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. Annex 7 of this proposal is based on a draft ISO standard and is excessively design orientated for use in a regulation. The annex is to be redrafted to define the appropriate performance requirements necessary for the type approval of compressed gaseous hydrogen containers. The initial draft of the new Annex 7 will be available in March 2002. The existing Annex 7 contains some modifications to the version found in Revision 7. Annex 7 is indicated by red text.
2. 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 1 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 2 of this Regulation).

2 DEFINITIONS, CONTAINER TYPES, PRESSURE CLASSIFICATIONS AND SERVICE CONDITIONS

2.1 DEFINITIONS

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

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

2.1.2 "*Automatic Valve*": A valve which 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-wrap is established.

2.1.5 "*Batch - Composite Containers*": A "batch" shall be a group of *Containers* successively produced from *Liners* having the same size, design, specified materials of construction and process of manufacture.

2.1.6 "*Batch - Metal Containers and Liners*": A "batch" shall be a group of metal *Containers* or *Liners* successively produced having the same nominal diameter, wall thickness, design, specified material of construction, process of manufacture, equipment for manufacture and heat treatment, and conditions of time, temperature and atmosphere during heat treatment.

2.1.7 "*Batch - Non-metallic Liners*": A "batch" shall be a group of non-metallic *Liners* successively produced having the same nominal diameter, wall thickness, design, specified material of construction and process of manufacture.

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

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

2.1.10 "*CGH_2*": Compressed gaseous hydrogen.

2.1.11 "*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 which is over-ridden becomes part of the complex system.

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

2.1.13 "*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*.

2.1.14 "*Controlled Tension Winding*": A process used in manufacturing *Composite Containers* with metal *Liners* by which compressive stresses in the *Liner* and tensile stresses in the *Over-wrap* at zero internal pressure are obtained by winding the reinforcing filaments under significant high tension.

2.1.15 "*Design Pressure*": The gas pressure at a uniform gas temperature of 85°C that a component is subjected to. The *Design Pressure* is equal to the *Working Pressure* multiplied by 1.25.

2.1.16 "*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.

2.1.17 "*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.

2.1.18 "*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.

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

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

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

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

2.1.23 "*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.

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

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

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

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

2.1.28 "*Hydrogen System*": An assembly of *Hydrogen Components* and connecting parts fitted on motor vehicles using hydrogen, excluding *the Hydrogen Conversion System(s)*. The boundary between the *Hydrogen System* and the *Hydrogen Conversion System(s)* 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.

2.1.29 "*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.

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

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

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

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

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

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

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

2.1.37 "*Pressure Relief Device*": A device that prevents a pre-determined pressure from being exceeded by relieving the pressure.

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

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

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

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

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

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

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

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

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

2.1.47 "*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.

2.1.48 "*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.

2.1.49 "*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.

2.1.50 "*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*.

2.1.51 "*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 will 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 Hydrogen Fuel Specification standard* ISO/FDIS 14687:1999 "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 of this Regulation.

The number of filling cycles for the *Hydrogen Components* approved in accordance with this Regulation and its Annexes shall be at least 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 minimum 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 of 3.

Calculation example:

Minimum 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 of 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 *Specific Component* shall be provided if not otherwise stated in the Annexes to this Regulation. Supplementary samples shall be supplied upon request.

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

4 MARKINGS

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

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

4.3 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 Type 1 and 2 designs, 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 they are not obscured by mounting brackets. 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 and maximum filling mass of Hydrogen (kg),
v) The internal volume in litres,
vi) Empty weight (kg),
vii) Year and month of approval, e.g. 2000/01,
viii) Approval mark in accordance with Paragraph 5.4 of this Regulation,
ix) When labels are used, the unique serial number referred to in ii) above shall be stamped on an exposed surface,
x) The marking "DO NOT USE AFTER yyyy/mm" where yyyy/mm is the year and month of approval plus the approved lifetime of the *Container*,
xi) The marking "Number of filling cycles xxxxx" where xxxxx is the number of filling cycles from Section 2.4.7 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 Paragraphs 4.1 and 4.3 of 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 which 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). This approval number consists of the *Specific Component* type approval number which 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 the 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 Unless indicated otherwise the following *Design Pressures* shall be used for all *Hydrogen Components* other than the *Container(s)*:

i) The *Hydrogen System* upstream of the first or only *Pressure Regulator* shall have a *Design Pressure* equal to at least the *Design Pressure* of the *Container*.

ii) The *Hydrogen System* downstream of a *Pressure Regulator* has a *Design Pressure* derived from the *Working Pressure* of that section of the *Hydrogen System,* unless the gas pressure never exceeds *Working Pressur*e regardless of gas temperature.

6.1.6 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.

6.1.7 *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.

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

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

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

6.1.10 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.

6.1.11 *Rigid Fuel Lines* shall be designed for a *Burst Pressure* of at least 3 times *Design 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 *Design Pressure* without rupturing.

6.1.12 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 *Design Pressure* or alternatively tested to a pressure of at least 3 times *Design Pressure* without rupturing.

6.2 PROVISIONS REGARDING HYDROGEN CONTAINERS

Hydrogen *Containers* shall be type approved pursuant to the provisions laid down in Annex 7 to this Regulation.

6.3 PROVISIONS REGARDING PRESSURE RELIEF DEVICES

6.3.1 Pressure Relief Device For The Container

6.3.1.1 The *Pressure Relief Device(s)* shall be temperature triggered only.

6.3.1.2 The *Pressure Relief Device(s)* shall limit the pressure inside the *Container* by opening a temperature fusible plug at 120°C +5°C/-10°C.

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

6.3.1.4 The rating of the *Pressure Relief Device(s)* shall be clearly marked. Tampering with the *Pressure Relief Devices* shall be prevented by means of a lead seal or equivalent system.

6.3.2 Pressure Relief Devices For Other Hydrogen Components

6.3.2.1 The *Pressure Relief Device(s)* shall limit the pressure to the test pressure of the downstream *Hydrogen Components*.

6.3.2.2 The *Pressure Relief Device(s)* shall be type approved pursuant to the provisions laid down in Annex 8A to this Regulation.

6.4 PROVISIONS REGARDING HYDROGEN VALVES

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

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

6.5 PROVISIONS REGARDING HEAT EXCHANGERS

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

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

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

6.6 PROVISIONS REGARDING RECEPTACLES

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

6.7 PROVISIONS REGARDING PRESSURE REGULATORS

The *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 EXCESS FLOW SYSTEMS

Excess Flow Systems shall be type approved pursuant to the provisions laid down in Annex 8I to this Regulation.

6.12 PROVISIONS REGARDING HYDROGEN FILTERS

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

6.13 PROVISIONS REGARDING ELECTRICAL COMPONENTS

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

6.13.2 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.

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

7.1 Every modification of a type of a *Specific Component* shall be notified to the Administrative Department which granted the type approval. The Administrative Department may then either:

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

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

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 which 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

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

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

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

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 which 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 which 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 which 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 13.4.1 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 which has granted approval under this Regulation shall be placed in vertical columns to the right of the symbol prescribed in Paragraph13.4.1 of this Regulation.

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

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

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

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 up to the *Design Pressure* for which it has been designed and type approved. 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 When pressurised to the *Design 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 or measured with a combined leakage and permeation rate less than 100 Ncm^3/hour or other equivalent test method.

14.1.5 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.

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

14.1.7 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.

14.1.8 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.

14.1.9 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.

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

14.1.11 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.

14.1.12 All *Pressure Relief Devices*, other safety components and vent lines shall be protected against casual vandalism so far as reasonably practicable.

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

14.1.14 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.

14.1.15 The *Hydrogen System* downstream of a *Pressure Regulator* shall be protected against overpressure due to the possible failure of the *Pressure Regulator*.

14.1.16 An *Excess Flow System* shall be part of the *Hydrogen System*.

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:

a) +/-20 g in the direction of travel
b) +/-8 g horizontally perpendicular to the direction of travel

Vehicles of categories M2 and N2:

a) +/-10 g in the direction of travel
b) +/-5 g horizontally perpendicular to the direction of travel

Vehicles of categories M3 and N3:

a) +/-6.6 g in the direction of travel
b) +/-5 g horizontally perpendicular to the direction of travel

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

14.2.4 The provision of Paragraph 14.2.3 shall not apply if the vehicle is approved according to 96/79/EC or ECE R 94 and 96/27/EC or ECE R 95.

14.2.5 *Pressure Relief Device(s)* in accordance with Paragraph 6.3.1 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 assures 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*.

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*, 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* 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* 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* (temperature triggered) shall be directly installed into the *Container* opening 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 If a *Container* is greater than 1.65m long a second *Pressure Relief Device* (temperature triggered) shall be fitted at the opposite end of the *Container* to that required in Paragraph 14.3.2.1 of this Regulation.

14.3.2.5 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*.

14.3.2.6 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.

14.3.2.7 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.

14.3.2.8 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* where fitted unless they are protected.

14.3.2.9 *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 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.

14.4.4 *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.

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

14.4.6 *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*.

14.4.7 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 14.7.1 to 14.7.5.

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 casual vandalism, 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 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.

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

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

14.6.7 The interface between the *Hydrogen System* and the refilling infrastructure shall prevent the *Design Pressure* in the Class 0 section of the *Hydrogen System* being exceeded.

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 14.1.4 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.

14.9 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 this Annex. Every *Container* shall be visually inspected at least every 36 months, and at the time of any re-installation, for external damage and deterioration, including under 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 Containers Involved In Fires

Containers which 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:

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

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

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

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

16 CONFORMITY OF PRODUCTION

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

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

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

17 PENALTIES FOR NON-CONFORMITY OF PRODUCTION

17.1 The 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 which 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 which 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(s)*:

1.1 Make(s):

1.2 Type(s):

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(s):*

2.1 Make(s):

2.2 Type(s):

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(s):*

3.1 Make(s):

3.2 Type(s):

3.3 Description:

3.4 Capacity: litres (water)

3.5 Dimensions:

3.6 Material(s):

3.7 *Working Pressure*: MPa

3.8 Drawings of the *Container(s)* and installation in the vehicle:

3.9 Number of filling cycles:

4 *Excess Flow System*:

4.1 Make(s):

4.2 Type(s):

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(s):

5.2 Type(s):

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(s):* yes/no [1/]

6.1 Make(s):

6.2 Type(s):

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(s): yes/no [1/]

7.1 Make(s):

7.2 Type(s):

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(s):* yes/no [1/]

8.1 Make(s):

8.2 Type(s):

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(s):* yes/no [1/]

9.1 Make(s):

9.2 Type(s):

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(s)[1/]: yes/no [1/]

10.1 Make(s):

10.2 Type(s):

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(s):* yes/no [1/]

11.1. Make(s):

11.2 Type(s):

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(s):

12.2 Type(s):

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(s):

13.2 Type(s):

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(s):

14.2 Type(s):

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.

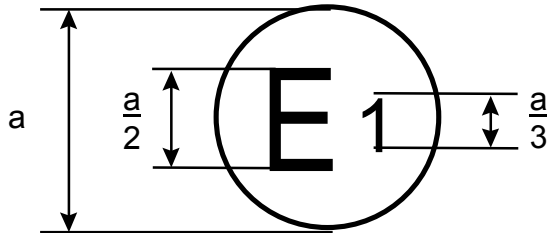
Notes:

[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

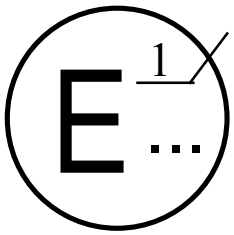
The above approval mark affixed to the *Hydrogen Component* shows that this component has been type approved in Germany (E1), pursuant to the Regulation No. xx under approval number 002439. The first two digits of the approval number indicate that the approval was granted in accordance with the requirements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

_____

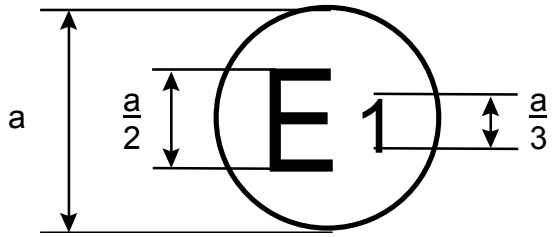
[1/] Distinguishing number of the country which has granted/extended/refused/withdrawn approval (see approval provisions in the Regulation).

[2/] Strike out what does not apply

Annex 5

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

Model A
(See Paragraph 13.4 of this Regulation)

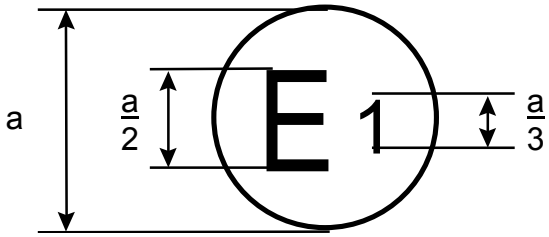


xx R-002439

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

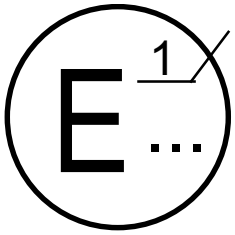
The above approval mark affixed to a vehicle shows that the vehicle has been type approved in Germany (E1), pursuant to the Regulation Nos. xx and 83. The approval numbers indicate that, at the dates when the respective approvals were given, Regulation No. xx was in its original form and Regulation No. 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: 2/

APPROVAL GRANTED

APPROVAL EXTENDED

APPROVAL REFUSED

APPROVAL WITHDRAWN

PRODUCTION DEFINITELY DISCONTINUED

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

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

2/ Strike out what does not apply

Annex 7

REQUIREMENTS AND APPROVAL TEST PROCEDURES FOR CONTAINERS

Contents **Page**

Annexes

1 SCOPE

This Annex specifies minimum requirements for serially produced light-weight refillable compressed gaseous hydrogen *Containers*. The *Containers* are intended only for the on-board storage of high pressure compressed hydrogen gas as a fuel for automotive vehicles to which the *Containers* are to be fixed. The service conditions do not include external loads that may arise from vehicle collisions, or integration of the *Container* into the vehicle, etc. *Containers* may be of any steel, aluminium or non-metallic material, design or method of manufacture suitable for the specified service conditions. *Containers* covered by this Annex are defined in Paragraph 2.2 of this Regulation.

Containers specified in Paragraph 2.2 of this Regulation in 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 this Annex.

