which shall be supplied to the Technical Service at the time of submission of the type approval application. This will be taken as the basic reference for the Verification Process set out in Paragraph 4 of this Annex.

ii) Additional material and analysis data which shall be retained by the vehicle 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 including:

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

ii) A list of all output variables that are controlled by "The System" shall be provided and an indication given, in each case, of whether the control is

direct or via another vehicle system. The *Range of Control* exercised on each such variable shall be defined.

iii) Limits defining the *Boundary of Functional Operation* 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 that are needed to achieve the control function in question. An outline schematic showing these *Units* in combination, shall be provided with both the equipment distribution and the interconnections clearly identified.

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 Links* and by a simplified diagrammatic layout for mechanical *Transmission Links*.

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

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

3.4 *Safety Concept* Of The Vehicle Manufacturer

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

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:

i) Fall-back to operation using a partial system,
ii) Change-over to a separate back-up system,
iii) Removal of the High Level Function.

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

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 shall be established and maintained by the vehicle manufacturer and shall be made open for inspection by the Technical Service at the time of the Type Approval.

3.4.5 The documentation shall itemise the parameters being monitored and shall set out, for each fault condition of the type defined in Paragraph 3.4.3 of this Annex, the warning signal to be given to the driver 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 of this Annex 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 of this Annex

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*.

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

4.2 The warning signal specified in Paragraph 3.4.3 of this Annex may, in general, be satisfied by one optical signal per complex vehicle system unless any other Regulation applicable to the same equipment specifically requires multiple signals.