2 REFERENCES

The following standards contain provisions which, through reference in this text, constitute provisions of this Annex:

American Society for Testing and Materials (ASTM) Standards

ASTM B117-97	Standard Practice For Operating Salt Spray (Fog) Apparatus
ASTM B154-95	Standard Test Method For Mercurous Nitrate Test for Copper and Copper Alloys
ASTM D522-93a	Standard Test Method For Mandrel Bend Test Of Attached Organic Coatings
ASTM D2344-84(1995)	Standard Test Method For Apparent Interlaminar Shear Strength of Parallel Fibre Composites By Short Beam Method
ASTM D2794-93	Standard Test Method For Resistance of Organic Coatings For The Effects of Rapid Deformation (Impact)
ASTM D3170-87(1996)e1	Standard Test Method For Chipping Resistance Of Coatings
ASTM D3359-99	Standard Test Method For Measuring Adhesion By Tape Test
ASTM D3418-99	Standard Test Method For Transition Temperatures Of Polymers by Differential Scanning Calorimetry
ASTM E399-90(1997)	Standard Test Method For Plain-strain Fracture Toughness Of Metallic Materials
ASTM E647-99	Standard Test Method For Measurement Of Fatigue Crack Growth Rates

ASTM G53-96	Standard Practice for Operating Light and Water Exposure Apparatus (Fluorescent UV-Condensation Type) For Exposure Of Non-metallic Materials

British Standards Institution (BSI) Standards

BS 7448:1 1991	Fracture Mechanics Toughness Tests: Part I - Method For Determination Of K_{IC}, Critical CTOD And Critical J Values Of Metallic Materials (Partially replaced)
BS PD 6493: 1991	Guidance On Methods For Assessing The Acceptability Of Flaws In Fusion Welded Structures

CEN: European Committee For Standards

EN 50054: 1998	Electrical Apparatus For The Detection And Measurement Of Combustible Gases – General Requirements And Test Methods
EN 50057: 1998	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: 1998	Electrical Apparatus For The Detection And Measurement Of Combustible Gases – Performance Requirements For Group II Apparatus Indicating Up To 100% (v/v) Gas

International Organisation for Standardisation (ISO) Standards

ISO 148: 1983	Steel - Charpy Impact Test (V-notch)
ISO 306: 1994	Plastics - Thermoplastic Materials - Determination Of Vicat Softening Temperature
ISO 642: 1999	Steel - Hardenability Test By End Quenching (Jominy Test)
ISO 2808: 1997	Paints And Varnishes - Determination Of Film Thickness
ISO 527: Pt.1: 1993	Plastics - Determination of Tensile Properties
ISO 4624: 1978	Plastics And Varnishes - Pull-off Test For adhesion
ISO 6892: 1998	Metallic Materials - Tensile Testing At Ambient Temperature
ISO 6506:1 1999	Metallic Materials - Brinell Hardness Test - Part1: Test Method
ISO AWI 7225 Ed.2	Gas Cylinders - Precautionary Labels
ISO 7866: 1999	Gas Cylinders - Refillable Seamless Aluminium Alloy Gas Cylinders: Design, Construction And Testing
ISO 9001:1994	Quality Systems - Model For Quality Assurance In Design, Development, Production, Installation and Servicing

ISO 9002:1994	Quality Systems - Model For Quality Assurance In Design, Development, Production, Installation and Servicing
ISO 9712:1999	Non-destructive Testing - Qualification And Certification Of Personnel
ISO 9809-1: 1999	Gas Cylinders - Refillable Seamless Steel Gas Cylinders - Design, Construction And Testing - Part I: Quenched And Tempered Steel Cylinders With Tensile Strength < 1100 MPa
ISO 12737: 1996	Metallic Materials - Determination Of The Plane-strain Fracture Toughness
ISO 11114-1 (7/98)	Transportable Gas Cylinders – Compatibility Of Cylinder And Valve Materials With Gas Contents – Part 1: Metallic Materials
PrEN ISO 11114-2 (02/99)	Transportable Gas Cylinders – Compatibility Of Cylinder And Valve Materials With Gas Contents – Part 2: Non-metallic Materials
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

3 SERVICE CONDITIONS

Unless indicated otherwise the service conditions specified in Paragraph 2.4 of this Regulation will apply throughout this Annex.

3.1 No. Of Pressure Cycles

Containers shall be approved for the number of pressure cycles calculated in Paragraph 2.4.7 of this Regulation.

3.2 External Surfaces

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.

3.3 Gas Permeation Or Leakage

Permeation of gas through the wall of the *Container* or between the *Liner* and the wrapping, or leakage between the end connections and the *Liner*, shall be considered in the design of *Containers*.

4 DESIGN APPROVAL

4.1 General

Application for approval and approval of a *Container* shall be carried out in accordance with Part I of this Regulation, however, this Paragraph contains additional requirements for *Containers* that shall be satisfied before approval may be granted.

The following information shall be submitted by the *Container Manufacturer* with a request for approval to the Competent Authority:

i) Statement of service (see Paragraph 4.2 of this Annex),
ii) Design data (see Paragraph 4.3 of this Annex),
iii) Manufacturing data (see Paragraph 4.4 of this Annex),
iv) Fracture performance and NDE (Non Destructive Examination) defect size (see Paragraph 4.5 of this Annex),
v) Specification sheet (see Paragraph 4.6 of this Annex),
vi) Additional supporting data (see Paragraph 4.7 of this Annex),
vii) Quality system (see Paragraph 4.8 of this Annex).

4.2 Statement Of Service

The statement of service shall include:

i) A statement that the *Container* design is suitable for use in the service conditions defined in Paragraph 3 of this Annex for the Service Life of the *Container* shall be provided,
ii) The *Service Life* shall be specified,
iii) The minimum in-service test or inspection requirements shall be specified,
iv) The *Pressure Relief Devices* or insulation required shall be specified,
v) Support methods, protective coatings, etc., required but not provided shall be specified,
vi) A description of the *Container* design shall be provided,
vii) Any other information necessary to ensure the safe use and inspection of the *Container*,
viii) The number of filling cycles shall be specified.

4.3 Design Data

4.3.1. Drawings

Drawings shall show the following information as a minimum:

i) Title, reference number, date of issue, and revision numbers with dates of issue if applicable,
ii) Reference to this Regulation and the Container Type,
iii) All dimensions complete with tolerances, including details of end closure shapes with minimum thickness and of openings,
iv) Mass including tolerance of the *Container*,
v) Material specifications, complete with minimum mechanical and chemical properties or tolerance ranges and the specified hardness range,
vi) Other data such as, *Auto-frettage Pressure* range, minimum test pressure, details of the fire protection system and of the exterior protective coating.

4.3.2 Stress Analysis Report

A finite element stress analysis or other stress analysis shall be provided, including a table summarising the calculated stresses in the report, unless the *Container* is designed in accordance with ISO 9809.

4.3.3 Material Test Data

A detailed description of the materials and tolerances of the materials properties used in the design shall be provided. Test data shall also be presented characterising the mechanical properties and the suitability of the materials for service under the service conditions specified in Paragraph 3 of this Annex.

4.3.4 Design Qualification Test Data

The *Container* material, design, manufacture and examination shall be deemed to be adequate for their intended service by meeting the requirements of the tests required for the particular *Container* design, when tested in accordance with the relevant methods of test detailed in this Annex. The test data shall also document the dimensions, wall thickness and weights of each of the test *Containers*.

4.3.5 Fire Protection

The arrangement of *Pressure Relief Device(s)* that will protect the *Container* from sudden rupture when exposed to the fire conditions specified in Paragraph A.15 (Appendix A of this Annex) shall be specified. Test data shall substantiate the effectiveness of the arrangement *of Pressure Relief Device(s)*.

4.3.6 Container Supports

Details of *Container* supports or support requirements shall be provided in accordance with Paragraph 5.11 of this Annex.

4.4 Manufacturing Data

Details of all fabrication processes, non-destructive examinations, production tests and batch tests shall be provided. The tolerances for all production processes such as heat treatment, end forming, resin mix ratio, filament winding tension and speed, curing times and temperatures, and *Auto-frettage* procedures shall be specified. Surface finish, thread details, acceptance criteria for ultrasonic scanning (or equivalent), and maximum lot sizes for batch tests shall also be specified.

4.5 Fracture Performance And Non-destructive Examination (NDE) Defect Size

4.5.1 Fracture performance

The *Manufacturer* shall demonstrate the Leak-Before-Break performance of the design as described in Paragraph 5.7 of this Annex.

4.5.2 NDE Defect Size

Using the approach described in Paragraph 5.15.2 of this Annex, the *Manufacturer* shall establish the maximum defect size for non-destructive examination which will prevent the failure of the *Container* during its *Service Life* due to fatigue, or failure of the *Container* by rupture.

4.6 Specification Sheet

A summary of the documents providing the information required in Paragraph 4.1 of this Annex shall be listed on a specification sheet for each *Container* design. The title, reference number, revision numbers and dates of original issue and version issues of each document shall be given. All documents shall be signed or initialled by the issuer. The specification sheet shall be given a number, and revision numbers if applicable, that can be used to designate the *Container* design and shall carry the signature of the engineer responsible for the design. Space shall be provided on the specification sheet for a stamp indicating registration of the design.

4.7 Additional Supporting Data

Additional data which supports the application for approval, such as the service history of material proposed for use, or the use of a particular *Container* design in other service conditions, shall be provided where applicable.

4.8 Quality Assurance Programme

The *Manufacturer* shall specify methods and procedures in accordance with ISO 9001 and ISO 9002.

4.9 Approval And Certification

4.9.1 Inspection And Testing

Evaluation of conformity is required to be performed in accordance with the provisions of Part I, Paragraph 8 of this Regulation.

In order to ensure that the *Containers* are in compliance with this Regulation they shall be subject to inspection performed by the Competent Authority in accordance with Paragraphs 5.13, 5.14 and 5.15 of this Annex.

4.9.2 Test Certificate

If the results of prototype testing according to Paragraph 5.13 of this Annex are satisfactory, the Competent Authority shall issue a test certificate. An example of a test certificate is given in Appendix B to this annex.

5 GENERAL REQUIREMENTS APPLICABLE TO CONTAINER TYPES 1 TO 4

5.1 General

The following requirements are generally applicable to *Container* Types 1 to 4. Type specific requirements are specified in Paragraphs 6 to 9 of this Annex and shall take precedence over the requirements of this Paragraph. The design of *Containers* shall cover all relevant aspects which are necessary to ensure that every *Container* produced to the design is fit for its purpose throughout its specified *Service Life*.

5.2 Design

This Regulation does not provide design formulas nor permissible stresses or strains, but requires the adequacy of the design to be established by appropriate calculations and demonstrated by *Containers* being capable of consistently passing the materials, design qualification, production and batch tests specified in this Regulation.

All designs shall ensure a "leakage before break" 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. The design shall identify the maximum size of an allowable defect at any point of a *Container* operating at the *Design Pressure*, which will not grow to a critical size within the specified retest period or *Service Life* if no retest is specified.

5.3 Materials

5.3.1 General

Materials used shall be suitable for the service conditions specified in Paragraph 3 of this Annex. Incompatible materials shall not be in contact with each other. The component materials which are in contact with hydrogen shall be compatible with hydrogen and expected additives and production contaminants, in accordance with EN11114-1 and prEN11114-2. Hydrogen compatibility of *Container* materials shall be determined in accordance with Paragraph A.27 (Appendix A of this Annex). The design qualification tests for materials are summarised in Table 7.2.

5.3.2 Steel

5.3.2.1 Composition

Steels shall be produced to predominantly fine grain practice. The chemical composition of all steels shall be declared and defined at least by:

i) Aluminium, carbon, manganese and silicon contents in all cases,
ii) Nickel, chromium, molybdenum, boron and vanadium contents, and any other alloying elements intentionally added.

The following limits shall not be exceeded in the cast analysis:

Tensile Strength	<950 MPa	≥950 MPa
Sulphur content	0,020%	0.010%
Phosphorus content	0,020%	0.020%
Sulphur and phosphorus content	0,030%	0.025%

5.3.2.2 Tensile Properties

The mechanical properties of the steel in the *Finished Container* or *Liner* shall be determined in accordance with Paragraph A.1 (Appendix A of this Annex). The elongation for steel shall meet the *Manufacturer's* design specifications.

5.3.2.3 Impact Properties

The impact properties of the steel in the *Finished Container* or *Liner* shall be determined in accordance with Paragraph A.2 (Appendix A of this Annex). Impact values shall not be less than that indicated in Table 7.3 of this Annex.

5.3.3. Aluminium

5.3.3.1 Composition

Aluminium alloys shall be quoted in line with Aluminium Association practice for a given alloy system. The impurity limits for lead and bismuth in any aluminium alloy shall not exceed 0.003 %.

5.3.3.2 Corrosion Tests

Aluminium alloys shall meet the requirements of the corrosion tests carried out in accordance with Paragraph A.4 (Appendix A of this Annex).

5.3.3.3 Sustained Load Cracking

Aluminium alloys shall meet the requirements of the sustained load cracking tests carried out in accordance with Paragraph A.5 (Appendix A of this Annex).

5.3.3.4 Tensile Properties

The mechanical properties of the aluminium alloy in the *Finished Container* or *Liner* shall be determined in accordance with Paragraph A.1 (Appendix A of this Annex). The elongation for aluminium shall meet the *Manufacturer's* design specifications.

5.3.4 Resins

5.3.4.1 General

The material for impregnation may be thermosetting or thermoplastic resins. Examples of suitable matrix materials are epoxy, modified

epoxy, polyester and vinylester thermosetting plastics, and polyethylene and polyamide thermoplastic material.

5.3.4.2 Shear Strength

Resin materials shall be tested in accordance with Paragraph A.25 (Appendix A of this Annex) and meet the requirements therein.

5.3.4.3 Glass Transition Temperature

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

5.3.5 Fibres

Structural reinforcing filament material types shall be glass fibre, aramid fibre or carbon fibre. If carbon fibre reinforcement is used, the design shall incorporate means to prevent galvanic corrosion of metallic components of the cylinder. The *Manufacturer* shall keep on file the published specifications for composite materials, the material manufacturer's recommendations for storage, conditions and shelf life and the material manufacturer's certification that each shipment conforms to the aforesaid specification requirements. The fibre manufacturer shall certify that the fibre material properties conform to the *Manufacturer's* specifications for the product.

5.3.6 Plastic Liners

The tensile yield strength and ultimate elongation shall be determined in accordance with Paragraph A.22 (Appendix A of this Annex). Tests shall demonstrate the ductile properties of the plastic *Liner* material at temperatures of -50 °C or lower by meeting the values specified by the *Manufacturer*. The polymeric material shall be compatible with the service conditions specified in Paragraph 3 of this Annex. In accordance with the method described in Paragraph A.23 (Appendix A of this Annex), the softening temperature shall be greater than 130 °C and the functioning temperature of the temperature triggered pressure relief device plus 10 °C, and the melting temperature shall be greater than 160 °C and the functioning temperature of the temperature triggered pressure relief device plus 30 °C.

5.4 Test Pressure

The test pressure used shall be 1.5 x *Design Pressure*.

5.5 Burst Pressures And Fibre Stress Ratios

For all types of cylinder the minimum actual *Burst Pressure* ratio shall not be less than the values given in Table 7.4 of this Annex. For Type 2, 3 and 4 *Containers* the composite *Over-wrap* shall be designed for high reliability under sustained loading and cyclic loading. This reliability shall be achieved by meeting or exceeding the composite reinforcement stress ratio values given in Table 7.4 of this Annex. Stress ratio is defined as the stress in the fibre at the specified minimum *Burst Pressure* divided by the stress in the fibre at *Design Pressure*. The *Burst Pressure* ratio is defined as the actual *Burst Pressure* of the cylinder divided by the *Design Pressure*.

The *Design Pressure* shall be in accordance with Paragraph 2.1.15 of this Regulation. The *Burst Pressure* is equal to the *Design Pressure* multiplied by the *Burst Pressure* ratio given in Table 7.4 of this Annex. For Type 4 *Containers*, the stress ratio is equal to the *Burst Pressure* ratio. For Type 2 and 3 *Containers* stress ratio calculations must include:

i) An analysis method with capability for non-linear materials (special purpose computer program or finite element analysis program),
ii) Elastic-plastic stress-strain curve for *Liner* material must be known and correctly modelled,
iii) Mechanical properties of composite materials must be correctly modelled,
iv) Calculations must be made at: *Auto-frettage*, zero after *Auto-frettage*, *Design Pressure* and minimum *Burst Pressures*,
v) Prestress from winding tension must be accounted for in the analysis,
vi) Minimum *Burst Pressure* must be chosen such that the calculated stress at minimum *Burst Pressure* divided by the calculated stress at the *Design Pressure* meets the stress ratio requirements for the fibre used,
vii) When analysing cylinders with hybrid reinforcement (two or more different fibres), the load share between the different fibres must be considered based on the different elastic modulii of the fibres. The stress ratio requirements for each individual fibre type must be in accordance with the values given in Table 7.4 of this Annex. Verification of the stress ratios may also be performed using strain gauges. An acceptable method is outlined in Appendix C to this Annex.

5.6 Stress Analysis

A stress analysis shall be performed to justify the minimum design wall thicknesses. It shall include the determination of the stresses in *Liners* and fibres of composite designs.

5.7 Leak Before Break Assessment

Type 1, 2, 3 and 4 *Containers* shall demonstrate Leak Before Break (LBB) performance in accordance with the requirements of Paragraphs 6, 7, 8 and 9 of this Annex. Demonstration of LBB performance is not required for *Container* designs that provide a fatigue life of 45,000 pressure cycles or greater when tested in accordance with Paragraph A.13 (Appendix A of this Annex). Two methods of LBB assessment are included for information in Appendix D of this Annex.

5.8 Inspection And Testing

The *Manufacturer* shall specify programmes and procedures for:
i) Manufacturing inspection, tests and acceptance criteria,
and
ii) Periodic in-service inspection, tests and acceptance criteria. The interval of visual re-inspection of the external *Container* surfaces shall be in accordance with Part II, Paragraph 14.10 of this Regulation unless varied by the Competent Authority. The *Manufacturer* shall establish the visual re-inspection rejection criteria based on the results of pressure cycling tests performed on *Containers* containing flaws. A guide for *Manufacturer's* instructions for handling, use and inspection is provided in Appendix E to this Annex.

5.9 Fire Protection

All *Containers* shall be protected from fire with temperature triggered *Pressure Relief Devices*. The *Container*, its materials, *Pressure Relief Devices* and any added insulation or protective material shall be designed collectively to ensure adequate safety during fire conditions in the test specified in Paragraph A.15 (Appendix A to this Annex).

Pressure Relief Devices shall be tested in accordance Annex 8A and Annex 9 to this Regulation.

5.10 Openings

5.10.1 General

Openings are permitted in *Container* heads only. The centre line of openings shall coincide with the longitudinal axis of the *Container*. Threads shall be clean cut, even, without surface discontinuities, and to gauge.

5.10.2 Tapered Threads

Openings with tapered threads may be used in all *Containers* Types. Tapered threads shall comply with a recognised international or national standard.

5.10.3 Straight Threads

Openings with straight threads shall comply with a recognised international or national standard. The thread shear stress at *Container* test pressure calculated using the equations given below shall not exceed one quarter of the ultimate shear stress of the threaded material.

$$A = p.n.L.d.[1/(2n) ¸ (d-D)/3] \qquad \text{Eqn.(1)}$$

$$T = P.p.(b/2)^2/10 \qquad \text{Eqn.(2)}$$

$$S = T/A \qquad \text{Eqn.(3)}$$

where:

A = shear area of internal thread, mm^2
n = number of threads per mm
d = minimum major diameter of external thread, mm
D = maximum pitch diameter of internal thread, mm
L = length of thread engagement, mm
P = hydrostatic test pressure, MPa
b = basic pitch diameter of external thread, mm
T = thrust force, N
S = average shear stress on internal thread, MPa

5.11 Container Supports

The *Manufacturer* shall specify the means by which *Container(s)* shall be supported for installation on vehicles. The *Manufacturer* shall also supply support installation instructions, including clamping force and torque to provide the required restraining force but not cause unacceptable stress in the *Container* or damage to the *Container* surface.

5.12 Exterior Environmental Protection

The exterior of *Containers* shall meet the requirements of the environmental test conditions of Paragraph A.14 (Appendix A to this Annex). Exterior protection may be provided by using any of the following:

i) A surface finish giving adequate protection (e.g. metal sprayed on aluminium, anodising); or
ii) The use of a suitable fibre and matrix material (e.g. carbon fibre in resin); or
iii) A protective coating (e.g. organic coating, paint) that shall meet the requirements of Paragraph A.9 (Appendix A to this Annex).

Any coatings applied to cylinders 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*.

Manufacturers are advised that an environmental performance test that evaluates the suitability of coating systems is provided in the informative Appendix F to this Annex.

5.13 Design Qualification Tests

For the approval of each *Container* type the material, design, manufacture and examination shall be proved to be adequate for their intended service by meeting the appropriate requirements of the material qualification tests summarised in Table 7.2 of this Annex and the *Container* qualification tests summarised in Table 7.5 of this Annex, with all tests in accordance with the relevant methods of test as described in Appendix A to this Annex. The test *Containers* or *Liners* shall be selected and the tests witnessed by the Competent Authority. If more *Containers* or *Liners* are subjected to the tests than are required by this Annex, all results shall be documented.

5.14 Batch tests

The batch tests specified in this Annex for each *Container* type shall be conducted by the *Manufacturer* on *Containers* or *Liners* taken from each batch of *Finished Containers* or *Liners*. Heat treated test samples shown to be representative of *Finished Containers* or *Liners* may also be used. Batch tests required for each *Container* Type are specified in Table 7.6 of this Annex.

In no case shall a *Batch* be permitted to exceed 200 *Finished Containers* or *Liners* (not including *Containers* or *Liners* used in destructive tests), or one shift of successive production, whichever is greater.

5.15 Production Examinations And Tests

5.15.1 General

Production examinations and tests shall be carried out on all *Containers* produced in a *Batch*. Each *Container* shall be examined during manufacture and after completion by the following means:

i) Ultrasonic scanning (or demonstrated equivalent) of metallic *Containers* and *Liners* in accordance with Appendix G to this Annex, or demonstrated

equivalent method, to ensure that the maximum defect size present does not exceed the size specified in the design.

ii) Verification that the critical dimensions and mass of the completed *Container* and of any *Liner* and *Over-wrapping* are within design tolerances.

iii) Verification of compliance with 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.

iv) Verification of markings.

v) Hardness tests of metallic *Containers* and *Liners* in accordance with Paragraph A.8 (Appendix A to this Annex) shall be carried out after the final heat treatment and the values thus determined shall be in the range specified for the design.

vi) Hydrostatic proof test in accordance with Paragraph A.11 (Appendix A to this Annex).

A summary of critical production inspection requirements to be performed on each *Container* is provided in Table 7.7 of this Annex.

5.15.2 Maximum Defect Size

For *Container* Type 1, 2 and 3 designs, the maximum defect size at any location in the metal *Container* or metal *Liner* that will not grow to a critical size within the specified *Service Life* shall be determined. 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* Type 2 and 3 designs, 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. Two such methods are outlined in the informative Appendix D to this Annex.

5.16 Failure To Meet Test Requirements

In the event of failure to meet 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 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 the 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 unrejected *Containers* shall then be considered as a new *Batch*.

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

5.17 Change Of Design

A design change is any change in the selection of structural materials or dimensional change not attributable to normal manufacturing tolerances.

Minor design changes shall be permitted to be qualified through a reduced test program. Changes of design specified in Table 7.8 of this Annex shall require design qualification testing as specified in the Table.

Table 7.1 – Not used

Table 7.2 - Material Design Qualification Tests

	Relevant Paragraph Of This Annex				
	Steel	Aluminium	Resins	Fibres	Plastic liners
Tensile Properties	5.3.2.2	5.3.3.4		5.3.5	5.3.6
Impact Properties	5.3.2.3				
Sustained Load Cracking Resistance		5.3.3.3			
Stress Corrosion Cracking		5.3.3.2			
Shear Strength			5.3.4.2		
Glass Transition Temperature			5.3.4.3		
Softening/Melting Temperature					5.3.6
Hydrogen compatibility	5.3.1	5.3.1	5.3.1	5.3.1	5.3.1
Fracture Mechanics *	5.7	5.7			
* Not required if using flawed Container test approach in Paragraph A.17 (Appendix A to this Annex)					

Table 7.3 - 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
Impact strength, J/cm²				
Mean of 3 specimens	30	35	40	60
Individual specimen	24	28	32	48

Table 7.4 - Minimum Burst And Stress Ratios

Container Type	1 All-metal	2 Hoop-wrapped		3 Fully-wrapped		4 Non-metallic	
Over-wrapping	Burst Pressure Ratio	Stress Ratio	Burst Pressure Ratio	Stress Ratio	Burst Pressure Ratio	Stress Ratio	Burst Pressure Ratio
All metal	2.25						
Glass		2.75	2.50 [1)]	3.65	3.50 [1)]	3.65	3.65
Aramid		2.35	2.35	3.10	3.00 [1)]	3.1	3.10
Carbon		2.35	2.35	2.35	2.35	2.35	2.35
Hybrid		2)		2)		2)	

Notes
1 - Minimum Burst Pressure ratio. In addition, calculations must be performed in accordance with Paragraph 5.5 of this Annex to confirm that the minimum stress ratio requirements are also met.
2 - Stress ratios and Burst Pressure ratios shall be calculated in accordance with Paragraph 5.5 of this Annex.

Table 7.5 - Container Design Qualification Tests

Test And Annex Reference		Container Type			
		1	2	3	4
A.6	LBB Assessment	X	X	X	X
A.7	Extreme temperature/cycle		X	X	X
A.12	Burst	X	X	X	X
A.13	Ambient temp/cycle	X	X	X	X
A.14	Acid environment test		X	X	X
A.15	Bonfire	X	X	X	X
A.16	Penetration	X	X	X	X
A.17	Flaw tolerance		X	X	X
A.18	High temp. creep		X	X	X
A.19	Stress rupture		X	X	X
A.20	Drop test			X	X
A.21	Permeation				X
A.24	Boss torque test				X
A.26	Hydrogen gas cycling				X

Notes:
X = Test required

Table 7.6 - Batch Tests

Test & Annex Reference		Container Type			
		1	2	3	4
A.1	Tensile	X	X†	X†	
A.2	Impact (steel)	X	X†	X†	
A.9.2	Coating*	X	X	X	X
A.12	Burst	X	X	X	X
A.13	Ambient cycle	X	X	X	X

Notes:
X = Test required
* Except where no protective coating is used
† Tests on Liner material

Table 7.7 - Critical Production Inspection Requirements

Inspection Requirement & Annex 7 Reference		Container Type			
		1	2	3	4
5.15.1	Critical dimensions	X	X	X	X
App. G	Flaws (ultrasonic or equivalent)	X	X	X	
App. A8	Hardness of metal cylinders and metal liners	X	X	X	
App. A11	Hydrostatic proof test	X	X	X	X
App. A10	Leak test	X	X	X	X
10	Markings	X	X	X	X
5.15.1	Surface finish	X	X	X	X

Note: X = Test required

Table 7.8 - Change Of Design	Type Of Test											
Design Change	Materials A.1, A.2, A.4, & A.5 as applicable	LBB Assess-ment A.6	Burst (Hydro-static) A.12	Cycling (Ambient Temp.) A.13	Acid Environ-mental A.14	Bonfire A.15	Penetra-tion A.16	Flaw tolerance A.17	Stress Rupture A.19 High. Temp. Creep A.18	Impact test A.20	Perm-eation A.21 Boss torque A.24 Hydrogen Cycling A.26	Hydrogen Compati-bility A.27
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	1, 2, 3		1, 2, 3
Plastic Liner Material		4	4	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	4	2, 3, 4
Resin Material			2, 3, 4		2, 3, 4		2, 3, 4	2, 3, 4	2, 3, 4	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	2, 3, 4		3, 4		
Length Change ≤ 50%			1, 2, 3, 4			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, 2, 3, 4	1, 2, 3, 4								
Dome Shape, Opening Size or Thread Size			1, 2, 3, 4	1, 2, 3, 4							4	
Coating Change					1, 2, 3, 4							
End Boss Design											4*	
Change In Manuf. Process			1, 2, 3, 4	1, 2, 3, 4								
Pressure Relief Device						1, 2, 3, 4						

Notes: x = Test required, e.g. 2,3 means Test required for Container Types 2 and 3 only
‡ Test only required when length increases

@ Only when thickness change proportional to diameter or pressure change

* A hydrogen cycle test should not be required for type 4 tanks, if only the opening size of the boss end is reduced and the liner to boss interface is not effected and the same materials are used for boss liner and seals."

6 TYPE 1 (METAL) CONTAINERS

6.1 General

The design shall identify the maximum size of an allowable defect at any point in the *Container* which will not grow to a critical size within the specified retest period, or Service Life if no retest is specified, of a *Container* operating to the *Design Pressure*. Determination of leak-before-break (LBB) performance shall be carried out in accordance with the appropriate procedures defined in Paragraph A.6 (Appendix A to this Annex). Allowable defect size shall be determined in accordance with Paragraph 5.15.2 of this Annex.

6.2 Stress analysis

The stresses in the *Container* shall be calculated for
i) 2.0 MPa,
ii) *Design Pressure*,
iii) Test pressure,
iv) *Burst pressure*.

The calculations shall use suitable analysis techniques using thin-shell theory that takes into account out-of-plane bending of the shell to establish stress distributions in the neck, transition regions and in the cylindrical part of the *Container*.

For *Containers* designed in accordance with ISO9809 a stress analysis report shall not be provided.

6.3 Manufacturing And Production Test Requirements

6.3.1 General

The ends of aluminium *Containers* shall not be closed by a forming process. The base ends of steel *Containers* which have been closed by forming, shall be NDE inspected or equivalent. 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.

6.3.2 Non-destructive Examination

The following tests shall be carried out on each metallic *Container*:

a) Hardness test in accordance with Paragraph A.8 (Appendix A to this Annex),
b) Ultrasonic examination, in accordance with Appendix G to this Annex, or demonstrated equivalent Non-destructive test (NDT) method, to ensure that the maximum defect size does not exceed the size specified in the design as determined in accordance with Paragraph 5.15.2 of this Annex.

6.3.3 Hydrostatic Pressure Testing

Each *Finished Container* shall be hydrostatically pressure tested in accordance with Paragraph A.11 (Appendix A to this Annex).

6.4 Container Batch Tests

Batch testing shall be conducted on *Finished Containers* which are representative of normal production and are complete with identification marks. All results shall be documented. Two *Containers* shall be randomly selected from each Batch upon which the following tests shall be carried out:

i) Batch materials tests. One *Container*, or a heat treated witness sample representative of a *Finished Container*, shall be subjected to the following tests:

a) Critical dimensions checked against the design,
b) One tensile test in accordance with Paragraph A.1 (Appendix A to this Annex) and meet the requirements of the design,
c) For steel *Containers*, three impact tests in accordance with Paragraph A.2 (Appendix A to this Annex) and meet the requirements of Paragraph 5.3.2.3 of this Annex,
d) When a protective coating is a part of the design, the coating shall be tested in accordance with Paragraph A.9.2 (Appendix A to this Annex).

All *Containers* represented by a batch test which fail to meet the specified requirements shall follow the procedures specified in Paragraph 5.16 of this Annex.

Where the coating fails to meet the requirements of Paragraph A.9.2 (Appendix A to this Annex), the batch shall be 100 percent inspected to remove similarly defective *Containers*. The coating on all defective *Containers* may be stripped and recoated. The coating batch test shall then be repeated.

ii) Batch burst test. One *Container* shall be hydrostatically pressurised to burst in accordance with Paragraph A.12 (Appendix A to this Annex).

If the burst pressure is less than the minimum calculated *Burst Pressure* the procedures specified in Paragraph 5.16 of this Annex shall be followed.

iii) Periodic pressure cycling test. *Finished Containers* shall be pressure cycled in accordance with Paragraph A.13 (Appendix A to this Annex) at a test frequency defined as follows:
a) One *Container* from each *Batch* shall be pressure cycled for the total number of times calculated in accordance with Paragraph 2.4.7 if this Regulation.
b) On 10 sequential production *Batches* of a design family, i.e. similar materials and processes, should none of the pressure cycled *Containers* in a) above leak or rupture in less than 1.5 times the total number of cycles calculated 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.
c) On 10 sequential production *Batches* of a design family, should none of the pressure cycled *Containers* in a) above leak or rupture in less than 2.0

times the total number of cycles calculated 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.

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

e) Should any reduced frequency pressure cycle test *Container* in b) or c) above fail to meet the required number of pressure cycles, then it shall be necessary to repeat the batch pressure cycle test frequency in a) for a minimum 10 production *Batches* in order to re-establish the reduced frequency of batch pressure cycle testing in b) or c) above.

f) Should any *Container* in a), b), or c) above fail to meet the minimum cycle life requirement calculated 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 5.16 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 minimum pressure cycling requirement calculated in accordance with Paragraph 2.4.7 of this Regulation, then the *Batch* shall be rejected.

6.5 Container Design Qualification Tests

6.5.1 General

Qualification testing shall be conducted on *Finished Containers* which are representative of normal production and complete with identification marks. Selection, witnessing and documentation of the results shall be in accordance with Paragraph 5.13 of this Annex.

6.5.2 Hydrostatic Pressure Burst Test

Three representative *Containers* shall be hydrostatically pressurised to failure in accordance with Paragraph A.12 (Appendix A to this Annex). The *Container Burst Pressures* shall exceed the minimum *Burst Pressure* calculated by the stress analysis for the design, and the *Burst Pressure* ratio shall be in accordance with Table 7.4 of this Annex.

6.5.3. Ambient Temperature Pressure Cycling Test

Two *Finished Containers* shall be pressure cycled at ambient temperature in accordance with Paragraph A.13 (Appendix A to this Annex) to failure, or to 3.0 times the total number of cycles calculated in accordance with Paragraph 2.4.7 of this Regulation. The *Containers* shall not fail before reaching the total number of cycles calculated in accordance with Paragraph 2.4.7 of this Regulation. *Containers* exceeding the total number of cycles calculated in accordance with Paragraph 2.4.7 of this Regulation shall fail by leakage and not by rupture. *Containers* which do not fail within 3.0 times the total number of cycles calculated in accordance with Paragraph 2.4.7 of this Regulation shall be destroyed either by continuing the cycling until failure occurs, or by hydrostatically pressurising to burst. Containers exceeding 3.0 times the total number of cycles calculated in accordance with Paragraph 2.4.7 of this Regulation are permitted to fail by rupture. The number of cycles to failure and the location of the failure initiation shall be recorded.

6.5.4 Bonfire Test

Tests shall be conducted in accordance with Paragraph A.15 (Appendix A to this Annex) and meet the requirements therein.

6.5.5. Penetration Test

Tests shall be conducted in accordance with Paragraph A.16 (Appendix A to this Annex) and meet the requirements therein.

6.5.6 LBB Performance

For *Container* designs not exceeding 45,000 cycles when tested in accordance with Paragraph 6.5.3 of this Annex, LBB performance tests shall be conducted in accordance with Paragraph A.6 (Appendix A to this Annex) and meet the requirements therein.

7 TYPE 2 (HOOP WRAPPED) CONTAINERS

7.1 General

During pressurisation, this type of *Container* design has a behaviour in which the displacements of the composite *Over-wrap* and the metal *Liner* are linearly superimposed. Due to different techniques of manufacture, this Annex does not give a specific method for design.

Determination of the leak-before-break (LBB) performance shall be in accordance with the appropriate procedures defined in Paragraph A.6 (Appendix A to this Annex). Allowable defect size shall be determined in accordance with Paragraph 5.15.2 of this Annex.

7.2 Design Requirements

7.2.1 Metal Liner

The metal *Liner* shall have a minimum *Burst Pressure* ratio of 1.30.

7.2.2 Composite Over-wrap

The tensile stress in the fibres shall meet the requirements of Paragraph 5.5 of this Annex.

7.2.3 Stress Analysis

The stresses in the *Over-wrap* and in the *Liner* after prestress shall be calculated. The pressures used for these calculations shall be zero, *Design Pressure*, test pressure and the *Burst Pressure*. The calculations shall use suitable analysis techniques using thin-shell theory taking account of non-linear material behaviour of the *Liner* to establish stress distributions at the neck, transition regions and the cylindrical part of the *Liner*.

For designs using *Auto-frettage* to provide prestress, the limits within which the *Auto-frettage Pressure* must fall shall be calculated.

For designs using *Controlled Tension Winding* to provide prestress, the temperature at which it is performed, the tension required in each layer of the *Over-wrap* and the consequent prestress in the *Liner* shall be calculated.

7.3 Manufacturing Requirements

7.3.1 General

The *Composite Container* shall be fabricated from a *Liner* over-wrapped with continuous filament windings. Filament winding operations shall be computer or mechanically controlled. The filaments shall be applied under controlled tension during winding. After winding is complete, thermosetting resins shall be cured by heating, using a predetermined and controlled time-temperature profile.

7.3.2 *Liner*: The manufacture of a metallic *Liner* shall meet the requirements given under Paragraph 6.3 of this Annex for the appropriate type of *Liner* construction.

7.3.3 Over-wrap

The cylinders shall be fabricated in a filament winding machine. During winding the significant variables shall be monitored within specified tolerances, and documented in a winding record. These variables can include but are not limited to:

i) Fibre type including sizing,
ii) Manner of impregnation,
iii) Winding tension,
iv) Winding speed,
v) Number of windings,
vi) Band width,
vii) Type of resin and composition,
viii) Temperature of the resin,
ix) Temperature of the liner.

7.3.3.1 Curing Of Thermosetting Resins

If a thermosetting resin is used, the resin shall be cured after filament winding. During the curing, the curing cycle, i.e. the time-temperature history shall be documented.

The curing temperature shall be controlled and shall not affect the material properties of the *Liner*. The maximum curing temperature for *Containers* with aluminium *Liners* is 177 °C.

7.3.4. 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 in Paragraph 7.2.3 of this Annex, and the *Manufacturer* shall establish the method to verify the appropriate pressure.

7.4 Production Test Requirements

7.4.1 Non-destructive Examination

Non-destructive examinations (NDE) shall be carried out in accordance with a recognised ISO or an equivalent standard. The following tests shall be carried out on each metallic *Liner*:

a) Hardness test in accordance with Paragraph A.8 (Appendix A to this Annex);
b) Ultrasonic examination, in accordance with Appendix G to this Annex, or demonstrated equivalent Non-destructive testing (NDT) method, to ensure that the maximum defect size does not exceed the size specified in the design.

7.4.2 Hydrostatic Pressure Testing

Each *Finished Container* shall be hydrostatically pressure tested in accordance with Paragraph A.11 (Appendix A to this Annex). 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 at test pressure. Any *Containers* not meeting the defined rejection limit shall be rejected and either destroyed or used for batch test purposes.

7.5 Container Batch Tests

7.5.1 General

Batch testing shall be conducted on *Finished Containers* which are representative of normal production and are complete with identification marks. Two *Containers*, or a *Container* and a *Liner* as appropriate, shall be randomly selected from each *Batch*. If more *Containers* are subjected to the tests than are required by this Annex, all results shall be documented. The following tests shall be carried out as a minimum on these samples.

Where defects are detected in *Over-wrapping* before any *Auto-frettage* or hydrostatic pressure testing, the *Over-wrapping* may be completely removed and replaced.

i) Batch materials tests.
One *Container*, or *Liner*, or heat treated witness sample that is representative of a *Finished Container*, shall be subjected to the following tests:
a) Dimensions checked against the design,
b) One tensile test in accordance with Paragraph A.1 (Appendix A to this Annex) and meet the requirements of the design,
c) For steel *Liners*, three impact tests in accordance with Paragraph A.2 (Appendix A to this Annex) and meet the requirements of the design,
d) When a protective coating is a part of the design, the coating shall be tested in accordance with Paragraph A.9.2 (Appendix A to this Annex) and meet the requirements therein. All *Containers* or *Liners* represented by a batch test which fails to meet the requirements specified shall follow the procedures specified in Paragraph 6.16 of this Annex.

Where the coating fails to meet the requirements of Paragraph A.9.2 (Appendix A to this Annex), the *Batch* shall be 100 per cent inspected to remove similarly defective *Containers*. The coating on all defective *Containers* may be stripped using a method that does not affect the integrity of the *Over-wrapping*, and recoated. The coating batch test shall then be repeated.

ii) Batch burst test.
One *Container* shall be tested in accordance with the requirements of Paragraph 6.4(ii) of this Annex.

iii) Periodic pressure cycling test.
In accordance with the requirements of Paragraph 6.4(iii) of this Annex.

7.6 Container Design Qualification Tests

7.6.1 General

Qualification testing shall be conducted on *Containers* which are representative of normal production and complete with identification marks. Selection, witnessing and documentation of the results shall comply with Paragraph 5.13 of this Annex.

7.6.2 Hydrostatic Pressure Burst Test

i) One *Liner* shall be hydrostatically burst in accordance with Paragraph A.12 (Appendix A of this Annex). The *Burst Pressure* shall exceed the minimum *Burst Pressure* specified for the *Liner* design.

ii) Three *Containers* shall be hydrostatically burst in accordance with Paragraph A.12 (Appendix A). *Container Burst Pressure* ratios shall exceed the specified minimum *Burst Pressure* ratio established by the stress analysis for the design, in accordance with Table 7.4, and in no case be less than the value necessary to meet the stress ratio requirements of Paragraph 5.5 of this Annex.

7.6.3 Ambient Temperature Pressure Cycling Test

Two *Finished Containers* shall be pressure cycled at ambient temperature in accordance with Paragraph A.13 (Appendix A to this Annex) to failure, or to 3.0 times the total number of cycles calculated in accordance with Paragraph 2.4.7 of this Regulation. The *Containers* shall not fail before reaching the total number of cycles calculated in accordance with Paragraph 2.4.7 of this Regulation. *Containers* exceeding the total number of cycles calculated in accordance with Paragraph 2.4.7 of this Regulation shall fail by leakage and not by rupture. *Containers* which do not fail within 3.0 times the total number of cycles calculated in accordance with Paragraph 2.4.7 of this Regulation shall be destroyed either by continuing the cycling until failure occurs, or by hydrostatically pressurising to burst. *Containers* exceeding 3.0 times the total number of cycles calculated in accordance with Paragraph 2.4.7 of this Regulation are permitted to fail by rupture. The number of cycles to failure and the location of the failure initiation shall be recorded.

7.6.4 Acid Environment Test

One *Container* shall be tested in accordance with Paragraph A.14 (Appendix A of this Annex) and meet the requirements therein. An optional environmental test is included in the informative Appendix H to this Annex.

7.6.5 Bonfire Test

Finished Containers shall be tested in accordance with Paragraph A.15 (Appendix A to this Annex) and meet the requirements therein.

7.6.6 Penetration Test

One *Finished Container* shall be tested in accordance with Paragraph A.16 (Appendix A to this Annex) and meet the requirements therein.

7.6.7 Flaw Tolerance Tests

One *Finished Container* shall be tested in accordance with Paragraph A.17 (Appendix A of this Annex) and meet the requirements therein.

7.6.8 High Temperature Creep Test

In designs where the glass transition temperature of the resin does not exceed the maximum design material temperature by at least 20°C, one *Container* shall be tested in accordance with Paragraph A.18 (Appendix A to this Annex) and meet the requirements therein.

7.6.9 Accelerated Stress Rupture Test

One *Finished Container* shall be tested in accordance with Paragraph A.19 (Appendix A of this Annex) and meet the requirements therein.

7.6.10 LBB Performance

For *Container* designs not exceeding 45,000 cycles when tested in accordance with Paragraph 7.6.3 of this Annex, LBB performance tests shall be conducted in accordance with Paragraph A.6 (Appendix A of this Annex) and meet the requirements therein.

7.6.11 Extreme Temperature Pressure Cycling Test

One *Finished Container* shall be tested in accordance with Paragraph A.7 (Appendix A of this Annex) and meet the requirements therein.

8 TYPE 3 (FULLY-WRAPPED) CONTAINERS

8.1 General

During pressurisation, this type of *Container* has a behaviour in which the displacements of the composite *Over-wrap* and the *Liner* are superimposed. Due to different techniques of manufacture, this Annex does not give a definite method for design. Determination of the leak-before-break (LBB) performance shall be in accordance with the appropriate procedures defined in Paragraph A.6 (Appendix A to this Annex). Allowable defect size shall be determined in accordance with Paragraph 5.15.2 of this Annex.

8.2 Design Requirements

8.2.1 Metal Liner

The compressive stress in the *Liner* at zero pressure and throughout the temperature range defined in Paragraph 2.4.6.1 of this Regulation shall not cause the *Liner* to buckle or crease.

8.2.2 Composite Over-wrap

The tensile stress in the fibres shall meet the requirements of Paragraph 5.5 of this Annex.

8.2.3 Stress Analysis

The stresses in the tangential and longitudinal direction of the *Container* in the composite *Over-wrap* and in the *Liner* when subjected to internal pressure shall be calculated. The pressure used for these calculations shall be zero, *Design Pressure*, test pressure and *Burst Pressure*. The limits within which *Auto-frettage Pressure* must fall shall be calculated, The calculations shall use suitable analysis techniques using thin-shell theory taking account of non-linear material behaviour of the *Liner* to establish stress distributions at the neck, transition regions and the cylindrical part of the *Liner*.

8.3 Manufacturing Requirements

Manufacturing requirements shall be in accordance with Paragraph 7.3 of this Annex except that the *Over-wrap* shall also include helically wound filaments.

8.4 Production Test Requirements

Production test requirements shall be in accordance with the requirements of Paragraph 7.4 of this Annex.

8.5 Container Batch Tests

The batch tests shall be in accordance with the requirements of Paragraph 7.5 of this Annex.

8.6 Container Design Qualification Tests

8.6.1 Container design qualification tests shall be in accordance with the requirements of Paragraphs 7.6 and 8.6.2 of this Annex, except that the *Liner* burst in Paragraph 7.6.2 (a) of this Annex is not required.

8.6.2 Impact Test

One or more *Finished Containers* shall be drop tested in accordance with Paragraph A.20 (Appendix A to this Annex).

9 TYPE 4 (NON-METALLIC) CONTAINERS

9.1 General

This Annex does not give a definite method for the design of *Containers* with polymeric *Liners* because of the variety of *Container* designs possible.

9.2 Design Requirements

Design calculations shall be used to provide justification of design adequacy. The tensile stresses in the fibres shall meet the requirements of Paragraph 5.5 of this Annex.

Tapered and straight threads in accordance with Paragraph 5.10.2 or 5.10.3 of this Annex shall be used on the metal end bosses.

Metal end bosses with threaded openings shall be able to withstand a torque force of 500 N-m, without damaging the integrity of the connection to the non-metallic *Liner*. The metal end bosses connected to the non-metallic *Liner* shall be of a material compatible with the service conditions specified in Paragraph 3 of this Annex.

9.3 Stress Analysis

The stresses in the tangential and longitudinal direction of the *Container* in the composite *Over-wrap* and in the *Liner* shall be calculated. The pressures used for these calculations shall be zero, *Design Pressure*, test pressure and *Burst Pressure*. The calculations shall use suitable analysis techniques to establish stress distribution throughout the *Container*.

9.4 Manufacturing Requirements

Manufacturing requirements shall be in accordance with Paragraph 7.3 of this Annex except that the curing temperature for thermosetting resins shall be at least 10 °C below the softening temperature of the plastic *Liner*.

9.5 Production Test Requirements

9.5.1 Hydrostatic Pressure Testing

Each *Finished Container* shall be hydrostatically pressure tested in accordance with Paragraph A.11 (Appendix A to this Annex). The *Manufacturer* shall define the appropriate limit of elastic expansion for the test pressure used, but in no case shall the elastic expansion of any *Container* exceed the average batch value by more than 10 per cent. Any *Containers* not meeting the defined rejection limit shall be rejected and either destroyed or used for batch test purposes.

9.5.2 Leak Testing

Each *Finished Container* shall be leak tested in accordance with Paragraph A.10 (Appendix A to this Annex) and meet the requirements therein.

9.6 Container Batch Tests

9.6.1 General

Batch testing shall be conducted on *Finished Containers* which are representative of normal production and are complete with identification marks. One *Container* shall be randomly selected from each batch. If more *Containers* are subjected to the tests than are required by this Annex, all results shall be documented. The following tests shall be carried out as a minimum on these.

i) Batch materials test

One *Container*, or *Liner*, or *Liner* witness sample that is representative of a *Finished Container*, shall be subjected to the following tests:

a) Dimensions checked against the design.
b) One tensile test of the plastic *Liner* in accordance with Paragraph A.22 (Appendix A to this Annex) and meet the requirements of the design.
c) The melt temperature of the plastic *Liner* shall be tested in accordance with Paragraph A.23 (Appendix A to this Annex), and meet the requirements of the design.
d) When a protective coating is a part of the design, the coating shall be tested in accordance with Paragraph A.9.2 (Appendix A to this Annex). Where the coating fails to meet the requirements of Paragraph A.9.2 (Appendix A to this Annex), the *Batch* shall be 100 per cent inspected to remove similarly defective *Containers*. The coating on all defective *Containers* may be stripped using a method that does not affect the integrity of the composite *Over-wrapping*, and recoated. The coating batch test shall then be repeated.

ii) Batch burst test

One *Container* shall be tested in accordance with the requirements of Paragraph 6.4(ii) of this Annex.

iii) Periodic pressure cycling test

On one *Container* the end boss shall be torque tested to 500 Nm in accordance with the test method in Paragraph A.24 (Appendix A to this Annex). The *Container* shall then be pressure cycle tested in accordance with the procedures provided in Paragraph 6.4(iii) of this Annex.

Following the required pressure cycling, the *Container* shall be leak tested in accordance with the method described in Paragraph A.10 (Appendix A to this Annex) and meet the requirements therein.

9.7 Container Design Qualification Tests

9.7.1 General

Container design qualification tests shall be in accordance with the requirements of Paragraphs 7.6, 9.7.2, 9.7.3 and 9.7.4 of this Annex.

9.7.2 Boss Torque Test

One *Container* shall be tested in accordance with Paragraph A.24 (Appendix A to this Annex).

9.7.3 Permeation Test

One *Container* shall be tested for permeation in accordance with Paragraph A.21 (Appendix A to this Annex) and meet the requirements therein.

9.7.4 Hydrogen Gas Cycling Test

One *Finished Container* shall be tested in accordance with Paragraph A.26 (Appendix A to this Annex) and meet the requirements therein.

10 MARKING

Markings on every *Container* shall be in accordance with Part I, Paragraph 4.3 of this Regulation.

11 PREPARATION FOR DISPATCH

Prior to dispatch from the *Manufacturer's* shop, every *Container* shall be internally cleaned and dried. *Containers* not immediately closed by the fitting of a valve, and *Safety Devices* if applicable, shall have plugs, which prevent entry of moisture and protect threads, fitted to all openings. A corrosion inhibitor, e.g. oil-containing, shall be sprayed into all steel *Containers* and liners prior to dispatch.

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. The statement shall be in accordance with Appendix B to this Annex.

Annex 7 - APPENDIX A

TEST METHODS

A.1 TENSILE TESTS - STEEL AND ALUMINIUM

A tensile test shall be carried out on the material taken from the cylindrical part of the *Finished Container* using a rectangular test piece shaped in accordance with the method 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* shall not be machined. The tensile test shall be carried out in accordance with ISO 6892.

NOTE - Attention is drawn to the method of measurement of elongation described in ISO 6892, particularly in cases where the tensile test piece is tapered, resulting in a point of fracture away from the middle of the gauge length.

A.2 IMPACT TEST, STEEL CONTAINERS AND STEEL LINERS

The impact test shall be carried out on the material taken from the cylindrical part of the *Finished Container* on three test pieces in accordance with ISO 148. The impact test pieces shall be taken in the direction as required in Table 7.3 of Annex 7 from the wall of the *Container*. 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 near as practicable to the nominal thickness of the *Container* wall. 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.

A.3 Not used

A.4 CORROSION TESTS - ALUMINIUM

Corrosion tests for aluminium alloys shall be carried out in accordance with ISO 7866 Annex A and meet the requirements therein.

A.5 SUSTAINED LOAD CRACKING TESTS - ALUMINIUM

The resistance to sustained load cracking shall be carried out in accordance with ISO 7866 Annex B and shall meet the requirements therein.

A.6 LEAK-BEFORE-BREAK (LBB) PERFORMANCE TEST

Three *Finished Containers* shall be pressure cycled 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) Cycle the pressure in the *Container* between not more than 2.0 MPa and not less than test pressure at a rate not exceeding 10 cycles per minute to a maximum of 15000 cycles.

The number of cycles to failure shall be reported, along with the location and description of the failure initiation.

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

A.7 EXTREME TEMPERATURE PRESSURE CYCLING

Two *Finished Containers*, with the composite wrapping free of any protective coating, shall be cycle tested without showing evidence of rupture, leakage, or fibre unravelling, as follows:

i) Condition for 48 hours at zero pressure, 85 °C or higher, and 95 per cent or greater relative humidity. The intent of this requirement shall be deemed met by spraying with a fine spray or mist of water in a chamber held at 85 °C,
ii) Hydrostatically pressurised for 500 cycles times the specified *Service Life* in years between not more than 2.0 MPa and not less than the *Design Pressure*, at a minimum of 85°C and 95 per cent humidity,
iii) Stabilise at zero pressure and ambient temperature,
iv) Then pressurise from not more than 2.0 MPa to not less than the *Working Pressure* for 500 cycles times the specified *Service Life* in years at -40 °C or lower,
v) 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.

Following pressure cycling at extreme temperatures, *Containers* shall be hydrostatically pressurised to failure in accordance with the hydrostatic burst test requirements, and achieve a minimum *Burst Pressure* of 85 per cent of the minimum design *Burst Pressure*. For *Container* Type 4 designs, prior to the hydrostatic burst test the *Container* shall be leak tested in accordance with Paragraph A.10 of this Appendix.

A.8 BRINELL HARDNESS TEST

Hardness tests shall be carried out on the parallel wall at the centre and a domed end of each *Container* or *Liner* in accordance with ISO 6506. The test shall be carried out after the final heat treatment and the hardness values thus determined shall be in the range specified for the design.

A.9 COATING TESTS (Mandatory if Paragraph 5.12(iii) of Annex 7 is used)

A.9.1 Coating Performance Tests

Coatings shall be evaluated using the following test methods, or using equivalent National Standards:

i) Adhesion testing in accordance with ISO 4624 using Method A or B as applicable. The coating shall exhibit an adhesion rating of either 4A or 4B, as applicable.
ii) Flexibility in accordance with ASTM D522 Mandrel Bend Test of Attached Organic Coatings, using Test Method B with a 12.7 mm (0.5 in) mandrel at the specified thickness at -20°C. Samples for the flexibility test shall be prepared in accordance with the ASTM D522 standard. There shall not be any visually apparent cracks.
iii) Impact resistance in accordance with ASTM D2794 Test method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact). The coating at room temperature shall pass a forward impact test of 18 J (160 in-lbs).

iv) Chemical resistance when tested in general accordance with ASTM D1308 Effect of Household Chemicals on Clear and Pigmented Organic Finishes. The tests shall be conducted using the Open Spot Test Method and 100 hour exposure to a 30 per cent sulphuric acid solution (battery acid with a specific gravity of 1.219) and 24 hour 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) Minimum 1,000 hours exposure in accordance with ASTM G53 Practice for Operating Light and Water Exposure Apparatus (Fluorescent W-Condensation Type) for Exposure of non-metallic Materials. There shall be no evidence of blistering, and adhesion shall meet a rating of 3 when tested in accordance with ISO 4624. The maximum gloss loss allowed is 20 per cent.

vi) Minimum 500 hours exposure in accordance with ASTM B117 Test Method of Salt Spray (Fog) Testing. Undercutting shall not exceed 3 mm at the scribe mark, there shall be no evidence of blistering, and 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 Chipping Resistance of Coatings. The coating shall have a rating of 7A or better, and there shall not be any exposure of the substrate.

A.9.2 Coating Batch Tests

i) Coating Thickness

The thickness of the coating shall meet the requirements of the design when tested in accordance with ISO 2808.

ii) Coating Adhesion

The coating adhesion strength shall be measured in accordance with ISO 4624, and shall have a minimum rating of 4 when measured using either Test Method A or B, as appropriate.

A.10 LEAK TEST

Containers shall be leak tested using the following procedure (or an acceptable alternative):

i) *Containers* shall be thoroughly dried and pressurised to *Design Pressure* with hydrogen, helium or a gas mixture containing at least 5% hydrogen or 10% helium.

ii) If the total leakage measured exceeds 0.004 Ncm^3/hr the Container shall be rejected.

A.11 HYDRAULIC TEST

Any internal pressure applied after *Auto-frettage* and previous to the hydrostatic test shall not exceed 90 per cent of the hydrostatic test pressure

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

Option 1 - Volumetric Expansion Test

i) The *Container* shall be hydrostatically tested to at least the test pressure. In no case may the test pressure exceed the *Auto-frettage Pressure*.
ii) Pressure shall be maintained for 30 seconds and sufficiently longer to ensure complete expansion. If the test 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) The *Manufacturer* shall define the appropriate limit of permanent volumetric expansion for the test pressure used, but in no case shall the permanent expansion exceed 5 per cent of the total volumetric expansion measured under the test pressure. Any *Containers* not meeting the defined rejection limit shall be rejected and either rendered unserviceable or used for batch test purposes.

Option 2- Proof Pressure Test

The hydrostatic pressure in the *Container* shall be increased gradually and regularly until the test pressure is reached. The *Container* test pressure shall be held for a sufficiently long period (at least 30 seconds) to ascertain that there is no tendency for the pressure to decrease and there are no leaks.

A.12 HYDROSTATIC PRESSURE BURST TEST

i) The rate of pressurisation shall not exceed 1.4 MPa per second at pressures in excess of 80 per cent of the design burst pressure. If the rate of pressurisation at pressures in excess of 80 per cent of the design *Burst Pressure* exceeds 0.35 MPa/second, then either the *Container* must be placed schematically between the pressure source and the pressure measurement device, or there must be a 5 second hold at the minimum design *Burst Pressure*. The test shall be carried out at ambient temperature.
ii) The minimum required (calculated) *Burst Pressure* ratio shall be in accordance with Table 7.4 of Annex 7, and in no case be less than the value necessary to meet the stress ratio requirements. The actual *Burst Pressure* shall be recorded. Rupture may occur in either the cylindrical region or the dome region of the *Container*.

A.13 AMBIENT TEMPERATURE PRESSURE CYCLING

Pressure cycling shall be performed 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) Cycle the pressure in the *Container* between not more than 2.0 MPa and not less than the *Design Pressure* at a rate not exceeding 10 cycles per minute.

The number of cycles to failure shall be reported, along with the location and description of the failure initiation.

A.14 ACID ENVIRONMENT TEST

On a *Finished Container* the following test procedure should be applied:

i) Exposing a 150 mm diameter area on the *Container* surface for 100 hours to a 30 per cent sulphuric acid solution (battery acid with a specific gravity of 1.219) while the *Container* is held at the *Design Pressure*. The test shall be carried out at ambient temperature.

ii) The *Container* shall then be burst in accordance with the procedure defined in Paragraph A.12 of this Appendix. The *Burst Pressure* shall exceed 85 per cent of the minimum design *Burst Pressure*.

A.15 BONFIRE TEST

A.15.1 General

The bonfire tests are designed to demonstrate that *Finished Containers* complete with the *Pressure Relief Device(s)* specified in the design will prevent the rupture of the *Container* when tested under the specified fire conditions. Extreme caution must be exercised during fire testing in the event that *Container* rupture occurs.

A.15.2 Container Set-up

i) *Containers* shall be placed horizontally with the *Container* bottom approximately 100 mm above the fire source.
ii) 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 specified fire protection system (*Pressure Relief Device(s)*). 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.

A.15.3 Fire Source

A uniform fire source of 1.65 m length shall provide direct flame impingement on the *Container* surface across its entire diameter.

Any fuel may be used for the fire source provided it supplies uniform heat sufficient to maintain the specified test temperatures until the *Container* is vented. The selection of fuel should take into consideration air pollution concerns. 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.

A.15.4 Temperature And Pressure Measurements

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 square.

Thermocouple temperatures and the *Container* pressure shall be recorded at intervals of every 30 seconds or less during the test.

A.15.5 General Test Requirements

Containers shall be pressurised with nitrogen and tested in the horizontal position at *Working Pressure* and at 25% of the *Working Pressure*.

Immediately following ignition, the fire shall produce flame impingement on the surface of the *Container* along the 1.65 m length of the fire source and across the *Container* diameter. Within 5 minutes of ignition the temperature of at least one thermocouple shall indicate at least 590 °C and this minimum temperature shall be maintained for the remaining duration of the test.

A.15.6 Containers 1.65 M Length Or Less

The centre of the *Container* shall be positioned over the centre of the fire source.

A.15.7 Containers Greater Than 1.65 M Length

If the *Container* is fitted with a *Pressure Relief Device* at one end, the fire source shall commence at the opposite end of the *Container*. If the *Container* is fitted with *Pressure Relief Devices* at both ends, or at more than one location along the length of the *Container*, the centre of the fire source shall be centred midway between the *Pressure Relief Devices* that are separated by the greatest horizontal distance.

If the *Container* is additionally protected using thermal insulation, then two fire tests at *Working Pressure* shall be performed, one with the fire centred midway along the *Container* length, and the other with the fire commencing at one of the *Container* ends.

A.15.8 Acceptable Results

The *Container* shall vent through a *Pressure Relief Device*, and shall not rupture. At no point during venting of the *Container* shall the pressure inside the *Container* rise by more than 5% of the pressure at which venting starts.

A.16 PENETRATION TESTS

A *Container* pressurised to *Working Pressure* ± 1.0 MPa with compressed gas shall be penetrated by an armour piercing bullet with a diameter of 7.62 mm or greater. The bullet shall completely penetrate at least one side wall of the *Container*. For *Container* Type 2, 3 and 4 designs, the projectile shall impact the side wall at an approximate angle of 45°. The *Container* shall show no evidence of fragmentation failure. Loss of small pieces of material, each not weighing more than 45 grams, shall not constitute failure of the test. The approximate size of entrance and exit openings and their locations shall be recorded.

A.17 COMPOSITE FLAW TOLERANCE TESTS

For *Container* Type 2, 3 and 4 designs only, one *Finished Container*, complete with protective coating, shall have flaws in the longitudinal direction cut into the composite *Over-wrap*. The flaws shall be greater than the visual inspection limits as specified by the *Manufacturer*.

The flawed *Container* shall then be pressure cycled from not more than 2.0 MPa to not less than *Design Pressure* for 3,000 cycles, followed by an additional 12,000 cycles at ambient temperature. The *Container* shall not leak or rupture within the first 3,000 cycles, but may fail by leakage during the last 12,000 cycles. All *Containers* which complete this test shall be destroyed.

A.18 HIGH TEMPERATURE CREEP TEST

This test is required for all *Container* Type 4 designs.

The test is required for all *Container* Type 2 and 3 designs in which the glass transition onset temperature of the resin matrix does not exceed the maximum material temperature given in Paragraph 2.4.6 of this Regulation by at least 20°C.

One *Finished Container* shall be tested as follows:

i) The *Container* shall be pressurised to the *Design Pressure* and held at a temperature of 95 °C for not less than 1000 hours.

ii) Following the test, the *Container* shall meet the requirements of the hydraulic test Paragraph A.11 of this Appendix, the leak test Paragraph A.10 of this Appendix, and the burst test Paragraph A.12 of this Appendix.

A.19 ACCELERATED STRESS RUPTURE TEST

For *Container* Type 2, 3, and 4 designs only, one *Container* free of protective coating shall be hydrostatically pressurised to the *Design Pressure* while immersed in water at 85 °C. The *Container* shall be held at this pressure and temperature for 1000 hours. The *Container* shall then be pressurised to burst in accordance with the procedure defined in Paragraph A.12 of this Appendix except that the *Burst Pressure* shall exceed 85 per cent of the minimum design *Burst Pressure*.

A.20 IMPACT DAMAGE TEST

One or more *Finished Containers* shall be drop tested at ambient temperature without internal pressurisation or attached valves. The surface onto which the *Containers* are dropped shall be a smooth, horizontal concrete pad or flooring. One *Container* shall be dropped in a horizontal position with the bottom 1.8 m above the surface onto which it is dropped. One *Container* shall be dropped twice vertically on each end at a sufficient height above the floor or pad so that the potential energy is 488 J, but in no case shall the height of the lower end be greater than 1.8 m. One *Container* shall be dropped twice at a 45° angle onto a dome from a height such that the centre of gravity is at 1.8 m; however, if the lower end 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 a centre of gravity of 1.8 m. All drop tests may be performed on the same *Container*.

Following the drop impact, the *Containers* shall be pressure cycled from not more than 2.0 MPa to not less than the *Design Pressure* for the total number of pressure cycles calculated in accordance with Paragraph 2.4.7 of this Regulation. The *Containers* may leak but not rupture, during the cycling. Any *Containers* completing the cycling test shall be destroyed.

A.21 PERMEATION TEST

This test is only required on *Container* Type 4 designs. One *Finished Container* shall be filled with compressed hydrogen gas to *Design Pressure*, placed in an enclosed sealed chamber at 85 °C, and monitored for leakage for a time sufficient to establish a steady state permeation rate. The permeation rate shall be less than 0.25 Ncm^3 of hydrogen per hour per litre internal volume of the *Container*.

A.22 TENSILE PROPERTIES OF PLASTICS

The tensile yield strength and ultimate elongation of plastic *Liner* material shall be determined at - 50 °C using ISO 527, and meet the requirements of Paragraph 5.3.6 of Annex 7.

A.23 MELTING TEMPERATURE OF PLASTICS

Polymeric materials from finished *Liners* shall be tested in accordance with the method described in ISO 306, and meet the requirements of Paragraph 5.3.6 of Annex 7.

A.24 BOSS TORQUE TEST

The body of the *Container* shall be restrained against rotation and a torque of 500 Nm shall be applied to each end boss of the *Container*, first in the direction to tighten the threaded connection, then in the untightening direction, and finally again in the tightening direction. The *Container* shall be deemed to meet the requirements of this Paragraph if it subsequently passes the burst test defined in Paragraph A.12 of this Appendix.

A.25 RESIN SHEAR STRENGTH

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. Following a 24 hour water boil the composite shall have a minimum shear strength of 13.8 MPa.

A.26 HYDROGEN GAS CYCLING TEST

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

One *Finished Container* shall be pressure cycled using compressed hydrogen gas from less than 2.0 MPa to *Design Pressure* for 1000 cycles. Each cycle, consisting of the filling and venting of the *Container*, shall not exceed 1 hour. The *Container* shall be leak tested in accordance with Paragraph A.10 of this Appendix and meet the requirements therein. Following the completion of the hydrogen gas cycling the *Container* shall be sectioned and the *Liner*/end boss interface inspected for evidence of any deterioration, such as fatigue cracking or electrostatic discharge.

A.27 HYDROGEN COMPATIBILITY TEST

Hydrogen compatibility testing shall be carried out in accordance with prEN/ISO 11114 - 4.

Annex 7 - APPENDIX B (Informative)

REPORT FORM

NOTE - This appendix is not a mandatory part of Annex 7.

The following forms may be used:

i) Report of Manufacture & Certificate of Conformance - Required to be clear, legible and in the format of Form 1.

ii) Report 1/ of Chemical Analysis of Material for Metallic *Containers*, *Liners*, or Bosses - Required Essential Elements, Identification, Etc.

iii) Report 1/ of Mechanical Properties of Material for Metallic *Containers* and *Liners* - Required To Report All Tests Required By This Regulation.

iv) Report 1/ of Physical and Mechanical Properties of Materials for Non Metallic *Liners* - Required To Report All Tests And Information Required In This Regulation.

v) Report 1/ of Composite Analysis - Required To Report All Tests And Data Required In This Regulation.

vi) Report of Hydrostatic Tests, Periodic Pressure Cycling and Burst Tests - Required to Report Test And Data Required In This Regulation.

Note: 1/ Report forms 2 through 6 shall be developed by the *Manufacturer* and must fully identify Containers and requirements. Each report shall be signed by the Competent Authority and the *Manufacturer*.

Form 1: Report of Manufacturer and Certification of Conformance

Manufactured by:

Located at:

Regulatory Registration Number:

Manufacturers Mark and Number:

Serial Number: to be inclusive

Container description:

SIZE: Outside diameter: ……..... mm Length: ……..mm

Marks stamped on shoulder or on labels of the Container are (delete as appropriate):

a) "HYDROGEN (H_2) ONLY":
b) "DO NOT USE AFTER":
c) *Manufacturer's* mark:
d) Serial or part number:
e) Working pressure in MPa:
f) ECE Regulation:
g) Fire protection: Type
h) Date of original test (month & year):
i) Tare mass of empty Container in kg:
j) Authorised Body or Inspectors Mark:
k) Water capacity in L:
l) Test pressure in MPa:
m) Any special instructions:
n) Number of filling cycles:

Each *Container* was made in compliance with all requirements of ECE Regulation No. xx in accordance with the *Container* description above. Required reports of test results are attached.
I hereby certify that all the attached test results proved satisfactory in every way and are in compliance with the requirements for the ECE type listed above.

Comments :

Competent Authority: Inspector's name:
Inspectors signature:
Place, Date:

Manufacturer's representative: Name and position:
Manufacturer's signature:
Place, Date:

Annex 7 - APPENDIX C (Informative)

VERIFICATION OF STRESS RATIOS USING STRAIN GAUGES

C.1 The stress-strain relationship for fibres is always assumed to be elastic, therefore, stress ratios and strain ratios are equal.

C.2 High elongation strain gauges are required.

C.3 Strain gauges should be orientated in the direction of the fibres on which they are mounted, e.g. with hoop fibre on the outside of the *Container*, mount gauges in the hoop direction.

C.4 Method 1 (applies to *Containers* that do not use high tension winding)

i) Prior to *Auto-frettage*, apply strain gauges and calibrate.
ii) Measure strains at *Auto-frettage* and zero after *Auto-frettage Pressure*, *Design Pressure*, and minimum *Burst Pressure* have been met.
iii) Confirm that the strain at *Burst Pressure* divided by strain at , *Design Pressure* meets the stress ratio requirements. For hybrid construction, the strain at, *Design Pressure*, is compared with the rupture strain of *Containers* reinforced with a single fibre type.

C.5 Method 2 (applies to all *Containers*)

i) At zero pressure after winding and *Auto-frettage*, apply strain gauges and calibrate.
ii) Measure strains at zero pressure, *Design Pressure*, and minimum *Burst Pressure*.
iii) At zero pressure, after strain measurements have been taken at the , *Design Pressure* and minimum *Burst Pressure*, and with strain gauges monitored, cut the *Container* section apart so that the region containing the strain gauge is approximately 125mm long. Remove the *Liner* without damaging the composite *Over-wrap*. Measure the strains after the *Liner* is removed.
iv) Adjust the strain readings at zero pressure, *Design Pressure*, and minimum *Burst Pressure* by the amount of strain measured at zero pressure with and without the *Liner*.
v) Confirm that the strain at *burst pressure* divided by strain at *Design Pressure* meets the stress ratio requirements. For hybrid construction, the strain at *Design Pressure* is compared with the rupture strain of *Containers* reinforced with a single fibre type.

Annex 7 - APPENDIX D (Informative)

FRACTURE PERFORMANCE METHODS

D.1 Determine fatigue sensitive sites on the *Container*. The location and orientation of fatigue failure in *Containers* shall be determined by appropriate stress analysis or by full scale fatigue tests on *Finished Containers* as required under the design qualification tests for each type of design. If finite element stress analysis is used, the fatigue sensitive site shall be identified based on the location and orientation of the highest tensile principle stress concentration in the *Container* wall or *Liner* at the *Design Pressure*.

D.2 Leak-Before-Break (LBB)

D.2.1 Engineering Critical Assessment

This analysis may be carried out to establish that the *Finished Container* will leak in the event of a defect in the *Container* or *Liner* growing into a through-wall crack rather than rupture. A leak-before-break assessment shall be performed at the *Container* side wall. If the fatigue sensitive location is outside the side wall, a LBB assessment shall also be performed at that location using a Level II approach as outlined in BS PD 6493. The assessment shall include the following steps:

i) Measure the maximum length, i.e. major axis, of the resultant through-wall surface crack (usually elliptical in shape) from the three *Containers* cycle tested under the design qualification tests (according to Paragraphs A.13 and A.14 of Appendix A to this Annex) for each type of design. Use the longest crack length of the three *Containers* in the analysis. Model a semi-elliptical through-wall crack with a major axis equal to twice the measured longest major axis and with a minor axis equal to 0.9 times *Container* wall thickness. The semi-elliptical crack shall be modelled at the critical locations where the stress ratio is maximum. The crack shall be oriented such that the highest tensile principal stress shall drive the crack.
ii) Stress levels in the *Container* wall/Liner at *Design Pressure* obtained from the stress analysis as outlined in Paragraph 5.6 of Annex 7 shall be used for the assessment. Appropriate crack driving forces shall be calculated using either Section 9.2 or 9.3 of BS PD 6493.
iii) Fracture toughness of the *Finished Container* or the *Liner* from a *Finished Container*, as determined at room temperature for aluminium and at - 40 °C for steel, shall be established using a standardised testing technique (either ISO/FDIS 12737, ASTM 813-89 or BS 7448) in accordance with Section 8.4 and 8.5 of BS PD 6493.
iv) Plastic collapse ratio shall be calculated in accordance with Section 9.4 of BS PD6493.
v) The modelled flaw shall be acceptable in accordance with Section 11.2 of BS PD6493.

D.2.2 LBB By Flawed Container Burst

A fracture test shall be performed on the *Container* side wall. If the fatigue sensitive locations as determined in Paragraph A.7 of Appendix A to Annex 7 is outside the side wall, the fracture test shall also be performed at that location. The test procedure is as follows:

i) Determination Of Leak-Before-Break Flaw Length

The length of the LBB flaw at the fatigue sensitive site shall be twice the length of the maximum length measured of the resultant through-wall surface crack from the three *Containers* cycle tested to failure under the design qualification tests.

ii) Container Flaws

For *Container* Type 1 designs having fatigue sensitive sites in the cylindrical part in the axial direction, external flaws shall be machined longitudinally, approximately at mid-length of the cylindrical part of the *Container*. The flaws shall be located at minimum wall thickness of the midsection based on thickness measurements at four points around the *Container*. For *Container* Type 1 designs having fatigue sensitive sites outside of the cylindrical part, the LBB flaw shall be introduced at the internal surface of the *Container* along the fatigue sensitive orientation. For *Container* Type 2 and 3 designs the LBB flaw shall be introduced in the metal *Liner*.

For flaws to be tested by monotonic pressure, the flaw cutter shall be approximately 12.5 mm thick with an angle of 45° and a dip radius of 0.25 mm maximum. The cutter diameter shall be 50 mm for *Containers* with outside diameter less than 140 mm, and 65 to 80 mm for *Containers* with outside diameter greater than 140 mm (a standard CVN cutter is recommended).

NOTE - The cutter should be sharpened regularly to assure tip radius meets the specification.

The depth of the flaw may be adjusted to obtain a leak by monotonic hydro-pressurisation. The crack shall not propagate by more than 10 per cent outside of the machined flaw measured on the external surface.

iii) Test Procedure

The test shall be performed by monotonic pressurisation or cyclic pressurisation as described below:

a) Monotonic Pressurisation To Burst

The *Container* shall be pressurised hydrostatically until pressure is released from the *Container* at the flaw location. The pressurisation shall be performed as described in Paragraph A.12 (Appendix A to this Annex).

b) Cyclic Pressure

The test procedure shall be in accordance with the requirements of Paragraph A.13 (Appendix A to this Annex)

iv) Acceptance Criteria For The Flawed Container Test

The *Container* passes the tests if the following conditions are met:

a) For flawed *Container* burst tests, the failed pressure shall be equal to or greater than *Design Pressure*.

For monotonic pressurised burst test, a total crack length measured on the external surface of 1.1 times the original machined length is allowed.

b) For cycle tested *Containers*, fatigue crack growth beyond the original machined flaw length is allowed. However, the failure mode must be a "leak". Propagation of the flaw by fatigue should occur over at least 90 per cent of the length of the original machined flaw.

NOTE - If these requirements are not fulfilled (failure occurs below *Design Pressure* and the failure is a leak), a new test can be performed with a less deep flaw. Also, if rupture type failure occurs at a pressure greater than *Design Pressure* and flaw depth is shallow, a new test can be performed with a deeper flaw.

D.3 DEFECT SIZE FOR NON-DESTRUCTIVE EXAMINATION (NDE)

D.3.1 NDE Defect Size By Engineering Critical Assessment

Calculations shall be performed in accordance with British Standard PD 6493, Section 3, using the following steps:

i) Fatigue cracks shall be modelled at the high stress location in the *Container* wall/ *Liner* as planar flaws.
ii) The applied stress range at the fatigue sensitive site, due to a pressure between 2.0 MPa and *Design Pressure* shall be established from the stress analysis required by Paragraph 5.6 of Annex 7).
iii) The bending and membrane stress component may be used separately.
iv) The minimum number of pressure cycles is 15,000.
v) The fatigue crack propagation data shall be determined in air in accordance with ASTM E647. The crack plane orientation shall be in the C-L direction, i.e. crack plane perpendicular to the circumferences and along the axis of the Container, as illustrated in ASTM E399. The rate shall be determined as an average of 3 specimen tests. Where specific fatigue crack propagation data are available for the material and service condition, they may be used in the assessment.
vi) The amount of crack growth in the thickness direction and in the length direction per pressure cycle shall be determined in accordance with the steps outlined in Section 14.2 of BS PD6493 by integrating the relationship between the rate of fatigue crack propagation, as established in e) above, and the range of crack driving force corresponding to the applied pressure cycle.
vii) Using the above steps, calculate the maximum allowable defect depth and length which shall not cause the failure of the *Container* during the design life due to either fatigue or rupture. The defect size for NDE shall

be equal to or less than the calculated maximum allowable defect size for the design.

D.3.2 NDE Defect Size By Flawed Container Cycling

For *Container* Type 1, 2 and 3 designs, three *Containers* containing artificial defects that exceed the defect length and depth detection capability of the NDE inspection method required in Paragraph 5.15. of Annex 7, shall be pressure cycled to failure in accordance with the test method in Paragraph A.13 (Appendix A to Annex 7). For *Container* Type 1 designs having a fatigue sensitive site in the cylindrical part, external flaws shall be introduced on the side wall. For *Container* Type 1 designs having the fatigue sensitive site outside the side wall, and for *Container* Type 2 and 3 designs, internal flaws shall be introduced. Internal flaws may be machined prior to the heat treating and closing of the end of the *Container*.

The *Containers* shall not leak or rupture in less than 1000 cycles times the specified *Service Life* in years. The allowable defect size for NDE shall be equal to or less than the artificial flaw size at that location.

Annex 7 - APPENDIX E (Informative)

CONTAINER MANUFACTURER'S INSTRUCTIONS FOR HANDLING, USE AND INSPECTION OF CONTAINERS

E.1 GENERAL

The primary function of this document is to provide guidance to the *Container* purchaser, distributor, installer and user for the safe use of the *Container* over its intended *Service Life*.

E.2 DISTRIBUTION

The *Manufacturer* shall advise the purchaser that the instructions shall be supplied to all parties involved in the distribution, handling, installation and use of the *Containers*. The document may be reproduced to provide sufficient copies for this purpose, however, it shall be marked to provide reference to the *Containers* being delivered.

E.3 REFERENCE TO EXISTING CODES, STANDARDS AND REGULATIONS

Specific instructions may be stated by reference to national or recognised codes, standards and regulations.

E.4 CONTAINER HANDLING

Handling procedures shall be provided to ensure that the *Containers* will not suffer unacceptable damage or contamination during handling.

E.5 INSTALLATION

Installation instructions shall be provided to ensure that the *Containers* will not suffer unacceptable damage during installation and during normal operation over the intended *Service Life*.

The *Manufacturer*'s instructions shall contain where relevant, details such as mounting design, the use of resilient gasket materials, the correct tightening torque and avoidance of direct exposure of the *Container* to the environment, chemicals and mechanical contacts.

Where applicable, the purchaser's attention shall be drawn to the need to provide installations such that liquids or solids cannot be collected to cause *Container* material damage.

The correct *Pressure Relieve Device(s)* to be fitted shall be specified.

E.6 USE OF CONTAINERS

The *Manufacturer* shall draw the vehicle manufacturer's attention to the intended service conditions specified by this Regulation, in particular the *Container's* allowable number of pressure cycles, its life in years, the gas quality limits and the allowable maximum pressures.

E.7 IN-SERVICE INSPECTION

The *Manufacturer* shall clearly specify the user's obligation to observe the required *Container* inspection requirements, e.g. reinspection interval, by authorised personnel. This information shall be in agreement with the design approval requirements.

Annex 7 - APPENDIX F (Informative)

ENVIRONMENTAL TEST

F.1 SCOPE

The environmental test demonstrates that hydrogen *Containers* of Types 2, 3 and 4 can withstand exposure to the automotive underbody environment and occasional exposure to other fluids.

F.2 SUMMARY OF TEST METHOD

A *Container* is first preconditioned by a combination of pendulum and gravel impacts to simulate potential underbody conditions. The *Container* is then subjected to a sequence of immersion in simulated road salt/acid rain, exposure to other fluids, pressure cycles and high and low temperature exposures. At the conclusion of the test sequence the *Container* will be hydraulically pressurised to destruction. The remaining residual burst strength of the Container shall be not less than 85 % of the minimum design burst strength.

F.3 CONTAINER SET-UP AND PREPARATION

Two *Containers* shall be tested in a condition representative of installed geometry including coating (if applicable), brackets and gaskets, and pressure fittings using the same sealing configuration, i.e. O-rings, as that used in service. Brackets may be painted or coated prior to installation in the immersion test if they are painted or coated prior to vehicle installation.

One *Container* shall be exposed to environmental conditions in accordance with Paragraph F.5(i) of this Appendix, Immersion Environment, and the other *Container* shall be exposed to environmental conditions in accordance with Paragraph F.5(ii) of this Appendix, Other Fluids Exposure. Both container shall be subjected to the appropriate pre-conditioning in the exposure areas and subjected to the complete pressure cycling requirements specified in Paragraphs F.6 and F.7 of this Appendix.

The upper section used for the “other Fluids Exposure“ test will be divided into 5 distinct areas and marked for preconditioning and fluid exposure (see Figure F.1 of this Appendix). The areas will be nominally 100 mm in diameter. The areas shall not overlap on the *Container* surface. While convenient for testing, the areas need not be oriented along a single line, but must not overlap the immersed section of the *Container*.

Although preconditioning and fluid exposure is performed on the cylindrical section of the *Container*, all of the *Container*, including the domed sections, should be as resistant to the exposure environments as are the exposed areas.

As an alternative, one container may be used for both the Immersion Environment and Other Fluids Exposure tests, as long as care is taken to prevent cross contamination among the fluids.

Other fluid
exposure areas

Immersion area
(lower third)

Figure F.1 - Container Orientation And Layout Of Exposure Areas

F.4 PRECONDITIONING APPARATUS

The following apparatus are needed for preconditioning the test *Container* by pendulum and gravel impact.

i) Pendulum Impact

The impact body shall be of steel and 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 shall be 1 m. 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 be not less than 30 Nm 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.

ii) Gravel Impact

Gravel impact machine shall be constructed according to the design specifications shown in Figure F.2 of this Appendix. The procedure for operation of the equipment shall follow that described in ASTM D3170, Standard Test Method for Chip Resistance of Coatings with the exception that the *Container* may be at ambient temperature during gravel impact.

iii) Gravel

Alluvial road gravel passing through a 16 mm space screen but retained on a 9.5 mm space screen. Each application is to consist of 550 ml of graded gravel (approx. 250 to 300 stones).

Figure F.2 - Gravel Impact Test

F.5 EXPOSURE ENVIRONMENTS

i) Immersion Environment

At the specified stage in the test sequence Table F.1 of this Appendix, the *Container* will be oriented horizontally with the lower third of the *Container* diameter immersed in a simulated acid rain/road salt water solution. The solution will consist of the following compounds:

Deionised water;
Sodium chloride: 2.5 % by weight ±0.1 %
Calcium chloride: 2.5 % by weight ±0,1 %
Sulphuric acid - Sufficient to achieve a solution pH of 4.0±0.2

Solution level and pH are to be adjusted prior to each test step which uses this liquid.

The temperature of the bath shall be 21 ± 5 °C. During immersion, the unsubmerged section of the *Container* shall be in ambient air.

ii) Other Fluid Exposure

At the appropriate stage in the test sequence shown in Table F.1 of this Appendix, each marked area is to be exposed to one of five solutions for 30 minutes. The same environment shall be used for each location throughout the test. The solutions are:

Sulphuric acid: 19 % solution by volume in water
Sodium hydroxide: 25 % solution by weight in water;
Methanol/gasoline: 30/70 % concentrations
Ammonium nitrate: 28 % by weight in water
Windshield washer fluid.

When exposed, the test sample will be oriented with the exposure area uppermost. A pad of glass wool one layer thick (approximately 0.5 mm) and trimmed to the appropriate dimensions is to be placed on the exposure area. Using a pipette, apply 5 ml of the test fluid to the exposure area. Remove the gauze pad after pressurisation of the *Container* for 30 minutes.

F.6 TEST CONDITIONS

i) Pressure Cycle

As defined in the test sequence, the *Container* shall be hydraulically pressure cycled between not more than 2.0 MPa and not less than *Design Pressure*. The total cycle shall be not less than 66 seconds and will include a 60 second minimum hold at *Design Pressure*. The nominal cycle process will be:

a) Ramp up from 2.0 MPa to *Design Pressure,*
b) Hold at *Design Pressure* for 60 seconds minimum,
c) Ramp down from *Design Pressure* to 2.0 Mpa,
d) Total minimum cycle time to be 66 seconds.

ii) Pressure During Other Fluid Exposure

Following application of the other fluids, the Container shall be pressurised to not less than *Design Pressure* for a minimum of 30 minutes.

iii) High And Low Temperature Exposure

As defined in the test sequence, the entire *Container* shall be exposed to high or low temperature air in contact with its external surface. The high and low air temperatures shall be in accordance with Paragraph 2.4.6 of this Regulation ± 5°C. For the low temperature exposure, the fluid temperature of Type 1 *Containers* shall be monitored using a thermocouple installed within the *Container*.

F.7 TEST PROCEDURE

i) Preconditioning of the Container.

Each of the five areas marked for other fluid exposure an the upper section of the *Container* shall be preconditioned by a single impact of the pendulum body summit at their geometric centre. Following impact, the five areas shall be further conditioned by a gravel impact application.

The central section of the bottom portion of the *Container* that will be submerged shall be preconditioned by an impact of the pendulum body summit at three locations spaced approximately 150 mm apart.

Following impact, the same central section that was impacted shall be further conditioned by a gravel impact application.

The *Container* shall be unpressurised during preconditioning.

ii) Test Sequence And Cycles

The sequence of the environment exposure, pressure cycles, and temperature to be used are defined in Table F.1 of this Appendix.

The *Container* surface is not to be washed or wiped between stages.

F.8 ACCEPTABLE RESULTS

Following the above test sequence, the *Container* shall be hydraulically tested to destruction in accordance with the procedure in Paragraph A.12 of Appendix A to this Annex. The *Burst Pressure* of the *Container* shall be not less than 85 % of the minimum design *Burst Pressure*.

Table F.1 - Test Conditions And Sequence

Test Steps			Environments	Number of pressure cycles	Temperature
Two Container Approach		Single Container Approach			
Immersion container	Other Fluids container	Alternative single container			
-	1	1	Other fluids (40 minutes)	-	Ambient
1	-	2	Immersion	500 x Service Life (yrs)	Ambient
-	2	-	Air	500 x Service Life (yrs)	Ambient
-	3	3	Other Fluids (40 minutes)	-	Ambient
2	4	4	Air	250 x Service Life (yrs)	Low
-	5	5	Other Fluids (40 minutes)	-	Ambient
3	6	6	Air	250 x Service Life (yrs)	High

Annex 7 - APPENDIX G

ULTRASONIC INSPECTION

G.1 SCOPE

Other techniques of ultrasonic inspection may be used, provided these have been demonstrated to be at least equivalent to this Annex and suitable for the manufacturing method adopted.

G.2 GENERAL REQUIREMENTS

Ultrasonic testing shall be carried out by the *Container Manufacturer*.

The ultrasonic testing equipment shall be capable of at least detecting the reference standard as described in Paragraph G.3.2 of this Appendix. It shall be serviced regularly in accordance with the *Manufacturer's* operating instructions to ensure that its accuracy is maintained. Inspection records and approval certificates for the equipment shall be maintained.

The operation of the test equipment shall be by trained personnel and supervised by qualified and experienced personnel certified to level 2 of ISO 9712:1992.

The outer and inner surfaces of any *Container* which is to be tested ultrasonically shall be in a condition suitable for an accurate and reproducible test.

For flaw detection the pulse echo system shall be used. For thickness measurement either the resonance method or the pulse echo system shall be used. Either contact or immersion techniques of testing shall be used.

A coupling method which ensures adequate transmission of ultrasonic energy between the testing probe and the *Container* shall be used.

G.3 FLAW DETECTION OF THE CYLINDRICAL PARTS

G.3.1 Procedure

The Container to be inspected and the search unit shall have a rotating motion and translation relative to one another such that a helical scan of the Container will be described. The velocity of rotation and translation shall be constant within ± 10%. The pitch of the helix shall be less than the width covered by the probe (at least a 10% overlap shall be guaranteed) and be related to the effective beam width such as to ensure 100 % coverage at the velocity of rotation and translation used during the calibration procedure.

An alternative scanning method may be used for transverse defect detection, in which the scanning or relative movement of the probes and the work piece is longitudinal, the sweeping motion being such as to ensure a 100% surface coverage with about 10 % overlap of the sweeps.

The *Container* wall shall be tested for longitudinal defects with the ultrasonic energy transmitted in both circumferential directions and for transverse defects in both longitudinal directions.

In this case, or when optional testing is carried out, on the transition areas between the wall and neck or wall and base, this may be conducted manually if not carried out automatically.

The effectiveness of the equipment shall be periodically checked by passing a Reference Standard through the test procedure. This check shall be carried out at least at the beginning and end of each shift. If during this check the presence of the appropriate reference notch is not detected then all *Containers* tested subsequent to the last equipment acceptance check shall be retested after the equipment has been reset.

G.3.2 Reference Standard

A Reference Standard of convenient length shall be prepared from a *Container* of similar diameter and wall thickness range, and from material with the same acoustic characteristics and surface finish as the *Container* to be inspected. The Reference Standard shall be free from discontinuities which may interfere with the detection of the reference notches.

Reference notches, both longitudinal and transverse, shall be machined on the outer and inner surface of the reference standard. The notches shall be separated such that each notch can be clearly identified.

The dimensions and shape of notches in the Reference Standard shall be as follows:

i) The length of the notches shall be no be greater than 50 mm.
ii) The width of the notches shall be no greater than twice the nominal depth of the notches. However, where this condition cannot be met a maximum width of 1.0 mm is acceptable.
iii) The depth of the notches shall be 5% $\pm$ 0.75 % of the nominal thickness of the reference standard with a minimum of 0.2 mm and a maximum of 1.0 mm, over the full length of the notch. Runouts at each end of the notch are permissible.
iv) The notches shall be sharp edged at their intersection with the surface of the of the *Container* wall. The cross section of the notches shall be rectangular except where spark erosion machining methods are used in which case the bottom of the notch may be rounded.
v) The shape and dimensions of the notches shall be checked by an appropriate method.

G.3.3 Calibration Of Equipment

Using the Reference Standard described in Paragraph G.3.2 of this Appendix, the equipment shall be adjusted to give clearly identifiable indications from both inner and outer reference notches. The amplitude of the indications shall be as near equal as possible. The indication of smallest amplitude shall be used as the rejection level and for setting visual, audible, recording or sorting devices. The equipment shall be calibrated with the Reference Standard or probe, or both, moving in the same manner, in the same direction and in the same speed as will be used during the inspection of the *Container*. All visual, audible, recording or sorting device shall operate satisfactorily at the test speed.

G.4 WALL THICKNESS MEASUREMENT

If the measurement of the wall thickness is not carried out at another stage of production, the cylindrical part shall be 100 % examined to ensure that the thickness is not less than the guaranteed minimum value.

G.5 INTERPRETATION OF RESULTS

Containers with indications which are equal to or greater than the lowest of the indications from the reference notches shall be withdrawn.

Surface defects may be removed. After removal of surface defects the *Container* shall be resubjected to ultrasonic flaw detection and thickness measurement.

Any *Container* which is shown to be below the guaranteed minimum wall thickness shall be rejected.

Annex 8

REQUIREMENTS FOR SPECIFIC COMPONENTS OTHER THAN HYDROGEN CONTAINERS

Annex 8A

PROVISIONS REGARDING THE APPROVAL OF PRESSURE RELIEF DEVICES

1. *Design Pressure*:

   Class 0: See Part I, Paragraph 6.1.5 of this Regulation

   Class 1 & 2: See Part I, Paragraph 6.1.5 of this Regulation

2. Set pressure:

   Design Pressure plus 10% for the appropriate section of the *Hydrogen System*

3. Temperatures:

   See Paragraph 2.4.6 of this Regulation

4. 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	Annex 9
pressure triggered devices only)	(100 operation cycles)
Corrosion resistance	Annex 9 */ ***/
Pressure cycle test	Annex 9
Temperature cycle test	Annex 9 **/

5. Further Requirements For Pressure Relief Devices (Temperature Triggered)

   Pressure Relief Devices (Temperature Triggered) specified by the *Manufacturer* shall be shown to be compatible with the service conditions listed in Paragraph 3 of Annex 7 and through the following qualification tests:

   One specimen shall be held at a controlled temperature of not less than 100°C and a pressure not less than test pressure for 24 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.
   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 *Design 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 *Design 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.

   i) Exposed brass pressure retaining components of *Pressure Relief Devices* shall withstand, without stress corrosion cracking, a mercurous nitrate test as described in ASTM B154. 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 *Design Pressure* for one minute during which time the component shall be checked for external leakage. Any leakage shall not exceed 10 Ncm^3/hr.

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

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*/ only for metallic parts

**/ only for non-metallic parts

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

Annex 8B

PROVISIONS REGARDING THE APPROVAL OF HYDROGEN VALVES

1. *Design Pressure*:

   See Part I, Paragraph 6.1.5 of this Regulation

2. Temperatures:

   See Paragraph 2.4.6 of this regulation

3. 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 */ ***/
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 **/
Temperature cycle test	Annex 9 **/

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*/ only for metallic parts

**/ only for non-metallic part

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

Annex 8C

PROVISIONS REGARDING THE APPROVAL OF HEAT EXCHANGERS

1. *Design Pressure*:

   See Part I, Paragraph 6.1.5 of this Regulation

2. Temperatures:

   See Paragraph 2.4.6 of this Regulation

3. 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 */
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 **/
Pressure cycle test	Annex 9
Temperature cycle test	Annex 9 **/

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*/ only for metallic parts

**/ only for non-metallic part

Annex 8D

PROVISIONS REGARDING THE APPROVAL OF RECEPTACLES

1. *Design Pressure*:

   See Part I, Paragraph 6.1.5 of this Regulation

2. Temperatures:

   See Paragraph 2.4.6 of this Regulation

3. 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 */
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 **/
Temperature cycle test	Annex 9 **/

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*/ only for metallic parts

**/ only for non-metallic part

Annex 8E

PROVISIONS REGARDING THE APPROVAL OF PRESSURE REGULATORS

1. *Design Pressure*:

   Class 0: See Part I, Paragraph 6.1.5 of this Regulation

   Class 1, 2, 3 & 4: 2.0 x Outlet *Design Pressure* of the upstream stage of the *Pressure Regulator* or the first upstream *Pressure Regulator*.

2. Temperatures:

   See Paragraph 2.4.6 of this Regulation

3. 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 */ ***/
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 **/
Pressure cycle test	Annex 9
Temperature cycle test	Annex 9 **/

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*/ only for metallic parts

**/ only for non-metallic parts

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

Annex 8F

PROVISIONS REGARDING THE APPROVAL OF SENSORS FOR HYDROGEN SYSTEMS

1. *Design Pressure*:

   See Part I, Paragraph 6.1.5 of this Regulation

2. Temperatures:

   See Paragraph 2.4.6 of this Regulation

3. Applicable test procedures for every sensor except Hydrogen Sensors:

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

4. Additional test procedure for pressure sensors only

Pressure cycle test	Annex 9

5. *Hydrogen Sensors* shall be designed and type approved in accordance with EN 50054, EN 50057 and EN 50058.

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*/ only for metallic parts

**/ only for non-metallic parts

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

Annex 8G

PROVISIONS REGARDING THE APPROVAL OF FLEXIBLE FUEL LINES

1 SCOPE

This annex covers three types of *Flexible Fuel Lines*:
i) Class 0 - High pressure
ii) Class 1 - Medium pressure
iii) Class 2 - Low pressure

2 GENERAL

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

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

Notes:

*/ only for metallic parts

**/ only for non-metallic parts

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

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

3 CLASS 0 - HIGH PRESSURE FLEXIBLE FUEL LINES

3.1 General Specifications

3.1.1 *Design Pressure* shall be in accordance with Paragraph 6.1.5 of this Regulation.

3.1.2 Temperatures shall be in accordance with Paragraph 2.4.6 of this Regulation.

3.1.3 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 shall 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 20 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: 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

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. The tensile strength shall be 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: 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

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 *Design 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: 1978 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 Hose Assemblies - Hydrostatic Testing.

3.5.4.2 The test pressure shall be 1.50 x *Design Pressure* 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 *Design Pressure*.

3.6 Couplings

The couplings shall be in accordance with Annex 8H of 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 as mentioned 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 4.0 x *Design Pressure* of the *Container* 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 0",
v) The marking “DO NOT USE AFTER yyyy/mm” where yyyy/mm is the year and month of approval plus the approved lifetime of the *Container*.

4 CLASS 1 - MEDIUM PRESSURE FLEXIBLE FUEL LINES

4.1 General Specifications

4.1.1 *Design Pressure* shall be in accordance with Paragraph 6.1.5 of this Regulation.

4.1.2 Temperatures shall be in accordance with Paragraph 2.4.6 of this Regulation.

4.1.3 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

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

4.2.2 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).

4.2.3 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.

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: 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

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: 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

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 *Design 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: 1978 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 3.5 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 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 (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

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 Hose Assemblies - Hydrostatic Testing.

4.5.4.2 The test pressure shall be 1.50 x *Design 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 *Design Pressure*.

4.6 Couplings

The couplings shall be in accordance with Annex 8H of 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 as mentioned 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 4.0 x *Design 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 1",
v) The marking “DO NOT USE AFTER yyyy/mm” where yyyy/mm is the year and month of approval plus the approved lifetime of the Container.

5 CLASS 2 - LOW PRESSURE FLEXIBLE FUEL LINES

5.1 General Specifications

5.1.1 *Design Pressure* shall be in accordance with Paragraph 6.1.5 of this Regulation.

5.1.2 Temperatures shall be in accordance with Paragraph 2.4.6 of this Regulation.

5.1.3 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.

5.2 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.

5.3 Specifications And Tests For The Lining

5.3.1 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.

5.3.2 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

5.4 Specifications And Tests For The Cover

5.4.1 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.

5.4.2 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.

5.5 Specifications For Flexible Fuel Line

5.5.1 Gas-tightness (Permeability)

5.5.1.1 One finished *Flexible Fuel Line* shall be filled with hydrogen, helium or a gas mixture containing at least 5% hydrogen or 10% helium to *Design 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.

5.5.1.2 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.

5.5.2 Resistance At Low Temperature

5.5.2.1 The test shall be carried out in compliance with the method described in ISO 4672: 1978 Rubber And Plastic Hoses – Sub-ambient Temperature Flexibility Tests method B.

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

5.5.2.3 The test piece shall not crack or rupture.

5.5.3 Bending test

5.5.3.1 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 5.5.4.2 of this Annex

5.5.3.2 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

5.5.3.3 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 5.5.3.2 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 5.5.3.2 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.

5.5.4 Hydraulic Test Pressure And Minimum Burst Pressure

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

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

5.5.4.3 The *Burst Pressure* shall not be less than 2.25 x *Design Pressure*.

5.6 Couplings

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

5.7 Assembly Of Flexible Fuel Line And Couplings

5.7.1 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.

5.7.2 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 as mentioned in Paragraph 5.5.4 of this Annex.

5.7.3 Gas-tightness

The *Flexible Fuel Line* assembly (*Flexible Fuel Line* with couplings) shall withstand for a period of five minutes a gas pressure of 4.0 x *Design Pressure* (outlet) of the first upstream *Pressure Regulator* without any leakage.

5.8 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 lifetime of the Container.

Annex 8H

PROVISIONS REGARDING THE APPROVAL OF FITTINGS

1. *Design Pressure*:

   See Part I, Paragraph 6.1.5 of this Regulation

2. Temperatures:

   See Paragraph 2.4.6 of this Regulation

3. Applicable test procedures:

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

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*/ only for metallic parts

**/ only for non-metallic parts

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

Annex 8I

PROVISIONS REGARDING THE APPROVAL OF EXCESS FLOW SYSTEMS

1. *Design Pressure*:

   See Part I, Paragraph 6.1.5 of this Regulation

2. Temperatures:

   See Paragraph 2.4.6 of this Regulation

3. 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 */ ***/
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 **/
Temperature cycle test	Annex 9 **/

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*/ only for metallic parts

**/ only for non-metallic parts

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

Annex 8J

PROVISIONS REGARDING THE APPROVAL OF HYDROGEN FILTERS

1. *Design Pressure*:

   Class 0: See Part I, Paragraph 6.1.5 of this Regulation

   Class 1 & 2: 2.0 x Outlet *Design Pressure*: of the upstream Pressure Regulator

2. Temperatures:

   See Paragraph 2.4.6 of this Regulation

3. 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 */ ***/
Resistance to dry-heat	Annex 9
Ozone ageing	Annex 9 **/
Pressure cycle test	Annex 9
Temperature cycle test	Annex 9 **/

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*/ only for metallic parts

**/ only for non-metallic parts

***/ 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 which 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
Overpressure or strength	X	X	X	4
External leakage	X	X	X	5
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	NA	NA	13
Vibration resistance	A	A	A	14
Service Temperatures	X	X	X	15
Connection	X	X	X	16

Key:

X	Applicable
NA	Not 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 durability 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 *Design Pressure*
Class 1	1.5 x *Design Pressure*
Class 2	2.0 x *Design 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 material temperature (see 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 material temperature (see Paragraph 2.4.6.1 of this Regulation) after 3 hours conditioning at this temperature and at 1, 10 and 100% of *Design 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 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 LEAKAGE TEST

6.1 The following tests for seat leakage are to be conducted on samples which have previously been subjected to the external leakage test of Paragraph 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 100% of *Design 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 100% of *Design 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 90% of *Design Pressure* when in the closed position.

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 which is calibrated in cubic centimetres. The inverted cylinder is to be closed by a water tight 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:

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

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 of 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 of 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 the *Design Pressure* of the component. 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.

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

A non-metallic part 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 *Design Pressure*.

13 PRESSURE CYCLE

13.1 Pressure cycle test requirements for *Containers* are specified in Annex 7 of this Regulation.

13.2 All *Flexible Fuel Lines* 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 the applicable *Design 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.

13.3 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 the applicable *Design 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.

13.4 All *Pressure Regulators* 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 the applicable *Design 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.

13.5 All pressure sensors 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 the applicable *Design 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.

13.6 All *Hydrogen Filters* 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 the applicable *Design 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 which 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 which are controlled by "The System" shall be provided and an indication given, in each case, of whether the control is direct or via another vehicle system. The *Range of Control* 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 which are needed to achieve the control function in question. An outline schematic showing these *Units* in combination, shall be provided with both the equipment distribution and the interconnections 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:
a) Fall-back to operation using a partial system,
b) Change-over to a separate back-up system,
c) Removal of the High Level Function.

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

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.